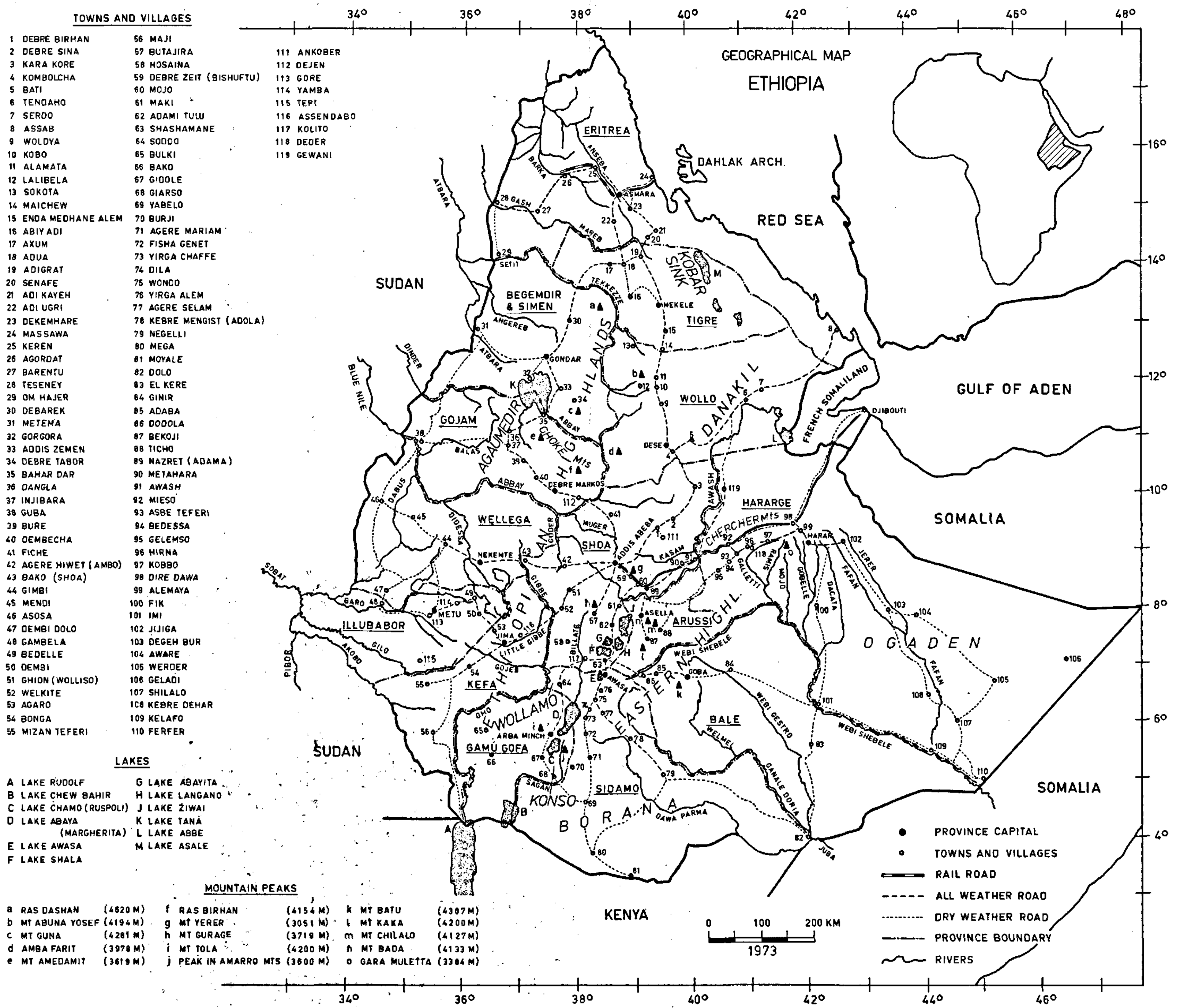
Oil plants in Ethiopia, their taxonomy and agricultural significance

C. J. P. Seegeler


TOWNS AND VILLAGES
1 DEBRE BIRHAN
2 DEBRE SINA
3 KARA KORE
4 KOMBOLCHA
5 BATI
6 TENDAHO
7 SERDO
8 ASSAB
9 WOLDYA
10 KOBO
11 ALAMATA
12 LALIBELA
13 SOKOTA
14 MAICHEW
15 ENDA MEDHANE ALEM
16 ABIY ADI
17 AXUM
18 ADUA
19 ADIGRAT
20 SENAFE
21 ADI KAYEH
22 ADI UGRI
23 DEKEMHARE
24 MASSAWA
25 KEREN
26 AGORDAT
27 BARENTU
28 TESENEY
29 OM HAJER
30 DEBAREK
31 METEMA
32 GORGORA
33 ADDIS ZEMEN
34 DEBRE TABOR
35 BAHAR DAR
36 DANGLA
37 INJIBARA
38 GUBA
39 BURE
40 DEMBECHA
41 FICHE
42 AGERE HIWET (AMBO)
43 BAKO (SHOA)
44 GIMBI
45 MENDI
46 ASOSA
47 DEMBI DOLO
48 GAMBELA
49 BEDELLE
50 DEMBI
51 GHION (WOLLISO)
52 WELKITE
53 AGARO
54 BONGA
55 MIZAN TEFERI
56 MAJI
57 BUTAJIRA
58 HOSAINA
59 DEBRE ZEIT (BISHUFTU)
60 MOJO
61 MAKI
62 ADAMI TULU
63 SHASHAMANE
64 SODDO
65 BULKI
66 BAKO
67 GIDOLE
68 GIARSO
69 YABELO
70 BURJI
71 AGERE MARIAM
72 FISHA GENET
73 YIRGA CHAFFE
74 DILA
75 WONDO
76 YIRGA ALEM
77 AGERE SELAM
78 KEBRE MENGIST (ADOLA)
79 NEGELLI
80 MEGA
81 MOYALE
82 DOLO
83 EL KERE
84 GINIR
85 ADABA
86 DODOLA
87 BEKOJI
88 TICHO
89 NAZRET (ADAMA)
90 METAHARA
91 AWASH
92 MIESO
93 ASBE TEFERI
94 BEDESSA
95 GELEMSO
96 HIRNA
97 KOBBO
98 DIRE DAWA
99 ALEMAYA
100 FIK
101 IMI
102 JIJIGA
103 DEGEH BUR
104 AWARE
105 WERDER
106 GELADI
107 SHILALO
108 KEBRE DEHAR
109 KELAFO
110 FERFER
111 ANKOBER
112 DEJEN
113 GORE
114 YAMBA
115 TEPI
116 ASSENDABO
117 KOLITO
118 DEDER
119 GEWANI
LAKES
A LAKE RUDOLF
B LAKE CHEW BAHIR
C LAKE CHAMO (RUSPOLI)
D LAKE ABAYA (MARGHERITA)
E LAKE AWASA
F LAKE SHALA
G LAKE ABAYITA
H LAKE LANGANO
J LAKE ZIWAI
K LAKE TANA
L LAKE ABBE
M LAKE ASALE
MOUNTAIN PEAKS
a RAS DASHAN (4620 M)
b MT ABUNA YOSEF (4194 M)
c MT GUNA (4281 M)
d AMBA FARIT (3978 M)
e MT AMEDAMIT (3619 M)
f RAS BIRHAN (4154 M)
g MT YERER (3051 M)
h MT GURAGE (3719 M)
i MT TOLA (4200 M)
j PEAK IN AMARRO MTS (3600 M)
k MT BATU (4307 M)
l MT KAKA (4200 M)
m MT CHILALO (4127 M)
n MT BADA (4133 M)
o GARA MULETTA (3384 M)
GEOGRAPHICAL MAP
ETHIOPIA
ERITREA
DAHLAK ARCH.
RED SEA
SUDAN
BEGEMDIR & SIMEN
TIGRE
KOBAR SINK
GOJAM
WOLLO
DANAKIL
GULF OF ADEN
FRENCH SOMALILAND
DJIBOUTI
WELLEGA
SHOA
ADDIS ABEBA
HARARGE
CHERCHER Mts
SOMALIA
ILLUBABOR
ARUSSI
KEFA
WOLLAMO
GAMU GOFA
SIDAMO
KONSO
BORANA
BALE
OGADEN
KENYA
PROVINCE CAPITAL
TOWNS AND VILLAGES
RAIL ROAD
ALL WEATHER ROAD
DRY WEATHER ROAD
PROVINCE BOUNDARY
RIVERS
0 100 200 KM
1973

Oil plants in Ethiopia, their taxonomy and agricultural significance

Promotor: dr. H. C. D. de Wit, emeritus hoogleraar in de algemene plantensystematiek en -geografie en in het bijzonder die van de tropen en de subtropen.

Co-promotor: dr. ir. J. D. Ferwerda, emeritus hoogleraar in de tropische landbouwplantenteelt.

C. J. P. Seegeler

Oil plants in Ethiopia, their taxonomy and agricultural significance

Proefschrift
ter verkrijging van de graad van
doctor in de landbouwwetenschappen,
op gezag van de rector magnificus,
dr. C. C. Oosterlee,
hoogleraar in de veeteeltwetenschap,
in het openbaar te verdedigen
op woensdag 1 juni 1983
des namiddags te vier uur in de aula
van de Landbouwhogeschool te Wageningen.

pudoc

Centre for Agricultural Publishing and Documentation

Wageningen – 1983

Abstract

Seegeler, C. J. P., 1983, Oil plants in Ethiopia, their taxonomy and agricultural significance. Agric. Res. Rep. (Versl. landbouwk. Onderz.) 921, ISBN 90 220 0815 0, (x) + 368 p., 16 figs, 26 photographs, 71 tables, 559 refs, Dutch summary, indices of common and scientific plant names, glossary.
Also: Doctoral thesis, Wageningen.

The book is the fourth in a series on Ethiopian useful plants. It treats 12 oleiferous plants, both from a taxonomic and agricultural standpoint, and 11 in less detail. Special chapters are dedicated to the role of the oil plants in Ethiopian agriculture, and on preparation and use of vegetable oil in Ethiopia. Most extensive descriptions are accompanied by a full-page drawing, photographs of the seeds or fruits, a list of synonyms, vernacular names and selected literature. Details on taxonomic problems, occurrence, ecology, husbandry, uses, and contents and specifications of the oil and the seeds or fruits are given too. Indices on common and scientific plant names are added.

Date of publication 20 April 1983.

Cover plate: *Guizotia abyssinica* (L.f.) Cass. Photograph by H. C. D. de Wit.

This thesis will also be published as Agricultural Research Report 921.

Printed in the Netherlands.

Stellingen

I
Een stabiele plantensystematiek is een bewijs van het achterwege blijven van botanisch onderzoek.

II
De meeste botanici hebben bij hun veldwerk geen belangstelling voor de toegepaste botanie. (W. Busse, 1904. Berichte der Deutschen Pharmazeutischen Gesellschaft 14: 188).

III
Vele publikaties over cultuurplantensystematiek zou men eer taxometrisch dan taxonomisch moeten noemen.

IV
De teelt van 'ideotypen' (volgens Donald) kan schadelijk zijn voor het behoud van de bodemvruchtbaarheid. (J. D. Ferwerda, 1980. Giessener Beiträge zur Entwicklungsforschung 1(6)39).

V
De vruchtwisseling wordt meer bepaald door behoeften dan door het streven naar behoud van de bodemvruchtbaarheid.

VI
Wilde planten groeien niet op plaatsen waaraan ze fysiologisch het best zijn aangepast maar waaraan andere soorten nog slechter zijn aangepast.

VII
De titel 'The origin of species', die Darwin koos voor zijn meesterwerk, is misleidend.

VIII
Bij voortgezet onderzoek aan boomvormige *Ricinus* dienen de rol die kruisbestuiving kan spelen en de gevolgen daarvan nader te worden vastgesteld (dit proefschrift).

IX

Onderzoekers van plantaardig materiaal (zaden, extracten, hout enz.) dienen op de hoogte te zijn van uiterlijk en levenswijze van de planten die het materiaal opleveren (vgl. D. Vroege, 1971: De schadelijke werking van het zaad van de *Ricinus communis* op de gezondheid, p. 18; Proefschrift Medische Faculteit Rotterdam, 171 blz.).

X

De NOS dient zich te beperken tot de taak waarvoor deze stichting werd ingesteld en goedgekeurd.

XI

Zijn voorliefde voor honden maakt het voor de Nederlander riskant met fier geheven hoofd op straat te lopen.

Aan mijn Moeder

Samenvatting

Na boeken over peulvruchten (Westphal, 1974), landbouwkundige systemen (Westphal, 1975) en over kruiden en medicinale planten van Ethiopië (Jansen, 1981) is dit boek het vierde in een serie publikatties over de nuttige planten van Ethiopië. De serie kwam voort uit een samenwerking in NUFFIC-verband tussen de Landbouwhogeschool (vakgroepen Plantensystematiek en -geografie en Tropische Plantenteelt) en de Universiteit van Addis Ababa (Landbouwfaculteit te Alemaya).

Het voorwoord en de inleiding gaan in op de manier waarop de gebruikte materialen en gegevens werden verkregen en verwerkt.

De inleiding bevat eveneens enige opmerkingen aangaande gebruik en voorkomen van olieleverende planten in Ethiopië; tevens wordt kort ingegaan op de begrippen 'olie' en 'oliezaad'. In hoofdstuk 2 worden 23 olieleverende planten beschreven, 12 tamelijk uitgebreid en 11 kort. De kort beschreven soorten zijn onbelangrijk in Ethiopië als olieleverancier, of hun oliehoudende delen zijn een bijprodukt van andere teelten. Ze hebben gemeen, dat mij te weinig materiaal ter beschikking stond om een gedetailleerde beschrijving te rechtvaardigen.

Per soort is er gestreefd naar de volgende volgorde van behandeling der onderwerpen:

- wetenschappelijke naam en somatisch chromosoomaantal dat het meest in de literatuur voorkomt;
- verklaring van de wetenschappelijke naam;
- auteur, oorspronkelijke publicatie en type van de naam;
- synonieme namen, relevant voor Ethiopië;
- chronologisch gerangschikte lijst van de belangrijkste literatuur met een korte indicatie omtrent de aard der inhoud;
- Ethiopische plaatselijke namen met toevoeging van de Engelse en Franse;
- aardrijkskundige verspreiding van de soort;
- uitgebreide botanische beschrijving van de soort, gebaseerd op herbariummateriaal van planten uit Ethiopië of opgekweekt uit zaad uit dat land;
- taxonomische aantekeningen, o.a. aangaande typificatie en het variatiepatroon van de soort in Ethiopië , vermelding van de geraadpleegde exsiccaten en zaden;
- ecologische gegevens zoals hoogte boven zeeniveau, temperatuur en bodems;
- bijzonderheden over de ontwikkelingscyclus van de soort;
- gegevens omtrent de teelt in Ethiopië;
- gebruik van produkten van de soort;
- chemische samenstelling van de zaden en karakteristieken van de betreffende olie.

Het derde hoofdstuk bevat een korte terugblik op het reilen en zeilen van het NUFFIC-project, dat aan de basis van dit boek lag. In het tweede deel van dit hoofdstuk wordt een overzicht gegeven van de dagen waarop de markten worden gehouden langs enige belangrijke wegen in Ethiopië.

Hoofdstuk 4 is een opsomming van planten die in Ethiopië voorkomen, met hun wetenschappelijke en inheemse namen, de plantedelen waarvan de olie is onderzocht, en het oliegehalte.

De lijst van geciteerde literatuur, een woordenlijst betreffende termen die gebruikt werden bij het beschrijven van de oliën en de indices op niet-wetenschappelijke en wetenschappelijke namen besluiten het boek.

Levensloop

Cornelis Jacobus Pieter Seegeler, geboren 2 oktober 1940 te Pontianak (toenmalig N.O.I.).

Studie Landbouwhogeschool, richting Tropische Plantenveredeling, 1959–1971

Ingenieursdiploma: plantenveredeling, tropische plantenteelt, erfelijkheidsleer en algemene plantenziektenkunde

1971–1977: werkzaam in bilateraal ontwikkelingsproject ter inventarisatie van Ethiopische voedingsgewassen; gedurende

1971–1974 in Ethiopië

1977–1982 gastmedewerker bij de Landbouwhogeschool

Contents

Preface

Following books on pulses (Westphal, 1974), agricultural systems (Westphal, 1975), and on spices and medicinal plants in Ethiopia (Jansen, 1981), this book is the fourth in a series on useful Ethiopian plants. These books and a number of smaller studies mentioned on p. 5 are the result of a cooperative project between the University at Addis Abeba and the Landbouwhogeschool at Wageningen. This project was sponsored by the Netherlands University Foundation for International Cooperation (NUFFIC). Some details of the project are treated in Chapter 3. Unfortunately no funds were available to continue the project with studies on cereals and tubiferous plants from Ethiopia so that, at least for the time being, this will be the last book of the series.

A grant from the Stichting (Trust) 'Landbouw Export Bureau 1916/1918' has allowed publication of this book in its present form and is gratefully acknowledged.

The present author started his investigations in February 1971 as a temporary member of staff of the Landbouwhogeschool (LH). In the July, he left for Ethiopia, where he was based at Alemaya Agricultural College, sponsored by this College and NUFFIC. He remained in Ethiopia until the end of 1973 and re-entered service with the LH in April 1974. In July 1977, his contract expired and he terminated this book as guest member of staff of the LH.

All this time, the Laboratory of Plant Taxonomy and Plant Geography under the guidance of Professor Dr H. C. D. de Wit and the Department of Tropical Crops Science headed by Professor Dr Ir J. D. Ferwerda at Wageningen provided all possible facilities and assistance. At Alemaya, these services were kindly rendered by the College of Agriculture (Dean: Dr Melak Haile Mengesha) with its Department of Plant Science (Head: Dr Brhane Gebre Kidan), and more particularly by the Herbarium of the latter department headed by Dr Amare Getahun, who was my main partner.

On numerous collecting trips during the time in Ethiopia, 1300 herbarium accessions of wild and cultivated plants were collected and close to 1600 seed samples (not only oilseeds), mainly on markets. Also numerous facts on cultivation, area and use were noted.

From 1973 to 1975, more than 1000 herbarium exsiccates were collected from plants grown at Wageningen from Ethiopian oilseed samples. They were collected at different stages of growth.

Key to abbreviations

!	(after a specimen), seen by the present author
al.	alii = others
C	central
c.	circa, about
Code	International Code of Botanical Nomenclature
conv.	convar = cultivar group ranking between species and provar
cv.	cultivar (cultivated variety)
cvs	cultivars
diam.	diameter
f.	(after a personal noun), filius = son
FAO	Food and Agriculture Organization of the United Nations, Rome
Gg	gigagram = 10^9 g = 1000 metric tons
KR	Herbarium of the Landessammlungen für Naturkunde, Karlsruhe, West-Germany
L	Rijksherbarium, Leyden, Netherlands
lecto.	lectotype
LINN	Linnaean Herbarium, London
Mg	megagram = 1 metric ton
MJ	megajoule
N	north
obs.	observation(s)
Pa	Pascal
p.p.	pro parte, partly
prov.	provar = a cultivar group
S	south
s.l.	sensu lato = in a broad sense
s.n.	sine numero
s.s.	sensu stricto = in a narrow sense
sp.	species (singular)
spp.	species (plural)
ssp.	subspecies (singular)
sspp.	subspecies (plural)
US	U.S. National Herbarium, Washington, D.C., U.S.A.
var.	varietas = botanical variety
W	west

1 Introduction

1.1 Introductory remarks

The treatment of species in this book comes in three categories: (1) plants treated extensively, (2) plants treated briefly but with original observations and (3) plants treated briefly, entirely from the literature.

The choice of species to be treated in some detail is in accordance with two guiding principles. The first is the presence of the species as a normal component of Ethiopian agriculture (such as Niger seed, sesame). The second is specificity to Ethiopia (such as *Maesa* and *Salvia*). A few species are treated in less detail because they are well known, of less importance, or because their oily seeds are a by-product of a plant grown for another purpose.

It is a laborious job to acquire insight into the variability of a plant species in a country like Ethiopia, rich as it is in habitats differing in several ecological factors. Drawing conclusions from phenotypic differences in the field is extremely risky.To obtain an adequate impression of variability would require cultivation of samples from different origins on many places and for several growing seasons. This was impossible within the scope of the present research.

To obtain at least some idea about variability, samples from as many different regions as possible of one crop were grown on the same field simultaneously. The seedling, and the flowering and fruiting stages were preserved as herbarium material and in alcohol; the ripe seeds were harvested to allow comparison with the original sample.

The cultivated species treated in this book were grown at Wageningen, mainly at the Department of Tropical Crops Science. Those species can be recognized by the heading 'grown at Wageningen' at the end of the note on studied exsiccates (extensively treated species) or by noted observations in the text (briefly treated species).

Some of the species could be grown outside, some needed a greenhouse and some needed a greenhouse with regulated short days, but in most species, cultivation through the complete growing cycle gave no problem at Wageningen.

Castor, however, behaved differently from what I had seen in Ethiopia. Its growth was enormous in the greenhouse (about 1 metre per month) and also outside (about 0.5 metre per month) but only very few plants produced flowers, even after more than a year. As Dr Jansen, author of the book on spices and medicinal plants, was about to leave for Ethiopia when this was known, I gave him a selection of seed-types and origins of this species for sowing at Alemaya. At Alemaya, all samples produced flowers within the first growing season.

Thus the descriptions of *Brassica* spp., safflower, niger, linseed and sesame are mainly based on material grown at Wageningen and seed samples collected in Ethiopia, while those of castor and species collected from the wild are mainly based on exsiccates from Ethiopia. The other species take an intermediate position, or are based entirely on the literature.

All collected specimens are conserved in Herbarium Vadense (WAG). A duplicate set of each number of the entire collection made in Ethiopia was left in the Herbarium of the College of Agriculture at Alemaya (ACD). The cited collection numbers refer to the material conserved in the Wageningen herbarium, unless otherwise indicated.

The extensively treated species are presented in the following way.

- Scientific name and somatic chromosome number, mostly found in literature
- Translation or explanation of the scientific name, mainly based on Backer (1936)
- The author and original publication of the name
- The type of the name
- Synonymous names, relevant to Ethiopia or regularly found in the (older) literature
- A chronologically arranged selected list of most important literature on the species. The references are usually abbreviated and full citations can be found in the Bibliography. To each publication the indications (tax.) or (agric.) are added, which point to the main aspect of the publication: taxonomy or agriculture. Under 'agriculture' is unterstood also uses and chemical composition.
- Ethiopian vernacular names. A choice was made of the usually numerous ways in which the names may be found spelt in the literature. The main source for these names was Cufodontis (1974, facsimile), but also my own notes and other literature were included. The language or area in which the names are used is given in parenthesis (e.g. Amarinya, Gallinya). To the vernacular names, those in English and French were added, if available.
- The geographic distribution
- A detailed botanical description, usually accompanied by a botanical drawing and sometimes photographs. The description was made by observation of the herbarium and alcohol collection, obtained as described above, with a binocular microscope, a pocket lens and the unaided eye. Measurements were made from boiled herbarium material or material in alcohol. The use of botanical terms conforms to B. D. Jackson, A Glossary of Botanic Terms, 4th ed., 1971 and G. H. M. Lawrence, Taxonomy of Vascular Plants, Appendix Illustrated Glossary of Taxonomical Terms, 11th printing, 1970. To describe the shapes of leaves and fruits, the proposed standardization of terms for flat shapes of the International Association for Plant Taxonomy (Taxon 11(5), 1962: p. 145–156) has been followed, for three-dimensional bodies using the ending '-oid' instead of '-ate'.
- Notes on typification, literature, variability of Ethiopian material, and citation of the material used for the description. In the citation, some of the collectors' names have been abbreviated the following way: Bos = J. J. Bos, JdeW = J. J. F. E. de Wilde, PJ = P. C. M. Jansen, SL = C. J. P. Seegeler, WdeW = W. J. J. O. de Wilde & B. E. E. de Wilde-Duyfjes, WP = E. Westphal & J. M. C. Westphal-Stevels. Al-

though the variability of a species is often impressive, no cultivars were distinguished because the species were not studied in a sufficient number of generations to establish the true breeding of morphological characters. And even then, data on physiological reactions should have been taken because they commonly form an integrated part of cultivar descriptions of field-crop species. Only for linseed was one cultivar distinguished. The reason why I felt justified in doing so was that the area where I found it was very limited, and because I found it twice with more than a year between, sold by traders who also offered different-looking linseed samples. The plants bred true, as could be expected in a crop with such strong selfing characteristics as *Linum usitatissimum*. The attentive reader may wonder why I distinguish cultivar groupings ('provars') in linseed but not in castor, while for the latter species comparable groupings were distinguished by some authors. There are two explanations for this: a. the keys provided by those authors did not work at all on my material, b. in the course of time my observations led me more and more to the conviction that an isonymous system of naming cultivars cannot be applied in our present state of knowledge.
– Ecology. The factors were treated in the following order: temperature/altitude, water, soil, light, other factors.
– 'Development of the plant' gives a survey of the way the plants develop during their cycle.
– Husbandry. This paragraph is included only if the species is cultivated; it is about the cultivation of the species.
– 'Uses' indicates the traditional use in Ethiopia, and sometimes elsewhere. Indications of non-traditional industrial uses may be included.
– The last paragraph, chemical and physical properties, gives information on the oil contents, oil, seed and fruit characteristics, and often some information on other components of the seeds as well. The data on this subject are merely indicative. For detailed information, the original publications should be consulted. In the text and tables of this paragraph, a notation of numbers is used which is familiar to taxonomists, but not always to people of other disciplines: $(n_1)n_2–n_3(n_4)$ should be read as 'common range $n_2–n_3$ with extreme values at n_1 and n_4'. In principle, the same succession of subjects has been followed with the shortly treated species.

During some years, students made observations on living material grown from Ethiopian oilseeds at Wageningen, as part of their research. The names of the students and the translated titles of their respective researches were:
– R. Henneman & Digna van Ballegooijen, A study of the growth of a number of Ethiopian oilseed crops (1973)
– E. B. Scheltens, Observations on cold-resistance and cold-tolerance of some Ethiopian oilseed crops (1976)
– A. R. van Klinken, Influence of daylength on growth and development of Brassica carinata (1976)
– J. H. den Oever, Salt tolerance of Brassica carinata (1977).
Most of their observations are reported under 'notes' or 'development of the plant'.

In the oils produced by plants, two groups are distinguished: (a) fixed non-volatile oils, also called fatty oils, and (b) essential volatile oils, also called aethereal oils. Both groups have basically different compositions and uses. Usually a plant species produces oil of only one of the groups.

On a world scale, the fixed oils are commercially the most important. Plants cultivated for essential oils are not considered in this publication. 'Oil' thus is to be read as fatty or fixed oil.

If the material is liquid at ordinary temperatures, it is commonly called an oil; if it is solid at such temperatures, a fat. Chemically there is no definite distinction between oils and fats and the words may be used indiscriminately.

Most plant species from which useful oils can be derived are found in the tropics, and the major oil-crops of the world are grown in the tropics too. In cooler climates, plants mostly accumulate carbohydrates in their fruits and seeds (Adam & Ferrand, 1958).

Oilseeds play an important role in the traditional nutrition of the Ethiopian; they are a major source of energy and proteins. In Ethiopian traditional cooking, little oil as such is used. The most common dishes are cooked, rather than fried, and pounded whole oilseeds may be added. The pan to bake the bread is traditionally greased with pounded whole seed, but I saw the greasing in a modern version by rubbing the pan with some cotton soaked in oil.

Traditionally pure oil is only prepared for medicinal purposes, for tanning leather and wood, and for greasing hair and body. For other purposes, the seeds are usually consumed entire.

Particularly with poor people and on fasting days, the stew to be served with the injera (flat bread) is mostly prepared from onions, ground pulses and spices, with addition of crushed roasted oil-seeds to obtain a smoother substance. Near Gonder, the wot (stew) may even be prepared from linseed with spices only (Knutson & Selinus, 1970; Selinus et al., 1971a). In non-fasting times, the well-to-do people usually replace pulses and oilseeds by meat and butter.

The fasting days are many, commonly 2 days per week and then still special days or periods. According to Knutson & Selinus (1970), the common people have 110–150 fasting days per year, but the more pious and the clergy may fast as many as 220 days per year. During such fasts, no food whatsoever of animal origin is eaten so that the oilseeds are the only source of fat and of the fat-soluble vitamins.

During fasting, there are also special dishes in which oilseeds play a role, and the consumption of oily seeds as snack meals is often increased (Knutson & Selinus, 1970).

Mixtures of roasted oilseeds with spices are used by travellers as 'instant food' (Messing, 1962). I found such a mixture of oilseeds only offered on the market of Gonder, the same area that Messing described. It is thus possible that it is a rather local use.

In many areas of Ethiopia, oilseeds are only partly used in the farmer's household.

The rest is sold on market, to traders or to oil-mills (Kuls, 1957; Rydén, 1972; pers. commun. Dr Amare G., 1972). The part of the yield kept for household consumption is commonly stored in clay containers in the house (my own obs.; Selinus et al., 1971a).

The available data on the total volume of Ethiopian oilseed produced all refer to the 1950s and 1960s (e.g. Bridges, 1960; Schäfer, 1964; Industries et T.O.M., 1967; Kaplan et al., 1971). They indicate a total production of c. 350–390 Gg and an export of c. 15% of this weight.

For the area occupied by oil crops, more different values are encountered. According to Bridges (1960), the most important oil crops together covered about 361000 ha, but Bridges did not include cotton, safflower and rape. To me, the figure of 650000 to 680000 ha for 1961–1962, as given by Statistical Abstract (1964), seems a more likely figure. If we combine the data in the FAO Production Yearbook 1980 for the years 1978–1980 on separate crops and presume that the area of Niger seed has increased to 400000 ha, the total area covered by oilseed crops seems to be still in this range.

In view of the large increase, notably in cotton area in the 1970s, this data seems improbable to me. Indeed, FAO Production Yearbook 1979 indicates a considerably higher cotton area, but a much lower average yield. As I do not know the reason for this discrepancy, I report the data in Table 1.

Table 1. Area (a; in 1000 ha), yield (y; in kg/ha) and production (p; in Gg) of the most important oilseeds in Ethiopia. Sources: Statistical Abstract, 1964 (on 1961) and FAO Production Yearbooks 1979, 1980. For further explanation of this Table see the text.

		Cotton	Niger	Linseed	Rapeseed	Sesame	Peanut	Safflower	Castor	Niger (fictive)	Total
1961	a	25	341	100	12.5	75	30	50	20		653.5
	y	170	600	500	400	400	500	500	500		
	p	4.2	205	50	5	30	15	25	100		344.2
1978	a	160		38	50	70	46	64	11	400	839
(FAO: 1979)	y	450		369	400	571	598	469	1000		
	p	72		14	20	40	28	30	11	240	455
1978	a	29		38	53	70	46	64	11	400	711
(FAO: 1980)	y	1886		369	406	571	598	469	1000		
	p	54		14	22	40	28	30	11	240	439
1979	a	165		36	50	80	46	65	11	400	853
(FAO: 1979)	y	455		373	400	574	603	476	1000		
	p	75		14	20	46	28	31	11	240	465
1979	a	28		36	52	79	47	64	11	400	717
(FAO: 1980)	y	2000		373	404	482	596	469	1000		
	p	56		14	21	38	28	30	11	240	438
1980	a	28		36	53	88	47	65	12	400	728
	y	2143		378	406	510	596	477	1000		
	p	60		14	22	45	28	31	12	240	440

The figures 728×10^3 ha and 853×10^3 ha are 5.6 and 6.6% of the 13×10^6 ha, which form the Ethiopian arable land. Oilseeds are therefore the third most important component in Ethiopian agriculture after cereals (39%) and pulses (6.6%) (FAO, 1980).

According to Mesfin (1970, Map 37), the main production areas of oilseeds are: NW Bale province with adjoining Arussi area (more than 10% of the cultivated land under oilseeds), E half of Welega and C Beghemder (with 8–10%) and Tigre, S Eritrea and most of the Tana region (5–7%). The rest of Ethiopia has less than 5% of the cultivated land under oilseeds.

Mesfin reports these land usages as average per awraja (governmental unit) and thus some smaller areas in large, mainly uncultivated awrajas are not represented (e.g. the Gambela-Baro region in Gambela awraja, where I saw much sesame).

Unfavourably Mesfin does not delimit his understanding of oilseeds, nor mention the year on which his map is based. My impression (1973) was that the area he indicates in Bale as very important (over 10%) is much more restricted eastwards but that the southern part of Shewa (Mesfin: below 2%) has more oilseeds, particularly in the 'lake district'. Other areas that he underestimates in my opinion are the Chercher Mountains (Mesfin: negligible), E Gojam (Mesfin: less than 4%), and SW Welo (Mesfin: negligible). I considered the Tana region up north to the Simien Mountains, Shewa Rift Valley and adjoining areas, SW Welo, E Illubabor and E Gojam, and the Chercher Mountains to be the most important oilseed areas of Ethiopia in 1973. There are some smaller areas in which oilseeds form an important component of agriculture in the lowlands near the Sudanese border.

Map 8 of the Ethiopian Ministry of Education (1962): 'Ethiopia, oil seeds distribution' still gives a fair impression of the importance of markets of different regions for the oilseeds, although I have the idea that the richness of Eritrea and Kefa is underrepresented. Surprisingly on this map, safflower was not included. Sunflower, on the other hand, is indicated for most markets. This conflicts with my own experiences and I think that 'sunflower' on that map should be read as 'safflower'. I found this mix-up of names regularly in Ethiopian publications.

Alphabetically by province and town, it reads as follows (0 = cotton, 1 = linseed, 2 = cucurbits, 3 = Niger seed, 4 = sesame, 5 = peanut, 6 = black mustard, 7 = castor, 8 = rapeseed, 9 = sunflower).

Arussi
Asella 1, 2, 3, 6, 7, 8, 9
Teferi Ber 1, 2, 3, 4, 6, 7, 8, 9
Ticho 1, 2, 3, 6, 7, 8, 9
Bale
Goba 0, 1, 2, 3, 4, 6, 7, 8, 9
Beghemder
Aykel 0, 2, 3, 4, 6, 7, 8, 9
Dabat 0, 1, 2, 3, 4, 6, 7, 8, 9
Debarak 0, 1, 2, 3, 4, 6, 8, 9
Debre Tabor 0, 1, 2, 3, 4, 6, 7, 8, 9
Gonder 0, 2, 3, 4, 6, 7, 8, 9
Nefas Mewcha 0, 1, 2, 3, 4, 6, 7, 8, 9
Eritrea
Adi Keyeh 1, 3
Adi Ugri 1, 3
Asmera 1, 3, 4, 5
Keren 0, 3, 4, 5
Gemu Gofa
Bulki 0, 1, 2, 3, 4, 6, 7, 8, 9
Chencha 0, 1, 2, 3, 4, 6, 7, 8, 9
Gidole 0, 1, 2, 3, 4, 6, 7, 8, 9

Hamer 0, 1, 2, 3, 4, 5, 6, 7, 8, 9
Gojam
Dangla 0, 1, 2, 3, 4, 6, 7, 8, 9
Debre Markos 0, 1, 2, 3, 4, 6, 7, 8, 9
Felega Birhan 0, 1, 2, 3, 4, 6, 7, 8, 9
Finote Selam 0, 1, 2, 3, 4, 6, 7, 8, 9
KHS Ber 0, 1, 2, 3, 4, 6, 8, 9
Harergie
Afdem 0, 1, 2, 3, 4, 5, 6, 7, 8, 9
Asbe Teferi 1, 2, 3, 4, 6, 7, 8, 9
Deder 1, 2, 3, 4, 6, 7, 8, 9
Dire Dawa 0, 1, 2, 3, 4, 5, 6, 7, 8, 9
Funyan Berha 1, 2, 3, 4, 5, 6, 7, 8, 9
Grawa 1, 2, 3, 4, 6, 7, 8, 9
Jijiga 0, 1, 2, 3, 4, 5, 6, 7, 8, 9
Illubabor
Bedele 1, 2, 3, 4, 5, 6, 7, 8, 9
Gambela 0, 4, 5
Gecha 0, 1, 2, 3, 4, 5, 6, 7, 8, 9
Gore 0, 1, 2, 3, 4, 5, 6, 7, 8, 9
Kefa
Jimma 0, 1
Maji 0, 1
Waka 0
Shewa
Addis Abeba 0, 1, 4, 6, 7
Ambo 0, 1, 3, 4, 6, 8, 9
Butajira 0, 1, 3, 4, 6, 7, 8, 9
Debre Birhan 0, 1, 3, 4, 6, 8, 9
Debre Sina 0, 1, 3, 4, 6, 7, 8, 9
Fiche 0, 1, 3, 4, 6
Ghiyon 0, 1, 3, 4, 6, 8, 9
Hosaina 0, 2, 3, 6, 7, 8, 9
Nazret 0, 1, 3, 5, 8, 9
Sidamo
Dila 0, 1, 2, 3, 4, 6, 7, 8, 9
Kebre Mengist 0, 1, 2, 3, 4, 5, 6, 7, 8, 9
Neghele 0, 3, 4, 6, 8,9
Sodo 0, 1, 2, 3, 4, 6, 7, 8, 9
Yabelo 1, 2, 3, 4, 6, 8, 9
Yirga Alem 0, 1, 2, 3, 4, 6, 7, 8, 9
Tigre
Abi Adi 0, 1, 3, 4, 8, 9
Adigrat 0, 1, 4
Adua 0, 1, 3, 4, 8, 9
Aksum 0, 1, 3, 4, 8, 9
Enda Selassie 0, 1, 3, 4, 6, 8, 9
Maychew 0, 1, 3, 4, 8, 9
Mekele 1, 3, 4, 8, 9
Welega
Arjo 0, 1, 2, 3, 4, 5, 6, 7, 8, 9
Asosa 0, 1, 2, 3, 4, 5, 6, 7, 8, 9
Dembidolo 0, 1, 2, 3, 4, 5, 6, 7, 8, 9
Ghimbi 0, 1, 2, 3, 4, 5, 6, 7, 8, 9
Nekempt 0, 1, 2, 3, 4, 5, 6, 7, 8, 9
Shambu 0, 1, 2, 3, 4, 5, 6, 7, 8, 9
Welo
Bati 0, 3
Debre Tsehay 0, 1, 3, 4, 6, 7, 8, 9
Dessie 0, 1, 3, 4, 6, 9
Haik 0, 1, 3, 4, 6, 8, 9
Kembolcha 0, 1, 3, 4, 6, 7, 8,9
Mekane Selam 0, 1, 3, 4, 6, 8, 9
Sekota 0, 1, 3, 4, 6, 8, 9
Tenta 0, 1, 3, 4, 6, 7, 8, 9
Wegel Tona 0, 1, 3, 4, 6, 7, 8, 9
Weldiya 0, 1, 3, 4, 6, 8
Wereilu 0, 1, 3, 4, 6, 8, 9

Some recent publications brought to my attention the changes in several place-names in Ethiopia. Unfortunately a full list of name-changes was not available to me so that I present names of places and provinces as they were before the Revolution.

There are three ways of separating oil quickly from the solids of the seed or fruit: separation by heat, by pressure, and by extraction. They all start by grinding the seeds or fruits after removal of extraneous matter from the bulk.

The simplest and probably oldest method is separation by heat. It is still common in many parts of Ethiopia. In its most primitive form, small lumps of the crushed material, often wrapped in a piece of cloth, may be used as such to grease a heated pan; in its more sophisticated form, the crushed material is combined with water and heated. The oil separates and starts to float; it can then be skimmed off.

The second method is separation by pressure. The simplest way is to wrap the crushed and perhaps heated material in a cloth and then to wring it out. It is easy to imagine how this method evolved from separation by heat. I saw this method used once in the Chercher Highlands.

In many parts of the world, traditional ways have been developed of separating the oil with mechanical presses. To my knowledge, this has not happened in Ethiopia, so that the oil-presses in the country are all of a more sophisticated type driven by a motor. In the literature, I only found one description of an oil-mill from Ethiopia. According to Suzzi (1904), the Baza people of Eritrea have an oil-mill consisting of a tree trunk fixed to the ground with a cavity on top. In that cavity, seed is crushed with a wooden cylinder propelled by a camel.

Solvent extraction is the most sophisticated process for oil separation. It is only used by rather large mills and leaves 1-2% of the oil in the residue.

After pressure separation, c. 4–8% of oil remains in the cake, which therefore has a higher feeding value for livestock than the solid residue from solvent extraction.

The residue from oilseeds and oilfruits is generally used for agricultural purposes, either for stockfeeding or as a fertilizer, but it is sometimes used as a foodstuff. Use is determined by composition, palatability and side-effects of substances in the residue. The value for stockfeeding is dependent mainly on content of residual oil and of protein.

The oil obtained in any of the ways described contains small amounts of impurities in the form of meal, moisture and other non-fatty substances, which can be removed by simple means such as sedimentation, filtration or centrifuging. From small mills in Ethiopia, this is usually the form in which the oil is sold to retailers. In large oil-mills, the oil may be given additional treatments (e.g. bleaching, deodorization), depending on the oil itself and on its anticipated use.

Of the wide range of plants cultivated for oil, only a few are suitable for large-scale commercial production and produce oil for which there is a large demand.

In areas where new crops are sought for diversification, oil crops are often considered because oil plants, particularly the annuals, have the following attractive properties.

- They show a large variability with forms adapted to a wide range of environmental conditions and cultural practices. They therefore can be included easily in nearly all the agricultural systems based on annuals.
- Extraction is relatively simple and does not require large factories.
- The oils can be consumed locally and can be exported. They often have a variety of uses, thus extending demand: the world market is substantial and is expected to continue to grow (FAO, 1979).
- With local production, valuable by-products stay in the country.
- The oils and the seeds can be stored easily for some time, even under warm conditions.
- Sometimes secondary industries can be established using the by-products (e.g. cattle feed).

The analysis of oilseeds and of their presscake for nutritive value is usually somewhat arbitrary. The various constituents are classed together under certain headings. There is, as a rule, no differentiation between the various substances included under the headings. The usual headings are: moisture, oil, protein (or albuminoids), carbohydrates, fibre and ash (mineral matter).

This way of expressing composition does not closely reflect the nutritive value of the substance analyzed. There is, for instance, no discrimination between the various nitrogen compounds present, nor is any idea given of the actual availability of the constituents. This is a great drawback to the value of such data, but they have the advantage that they can be obtained quickly (Williams, 1950).

In the description of an oil, both physical and chemical characteristics are used. Different methods may lead to different values. It is thus necessary to indicate the method used. That this is often forgotten leads to a poor comparability of data from different sources.

Especially for reasons of legal quality control, an intensive programme of standardization has been pursued for a number of years in most countries. This has resulted in the promulgation of standards, not only for the oils themselves but necessarily also for the methods of analysis, applicable to the oils (Williams, 1950).

Whereas volatile oils contain a variety of chemical components e.g. esters, ethers and alcohols, most fixed oils consist almost entirely of triglycerides with fatty acids. In oils produced for edible purposes, the main fatty acids are oleic and linoleic acid; the latter is an essential fatty acid.

Olive and peanut oil have oleic acid as their main component, while soya oil, cotton seed oil, and sunflower seed oil have linoleic as their main constituting fatty acid. Seed oils from crucifers deviate from this pattern because they contain variable but

Table 2. Some characteristics of average samples of certain oils (Weiss, 1971, p. 743, 744; Niger seed: Chavan, 1961).

	Density at 60 °C	Iodine value (Wijs)	Melting point (°C)	Refractive index at 60 °C	Saponification value	Titre (°C)	Unsaponifiable matter (g/kg)
Cottonseed	0.889–0.894	108	5–10	1.4572	195	32–37	5–20
Linseed	0.902–0.907	180	0	1.4655	192	14–16	5–15
Niger seed		132			191		5–12
Peanut	0.885–0.890	90	5–10	1.4550	189	28–32	4–10
Safflower	0.898–0.903	145	0	1.4620	191	15–17	5–15
Sesame	0.889–0.894	111	0	1.4582	192	22–26	5–15
Soya	0.895–0.900	130	0	1.4600	192	20–32	5–15
Sunflower	0.894–0.899	128	0	1.4597	191	17–20	3– 5

Table 3. Component fatty acids of average samples of some common edible oils (percentage by mass; data from Weiss, 1971, p. 743, and for niger from Chavan, 1961).

	Myristic	Palmitic	Stearic	Arachidic	Saturated total	Oleic	Linoleic	Linolenic	Unsaturated total
Cottonseed	1	21	2	1	25	25	50	–	75
Linseed	–	–	9	–	9	23	20	48	91
Niger seed	1	7	7	1	15	22	63	–	85
Peanut	–	8	4	3	15	55	25	–	80
Safflower	–	5	1	1	7	20	70	–	90
Sesame	–	8	3	1	12	47	41	–	88
Soya	–	9	2	1	12	32	53	3	88
Sunflower	–	5	2	1	8	35	57	–	92

Table 4. Content of amino acids in sample (A) and crude protein (B) of some oilseed residues (g/kg); data from Weiss, 1971, p. 735.

		Castor flour	Cottonseed meal	Linseed meal	Peanut meal	Safflower meal	Sesame meal	Soya bean meal	Sunflower seed meal
Crude protein		650	396	367	390	221	461	453	210
Arginine	A	83.9	43.8	34.1	40.2	17.2	54.9	33.8	16.3
	B	129.0	110.2	92.8	103.3	77.8	119.1	74.6	77.6
Histidine	A	13.6	10.7	6.6	8.4	4.4	10.2	11.2	4.6
	B	20.9	27.0	18.0	21.6	19.9	22.1	24.9	21.9
Isoleucine	A	34.6	15.9	16.8	16.9	8.5	19.7	24.9	9.5
	B	53.2	40.1	45.7	43.3	38.5	42.7	55.0	45.2
Leucine	A	41.6	24.6	21.9	26.0	12.2	31.9	34.8	12.5
	B	64.0	62.0	59.6	66.8	55.2	69.2	76.9	59.5
Lysine	A	22.0	16.7	13.3	13.8	6.0	12.7	27.9	8.0
	B	33.8	42.0	36.2	35.3	27.1	27.6	61.7	38.1
Methionine	A	11.6	5.9	6.1	4.1	3.4	12.2	6.3	4.6
	B	17.8	14.9	16.6	10.4	15.4	26.5	13.9	21.9
Phenylalanine	A	33.8	20.9	16.5	19.4	11.6	21.8	22.0	17.6
	B	51.9	52.5	44.9	49.7	52.5	47.3	48.6	51.2
Threonine	A	25.0	13.8	13.9	11.6	6.5	16.8	18.2	7.2
	B	38.4	34.7	37.8	29.8	29.4	36.4	40.3	34.3
Tryptophan	A	9.3	6.3	6.4	4.7	2.6	8.8	7.6	2.9
	B	14.3	15.9	17.4	12.2	11.8	19.1	16.9	13.8
Valine	A	43.8	19.8	20.4	18.8	10.9	23.3	24.5	10.3
	B	67.4	49.8	55.5	48.2	49.3	50.6	54.0	49.0

usually large amounts of erucic acid and also about 10% of linolenic acid (Appelqvist, 1966). Linolenic acid is also a major component of linseed oil. Of the plants considered in this study, castor has the most characteristic composition. Its main fatty acid is ricinoleic acid, which renders this oil unfit for normal human consumption.

A comparison of some oil characteristics, fatty acid composition, and protein contents and amino acid composition of some common oilseeds is presented in Tables 2, 3, and 4, respectively.

1.2 Ecological survey

Figure 1 presents a comparison of the ranges of altitude of the species of oil plants, treated in some detail in this publication. A count of the species on the perpendiculars indicates that the largest number of oil-plant species is found around 1900 m. At higher altitudes, the number of species rapidly decreases. Above 2400 m no species are found that do not occur below that altitude as well. The number of species below 1900 m decreases only gradually but some of these species do not even reach 1900 m: the

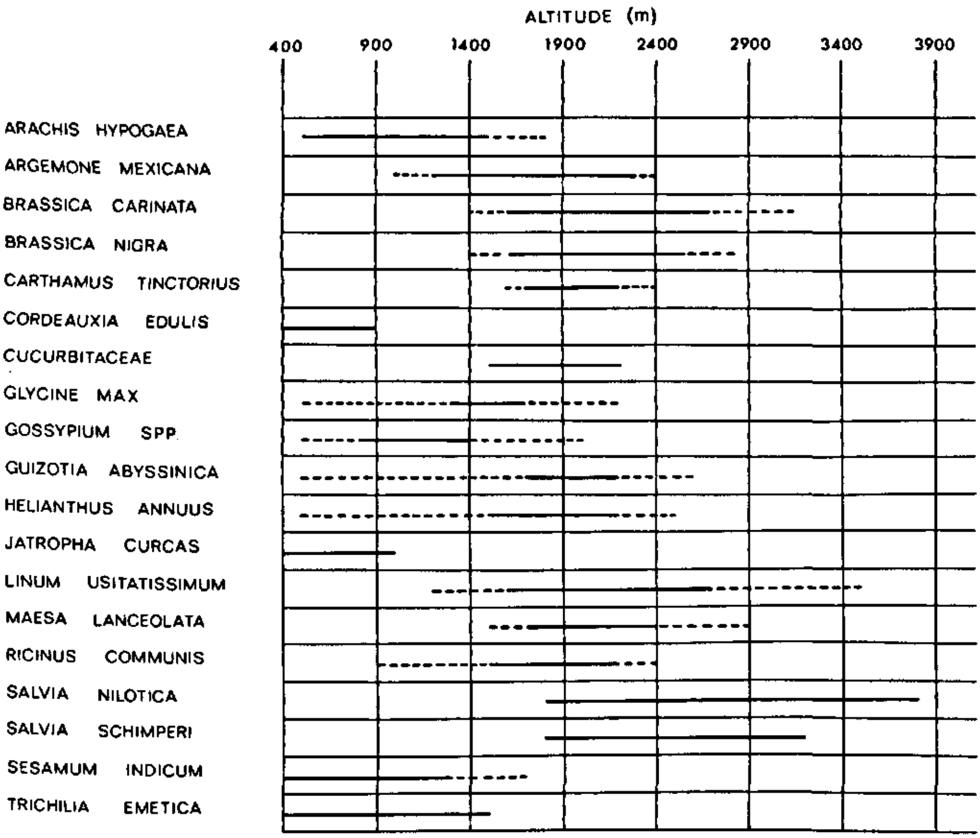


Figure 1. Altitudinal ranges of some Ethiopian oil-bearing plants.

diversity of oil-producing plants increases till 1900 m and decreases above that altitude.

There seems to be a natural boundary at c. 1500 m. This altitude coincides with the boundary between the hot lowlands (kolla) and the more temperate highlands (weina dega), and thus with different traditional living habits of the population: nomadic and sedentary, respectively.

Above 1500 m, the largest number of species show their best productivity and widest distribution. Of the species with their main area below 1500 m, the 'wild' ones are mainly used by nomads. The cultivated species may be found on a small scale in traditional cultivation (e.g. sesame on river banks) but are often found in large-scale plantings in development and resettlement schemes (e.g. cotton, sesame).

In summary, the most important areas for traditional oilseed cultivation in Ethiopia are between 1700 and 2200 m (Fig. 2). The climate at these altitudes is characterized by a rainy season that provides at least 3 months without a water deficit (Thornthwaite & Mather, 1962: recalculated for Eritrea because the precipitation, indicated as mm but actually cm) and a clear-cut dry season. The annual precipitation commonly varies from 600 to 1300 mm per year.

During the cropping season, average daily temperature is 16–22 °C, with maxima ranging 25–35 °C and minima 10–12 °C during the wet season. During the dry season, near harvesting time, temperatures are lower and during the night often below 0 °C. particularly in the drier areas and in valleys surrounded by high mountains.

Under the drier conditions, low temperatures can be more damaging because no dew is formed.

In large areas of Ethiopia, night frosts may occur at much lower altitudes such as 1500 m. This is particularly important if irrigation is envisaged, which is usually most profitable in the dry season, when there are hardly any clouds. A number of oil crops (e.g. safflower, linseed) resist some frost and low temperatures in the seedling stage. The best sowing time for the major portion of similar areas in Ethiopia would be September–October.

According to Westphal (1975, Maps 5, 7), the climates of most of the areas where oilseeds are produced should be classified as Cw (Delliquadri classification), while the soils could be described as Tropepts and Udalfs.

Most of the treated species form strong root systems and several of them show little resistance to excessive moisture. In the selection of a field for oilseed production, depth and permeability of the soil are important factors, heavy soils being mainly of interest in regions with low precipitation.

The majority of oilseeds in Ethiopia are produced by subsistance farmers in the highlands, thus in traditional agriculture. According to Amare (1980), oil crops are only an essential component of agriculture in the Central Highlands (SW Shewa, Central Mountains and Gojam). According to my observations, the Lake Tana Basin and W Arussi province should certainly be included. Amare's previous outline of 'Highlands' (1978, Fig. 1) gives a correcter image of the area where much oilseed is produced (though excluding areas over 2400 m).

The most common agricultural practice in the major portion of the oilseed area

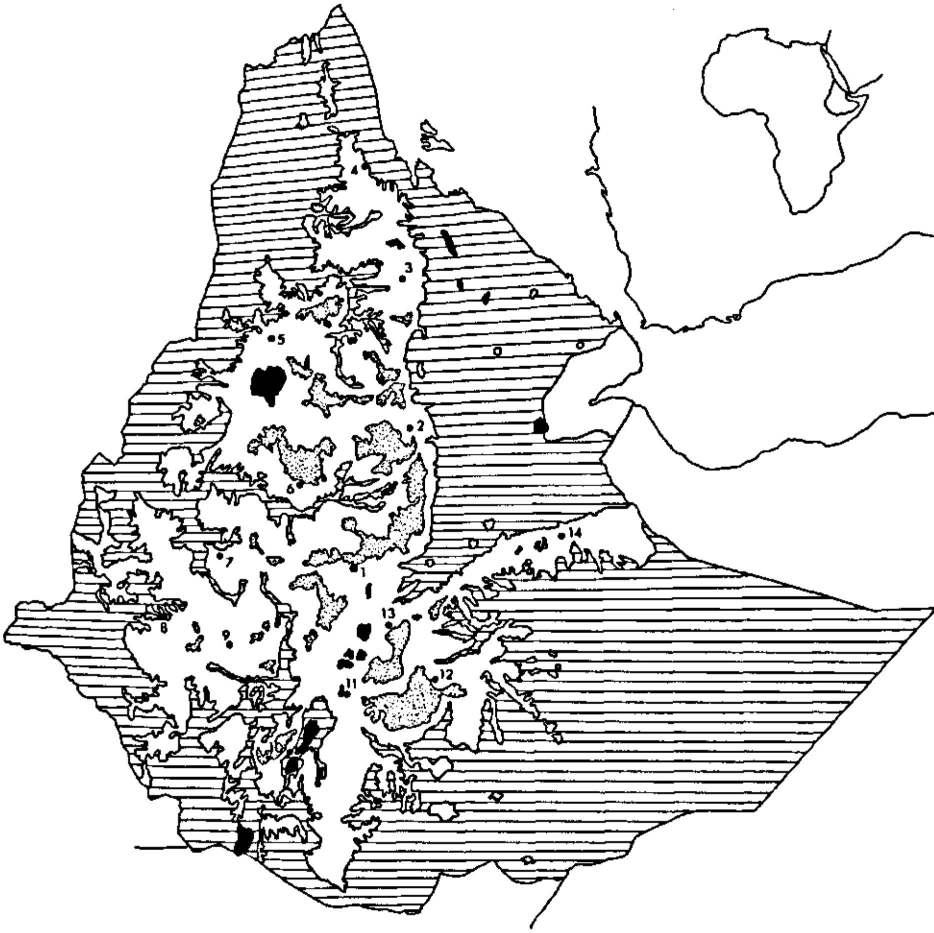


Fig. 2. Outlines of the climatic zones, commonly distinguished in Ethiopia (generalized). Hatched, hot lowlands ('kolla'); white, temperate highlands ('weina dega' and 'lower dega', the main area for traditional oilseed cultivation); dotted: cool to cold highlands ('upper dega' and 'chok'); black, lakes. Towns: 1. Addis Abeba; 2, Dessie; 3, Mekelle; 4, Asmara; 5, Gonder; 6, Debre Markos; 7, Nekempt; 8, Metu; 9, Jimma; 10, Arba Minch; 11. Awasa; 12, Goba; 13, Asella; 14, Harer.

is to plough the field a few times crosswise with the 'marasha', a plough that merely loosens the soil but does not turn it over, so that the subsoil is left untouched. After broadcasting, the seed is usually ploughed under. Weeding is done by hand or with a hoe, and harvesting with a sickle. After cutting, the plants are brought to the winnowing place where threshing is done by beating with a stick. Sieving and winnowing make the product ready for storage or sale.

According to Schäfer (1964), the yields of most traditional cultures in Ethiopia are not low because of the natural environment, but because of failing agricultural practices. This was shown in experimental plantings. He indicates the following reasons for low yields. (1) The soil is not worked deep enough, resulting in a root volume too small for optimum supply of nutrients and water. (2) The low yielding potential of the cultivars used. (3) The absence of a strict rotation: usually what is most needed is sown. (4) Fertilizer is not used. (5) Weeding of the field is usually insufficient because of the difficulties caused by broadcast sowing. (6) Phytosanitary methods are practically unknown.

His observations on seed-bed preparation may be true for level terrain, but the profit resulting from deeper ploughing on slopes (and the cultivated slopes may be steep in Ethiopia!) could lead to disaster and cause increased soil erosion. Even with the present ploughing, more than half of Ethiopia, including all areas important to oilseed cultivation, show an annual loss of soil of more than 2 Gg/km^2 (Mesfin, 1970, Map 16). Because many oil crops prefer lighter soils (see p. 14), it would not be advisable to change the present ploughing practices, which promote soil conditions suitable for oil crops.

Points 2 and 4 are related, as can be seen with Niger seed. Fertilizer application often makes the plants too heavy and they lodge; fertilizer may thus decrease yields instead of increasing them. Simple selection methods, though, may result in crops with a better production than imported cultivars, as for oil-bearing brassicas. Thus introduction of fertilizer practices and other cultivars should be closely tuned and carefully handled. Several of Schäfers conclusions (1, 2, 3, 4) need reconsideration.

The other points proposed by Schäfer hit the mark, although some phytosanitary measures are certainly present. Removal of apparently diseased plants from more or less healthy plantings is common practice, particularly for safflower and sesame.

2 Oil-bearing plants

2.1 Arachis hypogaea L. (Leguminosae, Papilionoideae) (2n = 40)

'Arachis': from the classical Greek arachos. The latter was a pulse but not belonging to the present genus. *'hypogaea'*: subterranean, its fruits ripening under the surface of the soil.

Linnaeus, Sp. pl. ed. 1: p. 741 (1753).
Type: LINN 909.1, a specimen grown in Hort. upsaliense.
Designated by Krapovickas & Rigoni (1960). (Microfiche!).

In Ethiopia 3 varieties in 2 subspecies.

A. subspecies hypogaea
Synonyms
Arachis africana Loureiro, Fl. cochinch. 2: p. 430 (1790).
A. hypogaea L. ssp. *procumbens* Waldron, Contr. bot. Lab. Univ. Pennsylvania 4(2): p. 312 (1919).
A. hypogaea L. ssp. *africana* (Lour.) Bois, Plantes aliment. Vol. 1: p. 96 (1927).
(Many more synonyms with Krapovickas & Rigoni, 1960).
var. hypogaea
Synonym
Arachis nambyquarae Hoehne, Comm. Linh. telegr. Matto Grosso Amaz. Annexo 5, Bot. XII.21: t. 190 (1922).

B. subspecies fastigiata Waldron, Contr. bot. Lab. Univ. Pennsylvania 4(2): p. 312 (1919).
Synonym
A. hypogaea L. var. *africana* Kurtz, Verh. bot. Ver. Brandenburg: p. 45 (1975).
B.1.: var. fastigiata (fide Kay, see p. 23).
B.2.: var. vulgaris Harz, Samenkunde: p. 642 (1885).

Because I did not see the publications of Waldron and Harz, and do not know whether any of their material was preserved, no types are designated.

Literature

1950: Baldrati, Trattato delle coltivazioni tropicali e subtropicali: p. 425–440. (agric. + tax.)
1960: Krapovickas & Rigoni, Rev. Inv. agric. 14: p. 197–228. (tax.)
1961: Cornejo, Oléagineux 16(1): p. 1–8. (agric.)
1969: Krapovickas, in: Ucko & Dimbleby, eds, The domestication and exploitation of plants and animals: p. 427–441. (tax.)
1972: Gibbons et al., Euphytica 21(1): p. 78–85. (tax.)
1973: Peanuts, culture and uses, 684 p. (no editor, authored chapters). (agric. + tax.)
1976: Forestier, Résumé d'une bibliographie de l'arachide. (agric.)
1977: Ackland, East African crops: p. 118–123. (agric.)
1980: Bunting & Elston, in Summerfield & Bunting, eds, Advances in legume science: p. 495–500. (agric.)

1980: Gregory et al., in Summerfield & Bunting, eds, Advances in legume science: p. 469–481. (tax.)
1980: Resslar, Euphytica 9(3): p. 813–817. (tax.)

Vernacular names: lewz, loze (Amarinya); ocholloni (Gallinya); full-sudani, full (Eritrea, Arabic).
Trade names: groundnut, peanut (English); arachide, cacahuète (French); maní, cacahuete (Spanish).

Geographic distribution

It seems likely that *Arachis hypogaea* originated in Bolivia, at the base of or in the foothills of the Andes. Presently there is an important centre of variability in this area of the subspecies (ssp. *hypogaea*) that has more affinity to the wild *Arachis* species than the other subspecies in habit, branching pattern, and inflorescence (Krapovickas, 1969). Archaeological evidence from Peru suggests a wide dissemination from the centre of origin at an early stage in its development as a cultivated plant (Gibbons, 1980).

At present, five centres of variability can be distinguished for the peanut in South America. The peanuts of the southern and easternmost centres belong to ssp. *fastigiata*, those of the other three centres to ssp. *hypogaea* (Krapovickas, 1969). (For differences between those sspp. see p. 22).

The Portuguese probably introduced the peanut into Africa from Brazil early in the Sixteenth Century (Gibbons et. al., 1972). It was possibly well established in the Senegambian area as early as 1574 (Greenway, 1944). Somewhat later, it was introduced from western South America into Asia, and eventually reached Africa also by that route. So stocks from widely separated South American areas have come together in Africa, creating a new pattern, different from that of South America. Some of the most widely grown cultivars in the United States are thought to have come from Africa; they are not found in South America, except as introductions. Africa can therefore be considered a secondary centre of variation (Gibbons et al., 1972).

The plant seems to be a rather recent introduction into Ethiopia. Although it grows well in many parts of the country (Carocci Buzi, 1938; Maugini, 1941; Tozzi, 1943; Lodi, 1959; Saunders, 1976), it has only locally gained an extensive place in traditional cultivation. The local population commonly does not know how to cultivate it (Maugini, 1941) and treats it as a garden crop rather than as a field crop (Tissot, 1938). These old observations still hold true, as far as I could see. Only in Eritrea, where peanut was established as a crop by the Italians (Baldrati, 1950: Keren in 1903), and around the town of Harer, I saw fields with this crop. These areas are also the ones most found in the literature (Corni, 1938; Joyce, 1943; Brooke, 1958; Westphal, 1975), but also the region north of Illubabor towards the Sudanese border is sometimes mentioned. Chini (1942) described how the Beni Shangul (NW Welega) cultivated peanuts mixed with other oil plants in the lower regions of their area. The Gumuz, dwelling in the kolla north of the Blue Nile also cultivate the peanut as normal part of their traditional agriculture (Westphal, 1975).

The area of peanut in Ethiopia is increasing steadily. In 1960, it was c. 35000 ha (Bridges, 1960); at present, it is nearly 50000 ha (FAO Yearbooks, 1979, 1980). The

Table 5. Area, yield and production of peanuts in shell in Ethiopia 1965–1980. (Source: FAO Production Yearbooks 1967–1980).

Year	Area (ha)	Yield (kg/ha)	Production (Gg)
1965	35000	510	18
1966	36000	530	19
1967	36000	530	19
1968	36000	560	20
1969	36000	560	20
1970	36000	560	20
1971	42000	571	24
1972	43000	581	25
1973	44000	591	26
1974	44000	591	26
1975	45000	600	27
1976	45000	600	27
1977	46000	598	28
1978	46000	598	28
1979	47000	596	28
1980	47000	596	28

data on Ethiopian area, yield and production for the years 1965–1980, as given by the FAO Production Yearbooks, are listed in Table 5.

In the world, there are more than 60 peanut-producing countries. Suitable growing conditions are mainly found in the tropics and subtropics between c. 40 °N and 40 °S, but in the Soviet Union peanut is cultivated almost as far as 51 °N. More than 70% of world production comes from crops in developing countries. The largest producers are India, China, the United States, Senegal and Nigeria. Of the continents, Asia is the largest producer, followed by Africa, but Africa supplies most to the world market (Gibbons, 1980). Senegal and Nigeria are the main African exporters (Forestier, 1976).

Description

Annual herb, 30–40 cm tall, villosulous to velutinous, at least in young parts, basally with prostrate, procumbent or erect, (light) green to purplish branches; with a taproot and a robust root system bearing nitrogen-fixing nodules but no root hairs.

Leaves alternate, the largest in the middle of the branches, up to 4 cm apart; stipules green, lighter near margin, up to $3\frac{1}{2}$ cm long, lanceolate, subfalcate, cuspidate to acuminate at apex, hairy at edge, lower third adnate to the petiole; petiole shallowly channelled above, green, hairy, particularly on the upper edges, glabrous above, up to 6 cm long; rhachis up to $1\frac{1}{2}$ cm long, similarly shaped, coloured and haired as petiole, with 2 pairs of leaflets on 1–2 mm long villose paler green to purplish petiolules connected by a bridge of hairs; leaflets green above, lighter beneath, up to 6 cm × 3 cm, obovate (to elliptic), obtuse, slightly retuse or shortly apiculate at apex, obtuse at base, glabrous above, beneath glabrous or sparsely villose, particularly on the veins, edge villose.

Flowers subsessile in axillary, spike-like, up to 5-flowered inflorescences, the lowest ones subterranean, small, whitish, hardly visible between the stipules, the higher ones clearly visible; bracts and bracteoles bifid, narrowly lanceolately to linearly lobed, basally vaginate, green, villose at edge and at base inside.

In aerial flowers, perianth and androecium apically free but for most of their length transformed into a slender, up to 30 mm long and c. 1 mm wide pilose white tube.

Free parts of calyx light to yellowish green, with 2 unequal carinate lips; upper lip c. 8 mm × 5 mm, broadly ovate with 3 acute apical lobes, sparsely pilose outside or setulose at margin, glabrous inside; lower lip c. 10 mm × 2 mm, narrowly ovate to narrowly triangular, glabrous inside, pilose outside, at margin setulose.

Free parts of corolla glabrous; standard orange-yellow, sometimes lighter with orange veins towards the base, rheniform to circular, retuse to emarginate apically, c. 15 mm × 17 mm; wings yellow, blade c. 6 mm × 8 mm, concave, rectangular, apically rounded, basally above the middle with a $1\frac{1}{2}$–2 mm long claw; keel whitish yellow, hook-shaped basally caudate, with a horizontal part c. $4\frac{1}{2}$ mm long and an apically involucrate vertical part c. 6 mm long.

Free part of androecium placed in a blunt angle atop the flower tube; consisting of a c. 5 mm long monadelphous tube terminated by 10 semiterete to terete glabrous white filaments that bend upwards sharply; 2 adaxial filaments antherless, $1\frac{1}{2}$ and 1 mm long, the other filaments with subbasifixed anthers that open introrsely with 2 lengthwise slits, either c. 3 mm long bearing ovoid to globular anthers c. $\frac{1}{2}$ mm long or, alternating, c. $1\frac{1}{2}$ mm long with anthers c. $1\frac{1}{2}$ mm long spatulate to slightly lanceolate in outline.

Ovary sessile, subellipsoid, c. 1 mm × $\frac{1}{2}$ mm, style implanted slightly aside of the apex.

Style filiform, bent as staminal tube, glabrous, white, up to 35 mm long.

Stigma filiform, setulose, white, c. 2 mm long.

Fruit a pod, stipitate, indehiscent, ovoid or oblong-cylindrical, small beaked, unilocular, 1–2 seeded, subterranean, outside without visible suture, not or moderately deeply constricted between the seeds, excluding the stipe up to 32 mm × 15 mm; pericarp of a rather leathery tissue with a prominent reticulation, creamy to brown when ripe; stipe up to 12 cm long, unripe yellowish green to purple above the ground, brown when ripe.

Seed exalbuminous with plano-convex cotyledons, ovoid to ellipsoid, c. 18 mm × 9 mm, in two-seeded pods, the apical seed often basally flattened, the basal seed apically so, often shallowly beaked or crested near the raphe, covered by a thin, papery, reddish to brownish testa.

Notes

(1) The genus *Arachis* L. is confined to South America east of the Andes, south of the Amazon and north of La Plata. The centre of highest variability of the genus is found in the SW parts of the Mato Grosso of Brazil (Krapovickas, 1969).

The genus comprises 22 species that have been validly named. Forty or more names have appeared in literature but they are not yet validly published or typified (Gregory et al., 1980; Resslar, 1980).

Most species are diploid with 20 chromosomes but there are also some tetraploid species (Gregory et al., 1980).

Several authors have distinguished sections and series within the genus, but they were not validly published (Resslar, 1980).

Arachis species are annual or perennial herbs with stipulate, 3–4 foliolate leaves and sessile, papilionate uni- or bicoloured orange, yellow or white flowers (variously marked with red), mounted on top of a flower tube 2–15 cm long. The geotropic ovary, on top of the fruit stipe, thrusts the 1–5 seeded carpel underground where it matures. In short-stiped forms, indeterminate laterals of first order (n+1) which arise from the main axis (n) may extend for at least 5 m along the ground. In long-stiped forms, n+1 axes can be totally reduced to underground inflorescences, with only the single n-axis exposed. The n+1 axes may be rhizomes bearing occasional inflorescences in the axils of scale leaves. The hypocotyls and roots sometimes form tubers and tuberoids. Taproots may vary from a few millimetres in diameter in annual species to 10 cm diameter and 1 m in length in perennial species (Gregory et al., 1980).

Morphological modifications, crossing patterns, and the sectional arrangement of the species generally accompany the physiographic features of the South American continent in such a way that different drainage basins contain different, sometimes unique, generic sections. Geocarpy promotes a colonial distribution of species within their respective areas. As a consequence, although cross-pollination may be required in some species for successful fruit-set, *Arachis* is essentially self-fertilized (Gregory et al., 1980).

The majority of *Arachis* species are perennial. Annual forms are found in NE Brazil and in NW Argentina. In the latter area, one of the species is tetraploid: *A. monticola* Krap. & Rigoni. This species is the only wild *Arachis* to give fully fertile hybrids with *A. hypogaea* (Krapovickas & Rigoni, 1957; Krapovickas, 1969). At present, it is thought to be an allotetraploid of *A. batizocoi* Krap. & Greg. and *A. cardenasii* Krap. & Greg. nom. nud. (Gregory et al., 1980).

(2) Krapovickas & Rigoni (1960) reviewed the nomenclature associated with the cultivated peanut, *A. hypogaea,* and concluded that the species is best divided into two subspecies: ssp. *hypogaea* (= ssp. procumbens Waldron) and ssp. *fastigiata* Waldron. Subspecies *fastigiata* consisted of var. *fastigiata* and var. *vulgaris* Harz. Later, Krapovickas (1969) suggested that the subspecies *hypogaea* be divided into var. *hypogaea* and var. *hirsuta* Kohler. Gregory et al. suggested in 1973 that the taxon commonly known as *A. nambyquarae* Hoehne be considered a variety of the subspecies *hypogaea*

(Resslar, 1980), but they did not repeat this proposal in 1980.

The two subspecies are distinguishable morphologically by their different branching habit, stature and leaf colour. They are distinct entities that show, in addition to their morphological differences, divergence in physiological and genetic characters. The characteristics of the subspecies are as follows:

ssp. *hypogaea* (Virginia)	alternately branched, usually 2 nodes with side branches, followed by 2 with flowers generally prostrate main axis without flowers considerable seed dormancy long vegetative period (5–10 months).
ssp. *fastigiata* (Spanish and Valencia)	sequentially branched (no such regularity as in ssp. *hypogaea*) plants erect main axis with flowers no seed dormancy short vegetative period (3–5 months).

The subspecies also had a different distribution in S America, and crosses between the sspp. sometimes result in progeny with lethal characters (Krapovickas, 1969; Gibbons & al., 1972), or in 'brachytic' plants. The latter plants have a dwarf habit and are completely sterile (Hammons, 1973).

Krapovickas & Rigoni (1960) and Krapovickas (1968) do not propose any further breakdown within the groups they define, but they mention endeavours of others in this field. In 1972, Gibbons et al. combined the taxonomic treatment of Krapovickas (1968) with the systems of Gregory et al. from 1951 and that of Bunting from 1955 and 1958. Gibbons et al. propose the follow hierarchy: species, subspecies, variety, cultivar group and cultivar cluster. *A. nambyquarae* is treated by them as a cultivar group.

They provide their system with a key, and it is this key that I used for the determinations of the cultivar clusters I encountered in Ethiopian material.

The characters used to distinguish between cultivar groups and cultivar clusters all have to do with dimensions and form of the fruit, number of seeds per pod, and sometimes with the colour of the testa.

I found the following taxa.

ssp. *hypogaea:* WP 971

ssp. *hypogaea,* cv. group Virginia, cv. clusters

Fung bunch: SL 1622, SL 1971, SL 1973

Kongwa runner: PJ 3012; SL 1749, SL 1952, SL 1972

ssp. *fastigiata* var. *vulgaris* Harz, cv. group Natal: G. Aweke & M. G. Gilbert 897.

My scanty material suggests that the peanuts from N Ethiopia belong to ssp. *fastigiata,* while those from E Ethiopia belong to ssp. *hypogaea.* The literature suggests a similar conclusion about the distribution of subspecies within Ethiopia, e.g. Brooke (1958): 'the one variety (near Harer) bears medium sized pods and is the runner type, the stems are more or less procumbent', and Kay (according to Forestier, 1976): 'In Eritrea, the peanuts are for direct use and belong to the Valencia type'.

For the cultivar group within ssp. *fastigiata*, the key of Gibbons et al. (1972) leads me to cv. group Natal, which is in another botanical variety than 'Valencia', mentioned by Kay. Apparently the cultivar group grown in Tigre is not the same as that of Eritrea.

The sample from the Harer region sown in Wageningen, was not as homogeneous as Brooke suggested. There were two clearly differing growth habits: 'runner' and 'open bunch'. These habits were the only differences in the phenotype, leading to the two cultivar clusters within cv. group Virginia indicated above.

The Ethiopian seeds were sown in mid April in a greenhouse with maximum temperatures of 30 to 35 °C, minimum temperatures of 22 to 25 °C with a relative air humidity ranging 40–60%. The first flowers appeared in runner plants on 28 June; the flowers in bunch plants appeared some days later. The seeds were ripe 14 September, five months after sowing (Henneman & Ballegooijen, 1973). Usually spreading bunch cultivars have a shorter cycle than runners (Ackland, 1977).

(3) According to Forestier (1976) the characters of the stipules seem to be more constant than these of the leaflets. This observation seems to me to be important for those who make descriptions of cultivars.

(4) In my opinion, the terms 'gynophore' and 'hypanthium' are not used properly in the literature on *Arachis hypogaea.*

I could not observe any form of a gynophore in the flower during anthesis. It is only after fertilization has taken place, that a meristem between the receptacle and the female parts becomes active. The organ so formed is thus no part of the flower but of the fruit. A correct name for the organ, therefore, could be 'fruit-stipe' or 'carpophore'.

Although the tube of the flower of *Arachis hypogaea* can be interpreted according to some definitions of a hypanthium {e.g. an enlargement or development of the torus under the calyx (Jackson, 1971), the cuplike receptacle derived usually from the fusion of floral envelopes and androecium, and on which are seemingly borne calyx, corolla and stamens (Lawrence, 1970)}, it does not conform to the common use of the term. In this common use, the free apical parts are deciduous after anthesis. In the peanut, the tube breaks off basally. I prefer to call the organ flower-tube.

(5) According to Resslar (1980), the names of the sections and series of *Arachis*, as proposed by Gregory et al. (1973), are nomina nuda. In my opinion, Gregory et al. provide in their key so much information on the characters of the taxa, that they are nomina illegitima rather than nomina nuda.

(6) Description was based on the following specimens.

Harergie	Just outside of Harer, rocky overgrazed area, c. 1700 m: PJ 3012; Leprosery Besidimo, c. 7 km from road Harer-Jijiga, c. 20 km from Harer, 1425 m: WP 971.
Tigre	Tekazze Valley near bridge in main road Gonder-Inde Selassie, 900 m: G. Aweke & M. G. Gilbert 897.
Grown at Wageningen	SL 1622, SL 1749, SL 1952, SL 1971–SL 1973

1. Temperature

The growing area of the peanut is characterized by an average temperature of more than 20 °C, or by a temperature (°C)-time product of c. 2900 °C·d in 160 days or less. In the latter case, the temperature should never fall below 15 °C and there should be a period of at least 100 days with average temperatures over 20 °C (Forestier, 1976).

A difference of only a few degrees in the mean temperature has a strong influence on the time of growth of a cultivar. Comparing the time from seed to harvest of cv. Natal Common in the Sudan rainlands (mean temperature during growing season 25 °C, time 90–95 days) with that in central Tanganyika (mean temperature c. 22 °C, time 105–110 days), we see a difference of about two weeks induced by only 3 °C difference in the mean temperature (Bunting & Elston, 1980).

The minimum temperature at which growth takes place is 14–15 °C, and the temperature should not fall below 16–20 °C during the growing season (Adam & Ferrand, 1958). For germination, a temperature of at least 12–13 °C is required. The plants then emerge after 10–12 days (Baldrati, 1950; Cornejo, 1961).

Best growth takes place at average temperatures of 24–30 °C. Higher temperatures favour vegetative growth and cause some cultivars to produce less flowers. Seed-set at such high temperatures is poor, even in plants which flower normally. This is caused by decreased vitality of the pollen grain combined with a longer style because the flower becomes larger, by a shorter life-span of the flower, and by a change of the inner balance of the plant favouring vegetative development (De Beer, 1963). A manifestly increased or decreased flowering could often be related to changes in temperatures 2–3 days before. There is, however, also a strong influence of available light (Forestier, 1976).

Ohashi et al. (1957) found that holding the seed for 10 days before sowing at temperatures of 15 or 25 °C continuously, increased seed yield by 10%. The seeds had higher oil contents and the oil had a lower acid value and lower iodine number.

Because of its preference for high temperatures, peanut is a crop for the lower regions. The highest field I saw of it in Ethiopia was at an altitude close to 1700 m near the town of Harer. Brooke (1958) even reported altitudes over 1800 m for that same region. Reports from other regions in Ethiopia usually mention altitudes below 1500 m (for instance Bako Res. Stn Progr. Rep., 1970, 1971; Amare Retta, 1976).

In the Ethiopian Highlands, the altitude limits are particularly invoked by the minimum temperatures during the nights in the period of maturation. They disturb the ripening process more than do the average daily temperatures (Baldrati, 1950), which are only slightly lower in that period than in the rest of the cropping season (Mesfin, 1970: Maps 17–21).

Higher temperatures seem to increase fat contents, but lower protein contents in the peanut (Bolhuis, 1962). This was also observed in Ethiopia. 'Growing the same cultivar at Keren at 1300 m on the western escarpment, and at Ghinda or Filfil at

1000 m on the eastern escarpment, always resulted in a lower oil content of the product from Keren' (Baldrati, 1950).

2. Water

The main production areas are found within semi-arid regions where precipitation exceeds potential evaporation for two to seven months of the year (Gibbons, 1980). All climates in which peanut is grown have in common a warm frost-free period of at least 90 days with, at least, 400 mm of rain (except where irrigation is used) and a dry period at harvest (Bunting & Elston, 1980).

Although peanuts will grow in climates with 12 wet months and very high precipitation, they also tolerate some drought, and will grow in areas with less than 400 mm of rain (Duke & Terrell, 1974). Such conditions are not, however, fit for profitable production. Much humidity affects the health, diminishes the yield and gives fruits of inferior quality (Cornejo, 1961). Drought causes poor vegetative growth, less flowering and bad penetration in the soil of the fruit stipes, particularly if the soil becomes hard; the nuts may become shrivelled (Billaz & Ochs, 1961; Ackland, 1977).

Though there is no stage of growth really resistant to drought, the plants are most sensitive at full flowering. Less sensitive is the stage of active vegetative growth and the beginning of flowering. The least sensitive is the period of the filling and maturation of the fruits. Drought even increases the oil contents of the seed if it coincides with the last stages of maturation (Forestier, 1976). It seems that more plants survive a strong drought if the seeds have been soaked in solutions of trace elements or calcium before sowing (Billaz & Ochs, 1961; Prevot & Billaz, 1962).

A precipitation of 400–1200 mm during the growing season is normally sufficient for good yields, at least if it is well distributed (Adam & Ferrand, 1958; Forestier, 1976). On average and counted over the whole cycle, the requirements seem to be between 4 and 6 mm per day. They could go as high as 7 mm during part of the cycle and stay below 2 mm during the first month (Forestier, 1976). According to Baldrati (1950), it was only possible to cultivate unirrigated peanut in Eritrea at altitudes below 1600 m, if the rainy season included a period of 70–80 days in which c. 250 mm of rain fell.

For a good germination, at least 20 mm of rain is required less than 48 h before sowing. If more than 43 mm has fallen, peanut will not suffer from a drought during the two weeks after sowing (Forestier, 1976).

In the higher areas of Ethiopia where peanuts are grown, these requirements are reasonably well met. In the hot lowlands, the precipitation is too low but, with irrigation, good yields have been achieved (Lodi, 1959; Amare Retta, 1976). Once the minimum requirements of the crop have been met, 100 mm of supplementary water makes the yield increase by 80–150 kg/ha (Forestier, 1976). In some areas inundated for part of the year, it is possible to cultivate peanuts on the water stored in the soil after the water has receded (Baldrati, 1950).

A wet season of three months is usually sufficient for quickly growing erect bunch cultivars. In areas with a longer period of rainfall, spreading bunch and runner cultivars should be chosen (Ackland, 1977).

3. Soil

The peanut is generally recommended for lighter soils, to which it is well adapted (Whyte et al., 1953; Adam & Ferrand, 1958; Cornejo, 1961; Ackland, 1977). On heavier soils, harvesting is difficult, but cultivation can still be profitable (Melka Werer Progr. Rep., 1971; Ackland, 1977). The amount of moisture in the soil at harvesting is often the main factor in fixing the workability of the soil at which cultivation is practised (Forestier, 1976).

Because light soils are commonly not very fertile, fertilizing is often profitable. Peanuts are sensitive to a correct balance of the nutritive element in the soil. This fact seems to be responsible for the often contradictory conclusions in fertilizer trials with peanut (Lachover & Arnon, 1964). An example is to be found in the Progress Reports of the Bako Research Station of 1970 and 1971. In 1970, fertilization with nitrophos increased yields by about 50%, whereas the next year there was no effect of dressing with urea and triple phosphate. Both years, the applications were at sowing time. It is striking that no potassium was applied, because that element, after nitrogen, is the second-most important element extracted from the soil by peanuts (Lachover & Arnon, 1964; Weiss, 1971). Phosphorus (Mémento, 1980: common dressing 13 kg/ha) usually gives a large increase in yield, as does farmyard manure. Also a dressing of sulphur often gives a remarkable increase in the yield of a peanut crop (Reid & Cox, 1973; Mémento, 1980). Because of the nitrogen-fixation capabilities of the peanut plant (110–135 kg/ha year, Forestier, 1976), nitrogen dressing commonly does not exercise much influence.

The ideal soil should be well drained, friable and rather light. Because the plant needs oxygen in the soil for fruit formation, the aeration of the soil is very important. The soil should be rich in calcium and contain a moderate amount of organic matter of which 1–2.2% suffices; higher amounts influence the quality of the fruits unfavourably. A peanut crop breaks down organic matter quicker than any other annual crop (Forestier, 1976).

Peanut prefers a deep soil, possibly because the water requirements on such soils are easier met for plants with a strong root system. Peanut roots often reach down as far as 2 metres, but stop earlier if water is in regular supply. The best growth is obtained when the upper 15 cm of the soil is provided with water up to half the field capacity. As long as the pF remains below 2.8, water-shortage will never be a problem (Forestier, 1976).

Peanuts will grow on both acid and alkaline soils with pH of 4.5 to over 8, but they are sensitive to salt (Duke & Terrell, 1974). They prefer, however, soils of a slightly acid character. Usually the pH range at which yields are economically interesting is 5.5–6.2. Lower pH causes the seeds to contain less oil, but the seed yield is not necessarily affected (Forestier, 1976; Gibbons, 1980).

Calcium should be available. Small calcium deficiencies show themselves only in the quality of the seeds, not in the yield nor in the growth of the plant. This is particularly important in areas where high production is obtained (Whitty, 1974).

For more information on the fertilization of peanuts, and on the role of nutrients and tracenutrients, see Reid & Cox (1973).

4. Light

Peanuts behave as day-neutral plants in respect of appearance and node number of the first flower. The duration of vegetative growth is determined primarily by temperature (Bunting & Elston, 1980).

Peanuts flower profusely under continuous lighting (Forestier, 1976). With shorter day, vegetative growth is less but the number of fruits is larger and they develop quicker. This is not caused by a difference in number of flowers or length of the vegetative period, but by differences in the proportion of seed set (Wynne et al., 1973).

Light intensity has a distinct influence too. Peanut grows poorly and produces badly in the shade. Even one cloudy day will cause the number of flowers to decrease for some days, but as the cloudy period progresses, its influence diminishes. In phytotron experiments, 10000 lx was considered insufficient for good growth. Good results were obtained at 16000 lx ('day': 12 h, 28 °C; 'night': 12 h, 20 °C; rel. humidity in both periods 80%) (Forestier, 1976).

5. Development of the plant

Germination of the peanut takes 4–6 days if shelled seeds are used. If whole pods are sown, it takes a few days more (Adam & Ferrand, 1958). The cultivars of subspecies *hypogaea* show seeds dormancy of some weeks, which protects against vivipary if the season is prolonged. Before these cultivars are sown, the period of dormancy ought to be finished. The cultivars of subspecies *fastigiata* show little or no dormancy. Dormancy can be shortened by high temperatures during storage and with chemicals (Forestier, 1976).

The root systems of ssp. *hypogaea* and of ssp. *fastigiata* cultivars have different dimensions and structure (Forestier, 1976), usually they are 40–50 cm long (Adam & Ferrand, 1958). Root hairs are absent (Cobley, 1976).

Three to four weeks after sowing, the small tubercles housing nitrogen-fixing bacteria develop (Adam & Ferrand, 1958). Low levels of phosphorus, molybdenum and potassium reduce the number of tubercles (Forestier, 1976).

Almost all peanuts belong to one of two structural types. Both types produce their first two primary branches in the axils of the cotyledons; the main axes then go on to produce two or more further primary branches (Bunting & Elston, 1980).

In the first structural type, the first two nodes on each primary branch typically bear secondary branches; then follow two inflorescences, followed in turn by two more secondary branches and then by two more inflorescences. On the secondary branches, tertiary branches and inflorescences alternate in pairs in the same way, but no inflorescences are formed on the main axis. These are the alternately branched Virginia types: ssp. *hypogaea* (Bunting & Elston, 1980).

In the second structural type, there may be, but often are not, secondary branches at the first nodes of the two cotyledonary branches. The next nodes on the primary branches, up to six or more, bear a sequence of inflorescences. In general, no more secondary branches are formed, though a few may arise in some forms at later nodes on the lower primaries. In this second type, inflorescences are also formed at higher nodes on the primary axis. This is the sequentially branched type: ssp. *fastigiata* Waldron. It includes the Spanish and Valencia forms (Bunting & Elston, 1980).

These two branching types define the main botanical division of the cultivated species. Though they are usually fully interfertile, very few intermediate types are known, and these have come mainly from relatively recent breeding programmes. The two subspecies also differ in leaf colour, some features of the testa colour and some other attributes (Bunting & Elston, 1980).

The well known habit difference, as between bunch and runner varieties, is superimposed on the difference between the structural types in branching pattern. The runner and spreading bunch forms are virtually all alternately branched; the more upright bunch forms are virtually all sequentially branched (Bunting & Elston, 1980). Genetically, the alternately branched, late runner habit is dominant over the early erect type. Very probably both chromosomic and plasmatic factors are involved (Hammons, 1973).

In regions with early maturing cultivars, the first flowers usually appear 30–40 days after emergence (Adam & Ferrand, 1958; Forestier, 1976). According to Forestier (1976), the floral primordia are already present in the seed, but Staritsky (1973) proved that this was not so in the cultivars (ssp. *fastigiata*) that he investigated. Most of the flowers are produced near the base of the stems. They are usually cleistogamic and many of them are even produced below the ground (Cobley, 1976). By this cleistogamy, the natural crossing is so low, that it is sometimes expressed per thousand, rather than in the traditional per cent (Forestier, 1976). According to Norden (1973), the proportion of outcrossing is associated with the production of atypical flowers and the proportion of such flowers differs considerably with the cultivar.

The flower has the following biology: flower becomes visible around 16h00 and it is pollinated around 04h00 next morning; it opens at sunrise and fades at noon; the fertilization takes place 12–16 hours after pollination (Forestier, 1976).

Flowering may continue as long as the soil contains some water, but the last flowers generally abort (Adam & Ferrand, 1958). Normally, the stage of full flowering in early cultivars lasts for about three weeks, but this stage may last for 70 days in late cultivars (Forestier, 1976).

After fertilization, the receptacle thickens and starts to elongate to form a fruit stipe. The fruit stipe pushes the ovary into the soil where, at a depth of 2–5 cm, the pod develops and matures (Cobley, 1963). The process of soil penetration takes 3–8 days and the stipe can develop pressures up to 13 bars (Forestier, 1976).

The first fertilized ovary in an inflorescence inhibits the growth of the stipes of flowers that emerge later in the same inflorescence so that, at least in the older cultivars, an inflorescence usually bears only a single fruit, even though several more fertilized ovaries, from the later flowers, accumulate in it. Consequently, no more than 10–20% of the flowers in older cultivars form fruits. If the first ovary or fruit is removed or damaged, or is treated with gibberellin, inhibition is offset and a later ovary in the same inflorescence can form a stipe and fruit (Bunting & Elston, 1980).

Little change takes place in the ovary until it is buried and has taken a horizontal position. The most obvious change is the development of lignified tissue, which forms a protective cap for the ovary, the style being pushed to one side in the process (Cobley, 1963; Forestier, 1976). It seems that good seed-set in peanuts can only be achieved when air and soil are moist, ensuring good development of the stipe, and when there is total darkness at the end of the fruit stipe (Adam & Ferrand, 1958; Forestier, 1976).

According to Adam & Ferrand (1958), nitrogen fixation takes place not only in the tubercles of the roots but also in the microflora covering the buried part of the fruit stipe. Meyer & Wergifosse (1960), on the other hand, found that when they tended them under sterile conditions, the fruit stipes developed completely normally.

After the ovary has taken its final position, the fruit develops in 10–20 days to its full size. The development of the seed is about two weeks behind that of the fruit. It first develops lengthwise, remaining very thin. After it has reached its final length, it fills rapidly. In early bunch cultivars (ssp. *fastigiata*), the growth of the seeds stops abruptly after about 6 weeks, whereas in late runner cultivars (ssp. *hypogaea*) this growth can go on for as long as 12 weeks and only stops gradually (Forestier, 1976).

Although seed weight is usually lower (see p. 33), it may reach nearly 800 mg. Seeds on lower stipes are usually heavier than those on higher ones. Likewise, the basal seed in a pod is usually the heaviest in that pod and the richest in oil (Forestier, 1976).

Most cultivars have a growing period of 110–120 days, early ripening cultivars need three months, late cultivars may need up to 10 months (Adam & Ferrand, 1958). With the earliest cultivars, the last fruits are ripe only three weeks after the first ones; in late cultivars this period is about twice as long (Forestier, 1976).

Yield is positively correlated to plant height, number of ripe pods, number of branches and weight of straw. In earlier ripening cultivars, those characters are all less developed than in later ones (Kushwaha & Tawar, 1972).

Husbandry

Near Harer, peanuts are usually grown in association with cereal grains (see below). Two years with peanut are succeeded by two years without them (Brooke, 1958). This practice is highly profitable for the cereal (Schilling, 1965). If peanuts are planted in that region year after year on the same field, their yield declines seriously by the fourth year (Brooke, 1958).

There is no special preparation of the seedbed. The general practice of ploughing 2–3 times crosswise is followed. This is sufficient, as peanuts have large seeds.

The best yields are obtained by sowing as early in the rains as possible. Only in areas with a long wet season may it be necessary to delay sowing so that harvesting coincides with dry weather. In general, late-sown peanuts give poor yields (Ackland, 1977).

Near Harer (1500–1800 m), this requirement is well met. The peanut is sown in April with the onset of the small rains and is planted in March if that month is exceptionally rainy (Brooke, 1958). Generally, there will be regular rains up till mid September after which the rains cease. The harvest is in November, 7 months after planting. In hotter areas elsewhere in Ethiopia (500–1500 m), where the cycle is shorter, peanut is sown at the onset of the big rains in June–July (Corni, 1938; Huffnagel, 1961).

Eritrea has a small region in which the main rains fall between October and April. These months are usually the driest elsewhere in Ethiopia. Thus in that particular region, near Ghinda, sowing has to be done in November while the crop is being harvested at Keren, less than 100 km away (Baldrati, 1950).

Seed is sown with a stick at a depth of 5–10 cm and at a distance of one step. In each hole, one or two seeds are dropped. According to Ackland (1977), this distance is far too large. For East Africa, he recommends sowing in rows c. 60 cm apart, and in the row 10–15 cm, depending on the cultivar. Similar distances gave the highest yields in Melka Werer and Didessa (Saunders, 1976). Ackland (1977) adds that the labour requirement (up till 50 days per ha with handsowing) and the amount of the seed needed usually make smallholders reluctant to stick to these recommendations.

Although fields may be planted solely with peanut, it is customary to plant them in association with maize and sorghum in the Harer region. Sometimes crops such as cucurbits and sesame may be planted in the field as well (Brooke, 1958). The cereals are sown first. This is done by broadcasting the seed, so that uneven distribution of cereal plants can hardly be avoided. Places where the stand of the cereal is too dense for proper development of the peanut are therefore thinned, a laborious job. The seedlings are transplanted or fed to animals.

The cultural practices are aimed at keeping the soil loose and clean of weeds. The looseness of the soil is particularly important when the fruit stipes have to penetrate, thus at flowering time. Keeping the field clean of weeds is particularly important as long as the plant is still small. The critical period for weed control in peanut is the first 4–6 weeks. After that period, weeding has far less effect (Carson, 1976). In view of the long growing season at higher altitudes, this period may be longer there.

The first cultivation is the most important one because the seedling has little competitive power (Adam & Ferrand, 1958). It is usually done as soon as the plant is clearly visible and it falls within 2 weeks of emergence. Later cultivations usually depend on the amount of weed growth.

Weeding during fruit formation should be done with extreme care (hand-pulling), or avoided: the fruit stipes are easily destroyed (Adam & Ferrand, 1958; Ackland, 1977).

Chemical weed control is possible. Practices were surveyed by Hauser et al. (1973)

and appear annually in the French agricultural review 'Cultivar'.

In East Africa, pests are generally less damaging in peanuts than are diseases (Ackland, 1977). As far as I could see from literature on Ethiopia, the situation there seems different but this may be caused by scanty publications. In 1952, Jannone reported that in 1940 he could not find any parasites of economic importance in Feddis, in the heart of the Harer peanut area, Stewart & Dagnatchew (1969) list only two damaging fungi on peanut, while Schmutterer (1971) lists 6 pests on the crop and Walter & Boxall (1974) list 14 insects on the stored crop.

According to Forestier (1976), insect control in peanut is mostly highly profitable: yield increases with control of insects are often larger than increases as a result of fertilizer.

Peanuts should be lifted when at least 70% of the fruits are mature. Maturity is indicated by darkening veins on the inner surface of the shells. By this stage, most of the leaves are yellow and many are shed. Postponing the harvest is undesirable: many pods may get detached from the plant and remain in the soil after lifting; some cultivars may germinate (Ackland, 1977). Harvesting too early, on the other hand, results in low oil contents (Baldrati, 1950).

Conditions should be dry for harvesting. If the soil is too wet, it adheres to the fruit, the seed of non-dormant cultivars starts to germinate, and carcinogenous aflatoxins may develop by fungal growth. In too dry soil, though, many pods remain in the soil after pulling (Ackland, 1977).

The usual practice after lifting is to turn the plants upside down in the sun and let them dry on the field for some days. Drying on stooks ensures quicker drying but has not been adopted by smallholders (Ackland, 1977). These remarks of Ackland on East Africa hold for Ethiopia too.

The pods are removed by hand or by threshing. The former procedure is very time-consuming and is only chosen if the amount is small. In the latter procedure, only a small proportion of the pods will be damaged if the plants are at the right stage of drying, but the straw has a lower nutritive value for cattle as most leaves are lost (Adam & Ferrand, 1958).

In Spain, there used to be a system that worked much faster than hand-picking but which kept the good quality of the straw. Small bundles of plants were beaten on the reinforced edge of a basket (Cornejo, 1961). This might be a useful method in Ethiopia, where I never saw it.

The whole culture of peanuts is very time-consuming. If everything is done by hand, 490–880 hours per hectare are needed (Forestier, 1976). This is about 1 h of work for 1 kg of unshelled peanut. In Ethiopia, ploughing is done with animal traction, so that the figure will be lower.

Handshelling is common practice in Ethiopia. It is very laborious: one man can shell only 14 kg of kernels in a day (Ackland, 1977). By trading the nuts in the pod, this work is commonly transferred to the consumer.

Average yields of Ethiopia range 500–600 kg/ha (in shell) (see Table 5), but there are several reports of higher yields on a field scale, some of which are surveyed below.

Author	Region	Yield (kg/ha)	Remarks
Corni (1938)	Eritrea	700–800	
Baldrati (1950)	Eritrea (Keren)	1400	Average
Brooke (1958)	Harer	550–675	
Kline et al. (1969)	Amibara	3750	Irrigated, 'Dire Dawa local variety'
Saunders (1976)	Melka Werer	4000	Experimental conditions, irrigated, without shell!

Seed can be stored best in the pod. Good quality seed, particularly for sowing stock, should be obtained if the harvest be done at maturity with selection on the field, if the moisture content of seed remain below 80 g/kg, if heat be avoided, also at drying on the field, and if insects be kept away (Martin, 1964). Seed stored in such a way will have a germination of more than 80% (Forestier, 1976).

In Ethiopia, storage is usually in the house so that an eye is kept on the stock. As the storage is during the dry season, the conditions are reasonably well met.

Uses

In the world, peanuts are mainly used for oil production and as a snack. The presscake forms a valuable cattle feed and the dry plants are fodder for cattle.

The oil is excellent for human consumption. It may be used for cooking, as salad oil, but also for manufacturing margarine and other edible products (Ackland, 1977). It is non-drying and therefore not used in the paint industry (Ubbelohde, 1920).

Most of the yield of peanut in Ethiopia is sold to traders for oil manufacture if an oil-mill is nearby. The oil is used locally for cooking, but also exported (Brooke, 1958; pers. commun. Amare G., 1972; Aykroyd & Doughty, 1974).

Like many oilseeds in Ethiopia, peanuts are eaten as a snack. If there is no oil-mill nearby, the use as a snack is most important (pers. commun. Amare G., 1972), but sometimes a stew is prepared from crushed roasted seeds with onions and peppers (Brooke, 1958; Aykroyd & Doughty, 1974).

Peanuts grown for export and for nibbling must be free from aflatoxins, and large (1400–1800 seeds per kilogram) (Ackland, 1977). The hull should be clean, undamaged and attractive. Chemical treatments should be harmless, tasteless and odourless (Gilier, 1961).

The presscake is a valuable cattle feed. It is not known as such in Ethiopia (Brooke, 1958; Aykroyd & Doughty, 1974). Where possible, it is exported (Asrat F., 1962; pers. commun. Amare G., 1972). In the steam era, the presscake was used as fuel in Ethiopia (Joyce, 1943).

Dry plants, after harvest, form an excellent fodder (production in Ethiopia c. 1 Mg/ha, according to Carocci Buzi, 1938). They are given to animals in Ethiopia (Brooke, 1958; Aykroyd & Doughty, 1974).

The ripe pod constitutes 65–80% of seed weight. The percentage is little influenced by the environment and is highly heritable. It is a characteristic of a cultivar (Forestier, 1976). A litre of such pods weighs 360 to 400 g. The weight of the different components of a kilogram of ripe dry peanut pods is distributed as follows: pericarp 280–300 g, seed-coat 14.5–32.0 g, cotyledons 677–719 g and for the embryo without its cotyledons 18–26 g (Baldrati, 1950).

The composition of peanuts is greatly dependent on the cultivar and on growing conditions (Young & Hammons, 1973; Forestier, 1976). At harvest, the seed contains about 400 g of moisture per kilogram, after drying less than 100 g, and after roasting less than 20 g. Peanuts are rather hygroscopic, rendering them quickly soggy when combined in water-rich products (Cobb & Johnson, 1973). The average composition of the kernel is given in Table 6. Some data on the composition of peanut from Ethiopia are given by Ågren & Gibson (1968). They are shown in Table 7. Ågren & Gibson used 5.22 to equate nitrogen and protein contents. According to Angelo & Mann (1973) and Forestier (1976), a better factor for this purpose would be 5.46.

In general, the oil contents of cultivars in subspecies *hypogaea*, with 380–470 g/kg, are lower than those in cultivars of subspecies *fastigiata*. The normal range in the latter subspecies is 470–500 g/kg. The oil of cultivars with a higher oil content is commonly less saturated. Differences in peanut oils of different cultivars or from different regions are mainly caused by differences in the relative fractions of oleic and linoleic acids. These fractions are negatively correlated (Forestier, 1976). The colour of peanut oil may vary from bright greenish to very pale yellow or colourless. The colour is strongly influenced by the state of maturity at harvest and the treatment after lifting the plant. Riper fruit and slower curing bring a lighter colour to the oil (Dickens & Pattee, 1973). Characteristics of the oil and its composition are given in Table 8 and Table 9, respectively.

Table 6. Average composition of peanuts and peanut presscake (data from Baldrati, 1950, and Cobb & Johnson, 1973; content of nutrients in g/kg, gross energy content in kJ/kg).

	Kernel	Presscake (whole peanut)	Presscake (decorticated peanut)	Hull	Blanched full fat roasted cotyledons
Moisture	50–80	75–118	66–107	74–91	16
Crude fat	376–518	72–89	69–102	26–28	498
Crude protein	211–338	233–341	429–448	73–76	260
Carbohydrates[1]	191–192	184–222	229–261	137–189	188
Crude fibre	16–19	c. 231	c. 76	554–566	24
Ash	16–33	45–69	42–48	55–132	38
Energy	23598				24577

1. One kg of seeds contains 32–64 g sugars; of these, 27–56 g are sucrose (Forestier, 1976).

Table 7. Composition of a sample of peanut and a sample of peanut presscake from Ethiopia (after Ågren & Gibson, 1968; data in terms of 1 kilogram of edible portion).

	Whole seed, dried, shelled	Presscake
Gross energy (MJ)	22.8	14.6
Moisture (g)	57	77
Nitrogen (g)	44	78
Crude protein (N × 5.46) (g)	240	425
Fat (g)	425	47
Carbohydrate total, incl. fibre (g)	268	412
Fibre (g)	35	76
Ash (g)	20	56
Calcium (mg)	510	1310
Phosphorus (mg)	2520	6000
Iron (mg)	300	794
β-carotene equivalent (mg)	0	0
Niacin (mg)	–	312
Tryptophan (mg)	2890	–
Ascorbic acid (mg)	0	–

Table 8. Characteristics of peanut oil (data from Ubbelohde, 1920, and Cobb & Johnson, 1973).

Acetyl value	8.5–9.5
Acid value	1–16
Colour visual	light yellow
Lovibond, 1 in.	Yellow: 16–25; red: 1–2
Free fatty acids (g/kg)	0.2–6.0
Latent heat of fusion (J/g)	90.8 (non-hydrogenated oil)
	103.3 (hydrogenated oil)
Hehner value	94.3–95.5
Iodine value	82–106
Melting range	0–3 °C
Polenske value	<0.5
Refractive index n_D (15.5 °C)	c. 1.4577
(20 °C)	1.4697–1.4719
(25 °C)	1.4676–1.4707
Reichert-Meissl value	0.48–1.6
Saponification value	188–197
Specific gravity at 15 °C	0.916–0.921
at 25 °C	0.910–0.915
Thiocyanogen value	58–75.5
Titre (°C)	26–32
Unsaponifiable matter (g/kg)	3–7
Viscosity at 20 °C (mPa.s)	71.07–86.15

Table 9. Fatty acid composition of saponifiable peanut lipids (after Cobb & Johnson, 1973; data as substance fraction of acids, %; acids < 1% omitted).

Saturated	palmitic	7.48–12.45
	stearic	1.75– 4.92
	arachidic	1.00– 1.88
	behenic	1.70– 3.78
	lignoceric	0.46– 2.60
	Total	about 20
Insaturated	oleic	33.3–67.44
	linoleic	13.90–35.13
	11-eicosenoic	0.74– 2.27
	Total	about 80

The protein contents of the peanut ((227) 250–280 (293) g/kg) are among the highest to be found in cultivated seeds. Only soybean can be richer in this nutrient (Forestier, 1976). The protein of peanuts consists mainly of two globulins called arachin and conarachin (Angelo & Mann, 1973). Peanut cultivars with a high protein content tend to have low oil contents, and vice versa, but there are exceptions (Forestier, 1976). Some data on the amino acids constituting the protein are given in Table 10.

The ash is particularly rich in phosphorus and potassium; it also contains calcium, which seems to be important for peanut (Baldrati, 1950). Some of its other constituents

Table 10. Amino acids (g) in one kilogram of peanut protein (after F = Forestier, 1976; A & M = Angelo & Mann, 1973).

	F	A & M
Alanine	39-42	42
Aspartic acid	105-115	106-140
Cystine	8	19
Glutamic acid	57	41-56
Histidine	21-28	20-21
Isoleucine	30-43	40-43
Leucine	60–70	67-70
Lysine	34	31-34
Methionine	10-12	11-12
Phenylalanine	53	54
Proline	49	-
Serine	55	c. 50
Threonine	26-29	29-34
Tryptophan	20	20
Tyrosine	39-44	44
Valine	37-45	47-80

Table 11. Contents of some components of peanut cotyledons in dry matter (mg/kg). (Data from Cobb & Johnson, 1973, and Mottern, 1973).

Minerals		Vitamins	
Aluminium	1000	Fat-soluble[1]	
Barium	80–300	A	0.9
Boron	26–500	Carotene	0.01
Calcium	100–800	D	not found
Chromium	10–300	E	263–594
Cobalt	0.3	α-tocopherol	119–253
Copper	7–300	γ-tocopherol	104–342
Fluorine	1.4	δ-tocopherol	58–250
Iodine	0.2	K	not found
Iron	18–1000		
Lead	0–500	Water soluble	
Magnesium	900–3400	B-Complex	
Manganese	8–500	B_1: thiamine	9.9
Molybdenum	8–30	B_2: riboflavin	1.3
Nickel	30–80	B_6: pyridoxine	3.0
Phosphorus	2500–2600	B_{12}: cyanocobalamin	not found
Potassium	5000–8900	Niacin/nicotinic acid	128–167
Silicon	375	Choline	1650–1740
Sodium	50[2]	Folic acid	2.8
Strontium	8–50	Inositol	1800
Sulphur	1900–2400	Biotin	0.34
Tin	0–50	Pantothenic acid	27.2
Titanium	300–800	C	58
Vanadium	100–500		
Zinc	17–800		

1. Results expressed as mg/100 g oil.
2. According to Mottern (1973): 4180 mg/kg.

can be found in Table 11.

The presscake forms a valuable animal food. Its average composition is given in Table 6; data on Ethiopian presscake are given in Table 7. The tables show that with crushing, c. 80 g of oil remains per kilogram of presscake. If primitive ways for oil extraction are used, commonly only half the oil is recovered (Carocci Buzi, 1938; Vegetable Oils & Oilseeds 1960–1963).

The plumules, which are separated industrially from the cotyledons before pressing, contain c. 300 g of nitrogenous matter per kilogram (Carocci Buzi, 1938) and a bitter oil (Ubbelohde, 1920).

An extensive survey of the literature on the known constituents of peanuts, raw, roasted and 'off-flavour' can be found in Cobb & Johnson (1973). Table 11 is derived from that publication.

2.2 Argemone mexicana L. (Papaveraceae) (2n = 28)

'Argemone': from the Greek argemon, a white spot on the cornea.
The genus was named to indicate the relationship with *Papaver argemone* L. The white latex of the latter species was used in the treatment of eye-diseases (signature doctrine).
'mexicana': Mexican.

Linnaeus, Sp. Pl. ed. 1: p. 508 (1753).
Type: LINN 670.1 (lecto, microfiche!)[1].

Synonym

Argemone spinosa Moench, Meth. Pl.: p. 227 (1794).

1. See note no. 1, p. 40.

Literature

1909: Fedde, Papaveraceae, in Engler, Das Pflanzenreich 40, Heft IV.104: p. 271–287. (tax.)
1949: Baldrati, Plantes oléifères de l'Erythrée et de la Somalie italienne, Rev. Bot. appl. 29: p. 234–239. (use)
1954: Cufodontis, Enumeratio, Bull. Rijksplant. Brussel 34(2) suppl.: p. 118–119. (tax.)
1958: Ownbey, Monograph of the genus Argemone, Mem. Torr. bot. Club 21(1): p. 1–27, 29–33. (tax.)
1962: Lucas, Papaveraceae, in: Hubbard & Milne-Redhead, Fl. trop. E Afr.: p. 1–3. (tax.)
1974: Lemordant, Ghiglione & Kalos, Sur la composition chimique des graines d'Argemone mexicana L., Adansonia (Sér. 2) 14(4): p. 645–654. (chem.)
1978: Dyke, Poppies and glaucoma, New Sci. 79(1119): p. 679–680. (chem.)

Vernacular names: medafe (Amarinya, Tigrinya); dandaro (Amarinya for spine); medafi *tilian*, *fifo* (Tigrinya); lege hare (Gallinya); prickly poppy, Mexican poppy, argemone (English); pavot épineux, pavot de Mexique (French); cardo santo (Spanish).

Geographic distribution

Argemone originates from Central America. It was introduced into Europe in 1592 from St Johns Island by the British (Ownbey, 1958), but the Portuguese introduced it into Africa and India (Dyke, 1978) at an unknown date. It is now naturalized in the drier regions of most tropical and subtropical countries (Fedde, 1909; Ownbey, 1958). On the African continent, its main areas of distribution are the drier regions of Southern Africa, the coastal countries of W Africa, Egypt, the Sudan, and E Africa (Lemordant et al., 1974).

The plant was present though rare in the region of Ghinda, Elaberet and Asmara at the onset of this century, whereas it was very abundant there in the forties (Baldrati, 1949). This suggests introduction of argemone into Eritrea in the 19th Century.

In Ethiopia, I saw most of it in the Northern parts of Welo, in Eritrea and Tigre, and in S and C Shewa with adjoining areas. The same areas are mentioned by Baldrati (1949) and Lemordant et al. (1974), respectively. I found it traded only in Tigre and Eritrea.

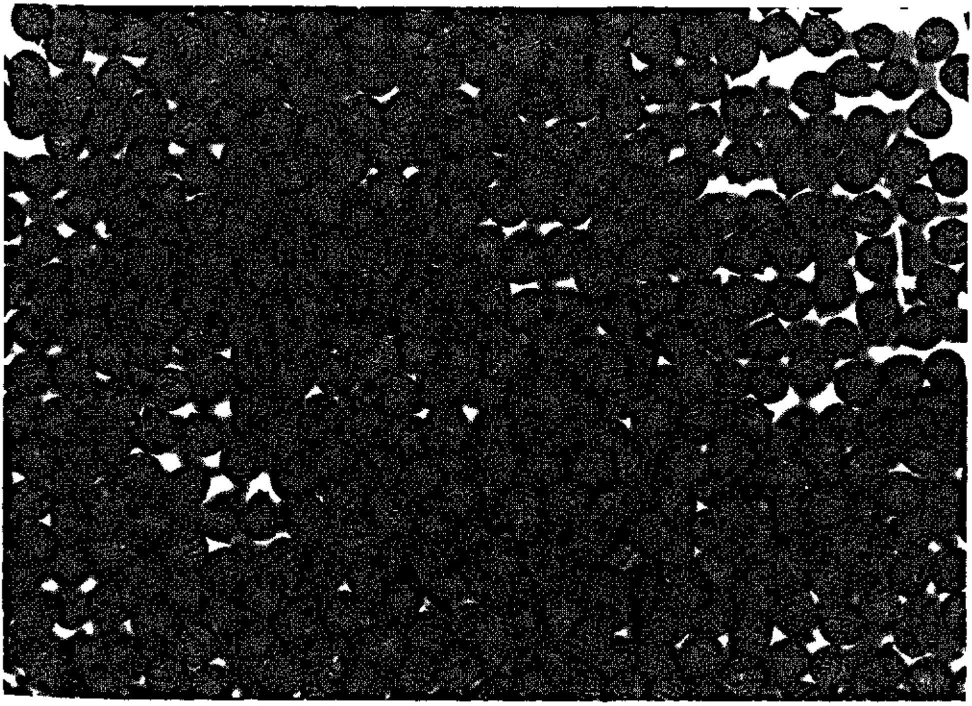
Annual, glabrous, erect to spreading, spiny herb, sometimes woody at base, up to 150 cm tall, in young stage usually with leaf rosette, all parts with yellow latex (Note 4, p. 41).

Root system with strong taproot, brown.

Stem terete, (sparsely) prickly, up to 11 mm diam., glaucous or greyish, often with reddish or purple shades.

Leaves herbaceous, alternate, ascending to spreading, flat to shallowly and irregularly concave, exstipulate, sessile, hemi-amplexicaul, often auriculate at base, pinnately lobed or incised, up to 23 cm × 9 cm, with a prickly dentate margin and with prickles on the veins, particularly beneath, above dark to greyish or glaucous green with irregu-

Photograph 1. Flower of *Argemone mexicana.*



Photograph 2. Seed of *Argemone mexicana* (SL 892; × 3).

larly outlined veins in greyish white, midrib sometimes purplish, beneath glaucous green with lighter veins; spines pale green with brown apex.

Flower bud terminal, erect, subglobular, diam. up to $1\frac{1}{2}$ cm, up to $2\frac{1}{2}$ cm high by 3 more or less spreading spiny apical horns.

Flowers c. 3–4 cm diam., on 6–50 mm long pedicels, with 2 or 1 foliaceous bracts c. 3–5 cm long just below them.

Sepals 3, caducous, imbricate, strongly concave, the terete spinescent apex forming $\frac{1}{3}$–$\frac{1}{2}$ of its length, green, outside more or less prickly.

Petals 6, seldom 5 or 4, imbricate, in 2 whorls of 3, soon deciduous, obovate, apically ± semicircular, basally cuneate, up to 33 mm × 19 mm, yellow to creamy.

Stamens numerous, free; filaments yellow, filiform, c. 5–10 mm long, abruptly constricted apically; anthers orange to yellow, basifixed, 2-celled, linear, c. 2–3 mm long, apiculate, with extrorse longitudinal dehiscence, rolling up inwards after pollen-release.

Ovary superior, ellipsoid, densely spinose, c. 11 mm × 4 mm, (grey-)green, 1-celled with 4–6 parietal placentas. Ovules very numerous, anatropic, uniformly oriented with the micropyle pointing towards the base of the ovary; raphe umbonate at the chalazal end.

Stigmas 4–6, sessile, opposite the placentas, persistent (elevated on a common stipe in fruit), more or less erect to spreading, irregular in outline, with a tomentulose concave surface, c. 2 mm long, crimson.

Fruit a prickly, 4–6 grooved, subellipsoid capsule, up to 50 mm × 23 mm, the persistent stigmas with stipe up to 4 mm long, opening apically by 4–6 valves splitting away from the vascular strands for about $\frac{1}{4}$ of the length of the fruit, exposing a cage-like frame of these vascular strands, attached apically to the persistent stigma; young fruit greyish green, mature fruit brown.

Seeds subspherical, up to 2 mm diam., crested by the dry raphe, the crest ending in a small beak at the micropyle; testa pitted in ± definite longitudinal rows between the chalaza and the micropyle, black to dark brown; endosperm oily; embryo occupying c. $\frac{2}{3}$ of seed length.

Seedling epigeal with strong root.

Hypocotyl terete, c. 1 cm long, glabrous, grey-green to purple.

Cotyledons linear, c. 35 mm × 1 mm, glabrous, margin entire, glaucous.

First leaves in a rosette, obovate, up to 5 cm × $1\frac{1}{2}$ cm, glabrous, margin very coarsely dentate, sometimes spinescent, grey-green with light grey-geen spots.

Notes

(1) Sheet 670.1 of the Linnaean Herbarium was named *Argemone mexicana* by Linnaeus. According to Ownbey (1958, p. 31), this specimen should be considered the holotype of the species.

In his description of *Argemone mexicana,* Linnaeus stressed the way the fruit opened by five valves: 'Argemone capsulis quinquevalvibus, foliis spinosis'. On the microfiche of LINN 670.1, only one fruit is visible which is too young to show any valve at all. It thus is clear that Linnaeus based his description on more material than this single specimen. LINN 670.1 therefore should be considered a lectotype.

The specimen does not give any clue to its origin. In Species Plantarum, Linnaeus indicated that the natural habitat of the species was Mexico, Jamaica, and the Caribbean area, but that it was also found in S Europe. According to Ownbey (1958, p. 33), the specimen in the Linnaean Herbarium is undoubtedly of Antillean stock, while Lucas (1962, p. 1) indicated C America as 'limited type area'.

(2) *Argemone mexicana* is both self and cross compatible. Though visited by many insects while flowering, it is predominantly self-pollinated with only a low proportion of crossing (Kaul, 1972, VI).

(3) The seeds retain their viability for at least several years, perhaps many (Ownbey, 1958).

The seed-coat is slightly waxy and not immediately permeable for water; because of its pitted surface, it traps some air when the seed is submerged. The seed, which also has a small air-pocket inside under the micropyle, can remain floating for at least one day. This seems to be an important feature in dispersal (Ownbey, 1958).

(4) According to Ownbey (1958), the colour of the fresh latex varies greatly in the genus *Argemone*. This feature is often of diagnostic importance. *A. mexicana* L., *A. ochroleuca* Sweet and *A. polyanthemos* (Fedde) Ownbey have generally bright yellow

latex. Other latex colours indicated by Ownbey for other species are very pale lemon-yellow, distinctly orange or reddish orange. In the material I studied, most labels indicated the latex to be yellow, but the label of PJ 3540, clearly *A. mexicana,* indicated that the stem exuded brown latex, a colour not mentioned by Ownbey.

(5) Many detailed reports of Indian investigations on *Argemone mexicana* were published by M. L. H. Kaul.

(6) Description was based on the following specimens.

Eritrea	Adi Caieh market: SL 892.
Harergie	College of Agriculture, Alemaya, c. 2000 m: Bos 7558, PJ 1919; few km W of Dire Dawa, c. 1200 m: WP 1849; Erer Valley, c. 15 km S of road Harer–Jijiga, 1300 m, sandy soil: WdeW 9951.
Shewa	Addis Abeba, 2300 m, open rocky place: WdeW 5897; 59 km from Awash on road to Nazareth, dry rocky lava area, c. 1260 m: PJ 3540; 123 km from Awash on road to Nazreth, 9 km from Welenchiti, 1550 m, in fields along the road: WP 1505; 11 km S of Shashemane along road to Yirga Alem, 1860 m, in sisal plantation, border of ploughed field: SL 3125.
Tigre	Adishow market: SL 1022; Enda Medhane Alem market: WP 4027.
Grown at Wageningen	SL 1694, SL 1864, SL 1873, SL 3945A, SL 3945B, SL 3971, SL 3972, WP 7370–WP 7372.

Ecology

Argemone grows in open places where the natural thicket is disturbed, on waste places, roadsides and abandoned fields. It develops well at altitudes up to 2300–2400 m (Ownbey, 1958; Lemordant et al., 1974).

In the areas where I saw most of it in Ethiopia, the annual precipitation is around 700 to 1000 mm, with a clearcut dry season. The soil seemed commonly to be well drained. Ownbey (1958) observed that in N America, argemone occurs almost exclusively in regions of low rainfall. If it occurs in areas with moderately heavy rainfall, it is found only on soils of low moisture-holding capacity.

In field and pot trials, Kaul (1972, VII) found that there was an interaction between the openness of the habitat and the soil on which argemone grows best. From analyses of soils and plants from partially shaded and open habitats, he found that argemone grows better upon nitrogen-rich soils in partial shade. It accumulates large amounts of nitrogen in such habitats. Plants growing in open habitats do well in nitrogen-poor soils and their tissues accumulate very little nitrogen. Best growth was achieved under the latter conditions.

In a trial by Henneman & van Ballegooijen (1973) in a greenhouse at Wageningen, argemone plants grown from SL 892 (from Adi Caieh) were submitted to 10 h natural plus 0, 3 or 6 h low-intensity light. The plants grown with 10 + 0 h developed more vigorously but flowered a month later than the plants grown with 10 + 6 h. The group of 10 + 3 h were intermediate. These plants were thus of the quantitative long-day type.

Development of the plant

Young plants first produce a basal leaf-rosette. The main stem arises from the heart and one or more additional stems may arise concurrently from axillary buds. The stem branches sympodially: each branch is terminated by a flower bud and new branches arise at the highest 1–2 buds below the flowers.

Husbandry

According to Baldrati (1949), argemone was cultivated in Eritrea in the forties but only if a commercial oil mill was nearby. He added that it was a late-ripening crop. This accords well with observations of Chakravarti & Pershad (1953), who found in India that argemone seed was only fully ripe 7 to 8 weeks after flowering. Baldrati (1949) also remarked that cultivation in association with sorghum seemed possible. He thought that seed could be produced in such amounts in Eritrea that an oil industry, based on argemone, was feasible, although the plant was not fit for animal feed because of the spininess.

I never saw argemone cultivated and I have the impression that it is only collected from the wild nowadays. It seems likely that it is far more abundant in the wild in Ethiopia now than 40 years ago (p. 37).

There is some evidence that other plant species inhibit the germination of argemone and thus replace it gradually in weedy populations (Sarma, 1974). If the oil remains a wanted article, it may be necessary to cultivate argemone again in the future.

Uses

The seeds are narcotic and poisonous. They contain two oils, an edible and a poisonous one (Oils & Oilseeds J., 1971; Dyke, 1978). The poisonous effects are particularly important as argemone seed may contaminate mustard seed in areas where it is a common weed. As the dimensions and colour of the seeds of argemone and some mustards are very similar, they are difficult to separate. Its oil is sometimes added to other oils as an adulterant (Lemordant et al., 1974). Tests for the detection of contamination or adulteration have been developed (for instance Hartman et al., 1972; Bose, 1974; Dyke, 1978).

Intoxications induce oedema, hyperpigmentations of the skin, sarcoid swellings, diarrhoea, anaemia and hypertension in the eye-ball leading to glaucoma (Lemordant et al., 1974; Dyke, 1978). In India, several outbreaks of dropsy as a result of adulterated oil caused the death of thousands. Autopsy of the victims showed typical changes in most body tissues, including the heart. The symptoms seem to be most severe among people with a poor protein diet, particularly if short of cysteine (Dyke, 1978).

The world over, traditional uses of the oil are mainly medicinal, for illumination, greasing and for soap manufacture (Ubbelohde, 1920; Chevalier, 1949). It may also be used to impregnate wood to avoid insect damage (Chevalier, 1949).

In doses of 2 to 4 g, the oil constitutes a mild laxative (Mensier, 1957; Lemordant et al., 1974) and it is used as such in Ethiopia. The laxative effect may be enforced by preparing oil from a mixture of argemone and castor seeds. Such a mixture is even traded (SL 1022). In the Horn of Africa, the seed is also used as a diuretic (Chiovenda, 1937). In American folk medicine, the latex of the plant was used in the treatment of syphilis, skin diseases (Mensier, 1957), warts, polyps and breast cancer (Dyke, 1978).

The only use in the kitchen I know of from Ethiopia is 'meshisha', i.e. greasing the mitad. This is also the only use reported by Wilson & Woldo (1979).

Chemical and physical properties

Argemones 1000-grain weight is c. 2.0 to 2.3 g (Mensier, 1957; Lemordant et al., 1974).

Lemordant et al., (1974) studied a sample from Nazreth in Ethiopia. In fresh matter, they found contents (g/kg) to be:

Water	72
Crude fat	367
Carbohydrates (excl. cellulose)	82
(Starch	65)
(Free sugars	17)
Crude protein	125
Cellulose	308
Ash	49
(Calcium	11)
(Potassium	5.8)

Table 12. Some characteristics of argemone oil.

	Lemordant et al. (1974)	Mensier (1957)	Ubbelohde (1920)
Specific weight (15°C)	0.923	0.922-0.926	0.9247-0.9259
(20°C)	0.919		
Iodine number	127	113-128	120-122.5
Saponification value	193	185-201	187-190
Acidity (as oleic)	1.52%		
Acid value			6-83.9
Unsaponifiable	12 g/kg	10-15 g/kg	
Refraction n_D (20°C)	1.4723		
n_D (40°C)	1.4665		1.4675
Refractive index		1.4731	
Acetyl number		27.9	
Sulphocyanogenic number		77.7	
Hehner value		93-95	95.1
Reichert-Meissl value		0.0-0.6	
Polenske value		1.16	

Table 13. Mass fractions of fatty acids in argemone oil (%).

	Lemordant et al. (1974)	Mensier (1957)	Badami & Gunstone (1962)	SL 892
Capric	trace			
Lauric	trace			
Myristic	trace		0.1	
Palmitic	13.1	11.1	9.1	11.1
Stearic	2.5	1.8	5.5	2.2
Oleic	23.1	21.3	33.2	25.5
Linoleic	58.4	58.6	53.6	60.9
Linolenic	2.2			
Ricinoleic			1.2	
Arachidic	trace		0.1	

The amount of oil found by them accords well with the amounts reported by other authors (for instance Mensier, 1957; Vaughan, 1970; Barclay & Earle, 1974), and with that of my sample SL 892, of which the oil contents in dry matter were 399 g/kg.

The physical and chemical characteristics of the oil vary with the origin of the seed and the method of extraction. It is described as non-drying (Oléagineux 1963, 18(8/9):556), semidrying (Ubbelohde, 1920) or drying (Baldrati, 1949). The colour varies from pale yellow (Chevalier, 1949) to dark brown (Oléagineux 1963, 18:556). The odour is acrid (Chevalier, 1949; Mensier, 1957). A survey of some data is presented in Table 12.

The data on the mass fractions of the composing fatty acids show wide differences. Some of them are presented in Table 13. This table also shows the composition found in the oil of my seed sample SL 892.

Lemordant et al., (1974) found one kilogram of Ethiopian argemone seed to contain

Table 14. Mass fraction (g/kg) of amino acids in fresh matter of argemone seed from Ethiopia (after Lemordant et al., 1974).

Alanine	4.4	Lysine	6.4
Arginine	15.8	Methionine	2.4
Aspartic acid	14.9	Phenylalanine	4.3
½-cystine	1.4	Proline	3.5
Glutamic acid	26.8	Serine	5.1
Glycine	11.5	Threonine	3.6
Histidine	4.9	Tyrosine	5.8
Isoleucine	3.9	Valine	4.7
Leucine	7.5		

20.5 g nitrogen. Their data on the amino acids of this seed are presented in Table 14.

An important minor constituent of argemone seed, and sometimes also of the oil, is sanguinarin with its derivate hydroxysanguinarin, a highly poisonous alkaloid. In the oil, it may be present in concentrations as high as 10 g/l (Dyke, 1978).

2.3 Brassicaceae Lindley (Cruciferae Benth. & Hook.)

Brassicaceae can be found in nearly all cultivated areas of the world, but particularly in temperate regions. They are grown as vegetables, oil crop, condiment, medicinal plants or ornamentals. The most important species cultivated for food are found within the genera *Brassica* L., *Sinapis* L., *Raphanus* L., *Crambe* L. and *Lepidium* L.

Brassicaceae are annual, biennial or perennial herbs, seldom woody, often with simple, forked or stellate unicellular hairs. Their leaves are alternate and exstipulate. The flower is racemose, usually ebracteate, bisexual, actinomorphic with a calyx in 2 whorls of 2 distinct sepals and a corolla of 4 distinct, usually clawed, petals placed crosswise (the name *Cruciferae* was derived from crux, Latin for cross); it has 6 stamens in two whorls, the outer whorl with 2 stamens, the inner one with 4, basally usually with nectaries; its ovary is usually superior, sessile, bicarpellate with parietal placentation, 2-loculate by presence of a complete false septum; the single or obsolete style is headed by a bifid stigma. The fruit is usually a silique or silicle, sometimes an indehiscent 1–few-seeded nut; it is extremely polymorphic and its form and size are important characters for the taxonomy in the family. The seed contains a large embryo and little or no endosperm; the way the cotyledons are enfolded around the radicle is a taxonomic character (Lawrence, 1970).

Because the habit and floral characteristics are relatively uniform, and because the stem and leaf characters are usually variable within taxa, there is great confusion on the delimitations of the taxa within the family. This is particularly apparent in species limits within a genus but even more so within infraspecific taxa, which are so important in cultivated plants.

The family comprises 350 genera and about 2500 species (Lawrence, 1970). According to Cufodontis (1974), about 75 species of this family were found in Ethiopia. The most important cultivated species in the country belong to *Brassica* and *Lepidium*, but also species of the other genera mentioned are grown. Some species may be collected from the wild, particularly in times of scarcity; *Erucastrum* Presl spp. are particularly mentioned in the literature.

The *Brassicaceae* I found used in Ethiopia all belong to the tribe *Brassiceae* DC. This tribe is characterized by a segmented fruit or by conduplicate cotyledons. If hairs are present, they are always simple (Tsunoda et al., 1980).

Cruciferous seeds contain variable but usually large amounts of oil. The oil of different species has in common that it contains erucic acid, which gives the oils great stability at high temperatures. Because regular consumption of this acid leads to heart ailments, it makes the oil less suitable for frying or salad oil. In several species, breeding is therefore aimed both at increasing the erucic acid content of the oil (industrial oils for high-temperature applications) and at decreasing it (cookery oils) (Appelqvist, 1966; Tsunoda et al., 1980).

2.3.1 Brassica L.

'Brassica': the Roman name for cabbage.

Literature

1919: Schulz, Cruciferae, in Engler's Das Pflanzenreich IV, 105(70): p. 1–290. (tax.)
1922: Bailey, The cultivated Brassica's I, Gentes Herb. 1: p. 53–108. (tax. + agric.)
1930: Bailey, The cultivated Brassica's II, Gentes Herb. 2: p. 211–267. (tax. + agric.)
1930: Burkill, The Chinese mustards in the Malay Peninsula, Gardens' Bull. Straits Settlements 5: p. 99–117. (tax. + agric.)
1950: Baldrati, Trattato: p. 376–385. (agric.)
1972: Harberd, A contribution to the cytotaxonomy of Brassica and its allies, Bot. J. Linnaean Soc. 65: p. 1–23. (tax.)
1980: Prakash & Hinata, Taxonomy, cytogenetics, and origin of crop Brassicas: a review, Opera Botanica 55, 57 pp. (tax.)
1980: Tsunoda et al., Brassica crops and wild allies, 354 pp. (tax. + agric.)

In Ethiopian agriculture, *Brassica* is, by far, the most important genus of the *Brassicaceae*. It is particularly grown as a vegetable, oilseed or condiment, but also for medicinal purposes.

In the literature on Ethiopia, the species involved in describing the cultivated brassicas are: *Br. campestris* L., *Br. carinata* A. Braun, *Br. integrifolia* (West) Rupr., *Br. juncea* (L.) Czern., *Br. nigra* (L.) Koch and *Br. oleracea* L.

The nomenclature of some of the species and the taxonomy within them is confused. The morphological characteristics of several species show such an overlap that species determinations based on them alone are often unreliable. The confusion tends to become greater with the introduction of hybrids between species and genera. Special techniques such as anatomy and microscopy of the seed and its coat (e.g. Heydel & Prüter, 1964; Berggren, 1972; Bengoechea & Gómez-Campo, 1975), chromatography (e.g. Hoshi & Hosoda, 1978), electrophoresis or serology (e.g. Vaughan & Waite, 1967; Nakamura, 1977), and karyology (e.g. Harberd, 1972; Gosh et al., 1978; Tsunoda et al., 1980) can support questionable determinations.

In Ethiopia, *Br. oleracea* is exclusively grown as vegetable for domestic use and for export to Djibouti. The seed is generally imported and the species is not given any further attention in this publication.

Some oilseed brassicas exotic to Ethiopia have been tried there with varying success and have been the source of some publications (e.g. *Br. napus* L. by Schmutterer 1971, Arssi Rural Development Unit 1978a & b, and Westphal & Pinto 1978). They are not further considered here and neither are the brassicas grown for their fleshy parts.

For Ethiopia, there seems to be little doubt about the identity of *Br. campestris*

Table 15. Area (in 1000 ha), yield (kg/ha) and production (Gg) of rapeseed in Ethiopia 1965–1980. (Source: FAO Production Yearbooks). The jump in 1973 is presumably due to a different source of information.

Year	Area	Yield	Production	Year	Area	Yield	Production
1965	13	400	5	1973	50	400	20
1966	14	400	6	1974	50	400	20
1967	16	400	6	1975	50	400	20
1968	16	400	6	1976	50	400	20
1969	16	400	6	1977	50	400	20
1970	16	400	6	1978	53	406	22
1971	15	400	6	1979	52	404	21
1972	15	400	6	1980	53	406	22

and *Br. nigra*, although the limits of the former species are still a matter of dispute (e.g. Vaughan, 1977), but on the correct name of the other species grown as oilseed in Ethiopia, there is considerable confusion in the literature.

It is mostly called *Br. carinata*, particularly so with authors working on breeding or cytology of *Brassica*. But people investigating species of *Brassica* morphologically tend to differ in opinion very much on the scientific name of Ethiopian rape.

It is outside my scope here to make a monograph of genus *Brassica*. I have followed the system of Bailey (1930), and prefer to call the Ethiopian species *Brassica carinata*. Other authors included it in *Br. integrifolia* (e.g. Schulz, 1919; Jonsell 1980) or in *Br. juncea* (e.g. Thellung, 1908; Baldrati, 1949; 1950). It has, however, a chromosome number ($2n = 34$) differing from those species which both have $2n = 36$ and it is not cross-fertile with them (Harberd, 1972). In the system of Bailey (1930), *Br. integrifolia* is considered conspecific with *Br. juncea*.

According to Schulz (1919) and Cufodontis (1974), *Br. integrifolia* var. *timoriana* (DC.) O. E. Schulz is found in N Ethiopia. I did not encounter it. This variety was, together with *Br. carinata*, included in *Br. juncea* by Thellung (1908) and Burkill (1930). I did not study the type material or the material Schulz cited from Ethiopia (Schweinfurth 2225), but in view of the dimensions supplied by Schulz for *Br. integrifolia* var. *timoriana* (pedicel c. 5 mm, small siliques 1.6–3.2 cm long and 1.5 mm diam., with $1\frac{1}{2}$–5 mm long beak) it could well be that he saw a rather young fruiting stage of *Br. carinata*.

The vernacular names provided by Cufodontis at least suggest that this species is not distinguished by the Ethiopians from *Br. carinata*.

The production and yield of Ethiopian rapeseed is given by FAO Production Yearbooks (Table 15).

2.3.1.1 Brassica campestris L. ($2n = 20$)

'campestris': growing in the fields.

Linnaeus, Sp. Pl. ed. 1: p. 666 (1753).

Synonyms

Brassica rapa L. var. *campestris* Koch, Syn. Fl. Germ.: p. 59 (1843).
Brassica amplexicaulis Hochst. ex Rich., Tentamen Fl. Abyss. I: p. 23 (1874).
Erysimum amplexicaule Hochst. ex Rich., l.c.: p. 20.
Brassica lanceolata Auct. non Lange: Schweinfurth, Bull. Herb. Boissier 4, App. II: p. 183, p.p. (1896).
(Fide Cufodontis, 1974: p. 148.)

Vernacular names: gommenzer, gwemenzer (Amarinya); midan rafu, mid'arafu (Gallinya); adri (Tigrinya).
Trade names: turnip rape, rapeseed, oil turnip, Polish (rape) (English); navette (French).

The species is indigenous to the Mediterranean region. It is wide-spread in Asia, Europe and N America (Schulz, 1919). It is known from the C, N and E parts of Ethiopia (Cufodontis, 1974).

The world over, the present day *Br. campestris* comprises a vast number of morphological forms. The various taxa in the complex can be divided into three distinct groups purely on a morphological basis but within the limits of homology: oleiferous, leafy and rapiferous.

Although their chromosome numbers differ, *Br. campestris* seems to cross easily with *Br. napus*, the European colza (Schulz, 1919; Johnston, 1974; Kuznetsova & Kapitonova, 1979), which is a recent introduction into Ethiopia.

The infraspecific taxonomy is complex and confoundedly so by inaccurate use of taxa in non-systematic publications (e.g. Bengtsson et al., 1972: within *Br. campestris* forma *annua*, they adopted 4 varieties).

As an oil crop, the species is important in India (cv. groups: yellow sarson, brown sarson and toria) and grown in Europe and N America. On the limits of the species and of lower taxa, there is great confusion (e.g. Prakash & Hinata, 1980).

Plants of this species may be similar to plants of *Br. carinata* but the two species can be easily distinguished by the nature of the base of the leaf or petiole. In *Br. campestris*, the leaves half clasp the stem; in *Br. carinata* not.

I did not encounter *Br. campestris* in my material grown from Ethiopian market samples. The only Ethiopian material of the species in Herbarium Vadense (JdeW 6968, from Maichew, Tigre) was collected as a weed. Rydén (1972), however, found it in the Chilalo Awraja in Arussi, but only at one place. He noted that the local farmers did not make any distinction between the species and the more common *Br. carinata* in name, in cultural practices or use (Linder, 1976).

The species is attacked by *Mycosphaerella brassicicola* (Duby) Lind. in E Ethiopia (Ashagari, 1973).

Rydén gave the following account of *Br. campestris* from Arussi.

Table 16. Relative substance fractions (%) of fatty acids in the oil of spheric and elliptic samples of seeds of *Brassica campestris* from Ethiopia, reported by Rydén (1972), and typical ranges for the species as reported by Appelqvist (1971). The fraction 'oleic' was reported as 'petroselinic' by Rydén.

Sample	Palmitic	Stearic	Oleic	Linoleic	Linolenic	Erucic	Rest
Spheric	3.8	2.2	19.0	10.5	15.0	49.5	1.4
Elliptic	3.8	2.8	20.3	14.0	16.5	41.2	1.4
Appelqvist	2–3	–	17–34	14–18	9–11	24–40	–

Brassica campestris L. A slender erect annual herb, 0.5–2 m tall. Lower basal leaves often pinnatifid with large terminal lobes; at least upper leaves clasping; all leaves somewhat hairy. Inflorescence an ebracteate raceme; sepals erect; petals about 2 cm long, yellow; stamens 6; stigma capitate; self-sterile. Fruit a silique 2.5–5 cm long and patent with convex valves; tipped by an indehiscent and seedless beak, about $\frac{1}{2}$–$\frac{1}{3}$ of the silique in length. Seeds in a single row in each locule. Cotyledons obcordate, emarginate. Seed spherical, c. 2 mm long, black or dark-red. Network high, considerably over the seed surface, sometimes over or at the same level. Hilum very small, darker than the seed.

Both samples of Rydén's originated from Bobora at 2600 m. One sample had black spherical seeds with oil contents of 354 g/kg; the other sample contained 298 g of oil per kilogram. It had dark-red seed with an irregular to elliptical form.

The fatty acids in the oil of *Br. campestris* from Ethiopia as presented by Rydén (1972) and the typical ranges of the common fatty acids in the oil given by Appelqvist (1971) are presented in Table 16. Tsunoda et al. (1980) gave figures similar to those of Appelqvist but indicated the presence of about 10% eicosenic acid in the oil.

According to Rydén (1972), the results for the two samples of *Brassica campestris* showed the same analytical pattern as those for *Br. carinata*. The values for erucic and linoleic acid were 'normal' and the values for linolenic acid are slightly high if the oil were to be used for human consumption. But from a comparison of the data of Appelqvist (1971) and Rydén (1972), it seems that the oil of Ethiopian *Br. campestris* deviates from the common range because it has high contents of erucic, linolenic and palmitic acids, but is low in linoleic and oleic acid.

2.3.1.2 Brassica carinata A. Braun (2*n* = 34)

'carinata': from the Latin 'carina' = keel of a ship, keeled, because of the form of the valves of the fruit.

A. Braun, Bemerkungen Fl. Abyss., in Flora XXIV(17): p. 267 (1841).
Type: A. Braun s.n. (1840), cultivated in the Botanical Garden of Karlsruhe (KR!, US!).

Synonyms

Sinapis abyssinica A. Br. ex Regel, Annot. bot in Ind. sem. Hort. Petrop.: p. 34 (1856). (Fide O. E. Schulz, 1919).

Melanosinapis abyssinica Hort. ex Regel, l.c. (Fide O. E. Schulz, 1919).
Sinapis juncea Auct. non L.: Schweinfurth & Ascherson in Schweinfurth, Beitrag Fl. Aethiop., p. 270 (1867), p.p.
Brassica juncea (L.) Coss. ssp. *eu-juncea* Thellung, Verhandl. Bot. Ver. Prov. Brandenburg L(2): p. 152 (quoad pl. abyss.) (1908).
Brassica integrifolia (West) Schulz var. *carinata* (A. Br.) O. E. Schulz, Pflanzenreich IV.105: p. 58 (1919).
Brassica integrifolia (West) Ruprecht sensu Jonsell, Fl. Cameroun 21: p. 4 (1980), p.p.

Vernacular names: gommenzer, gwemenzer, guraghe gommen, gomense, mashashe (Amarinya); kosa, yeken (Chako); midan-rafu, mid'arafu (Gallinya); woga, fishu, shea-fishu (Janjero); sachab (Kaffinya); gomano (Konso); shana (Sidaminya); hamli, grumba, adri (Tigrinya).
Trade names: Abyssinian mustard, Abyssinian rape, Abyssinian cabbage, one-month cabbage (English); moutarde Abyssin, colza Abyssin, chou Abyssin (French).

Geographic distribution

Brassica carinata is only known as a cultivated plant from the highlands of Ethiopia and N Kenya; wild forms are not known. It is commonly believed to have originated in Ethiopia, but some people believe that *Br. carinata* was introduced into Ethiopia by the Italians (e.g. Holovlaský, 1972; Linder, 1976). I do not share this opinion, because the species is not a common crop in Italy and it is too polymorphic in Ethiopia to be a recent introduction. It is, however, true, that in Sicily some plants were found that had the same chromosome number as *Br. carinata* (Note 3). Some of these could probably be explained as an escape of a colonial 'souvenir'; the obvious ties between the Ethiopian and the Mediterranean flora may also be remembered.

'Gommenzer' is widespread in Ethiopia. Outside the hot lowlands (kolla), the seeds can be found on most markets and in many gardens near houses. I did not see it as a field-covering crop, but it was grown as such in Arussi (Rydén, 1972). I saw it mostly as a minor component in fields with cereals or sweet potatoes, where it was often a casual. Farmers, particularly in Harergie, often said that the plant was left at weeding as 'food given by God'. In the Tana region, I saw it as a border to fields planted with grains or peppers.

On average, 'gommenzer' is especially a crop on farms of area less than 2 ha. It there covers less than $\frac{1}{2}\%$ of the surface (Prov. Milit. Gov., 1977). Of the total Ethiopian farmland, about 0.1% of the surface is covered with *Br. carinata* (Holovlaský, 1972; Prov. Milit. Gov., 1977).

In view of wide distribution and use-at-home, data on annual Ethiopian production of c. 5–6 Gg (e.g. FAO Prod. Yearbooks before 1972; Asrat Felleke, 1965; Holovlaský, 1972) seem unrealistic to me and the 20 Gg or more, reported by FAO after 1972 and by Vegetable Oil and Oilseeds (e.g. 1965) is a better estimate (Table 15).

Description

Erect annual herb with a strong white taproot, usually much and strictly branched from c. 30 cm upwards, the lower branches wilting in a crop, up to 190 cm tall and

Photograph 3. Young plant of *Brassica carinata.*

up to 125 cm wide. The leafy vegetable forms (not considered in this publication) persist for 3–4 years and can be 2 m tall or more (Smeds, 1955).

Stem up to 2 cm diam., subcylindric, glabrous, usually waxy, greyish to whitish green, often purplish tinged or dotted, especially or only at base and nodes; full-grown plants leafy from the first branches upwards.

Branches of first order at an angle of c. 30–60°, subcylindric, sometimes with a few longitudinal ridges, coloured and waxy, like the stem, or less so; branches of higher order less coloured.

Leaves alternate, petiolate, the uppermost sometimes subsessile; petiole up to 19 cm long, semiterete in the lower half and slightly flattened and widened near base, more cylindrical and canaliculate in upper half, glabrous, often waxy, light green, green with purple rims or purple, with (0)1–2 lateral segments up to 5½ cm diam.,

Photograph 4. Flowering branch of *Brassica carinata*.

which are subcircular, elliptic or obcordate with entire to shallowly dentate margin, often with several (much) smaller, more ovato-triangular, acute to acuminate segments as well; blade of lower leaves ovate to oblong, usually lyrate and irregularly (shallowly) lobed or sinuate, obtuse to acute at apex, usually oblique and with 1–3 deep lobes at base, up to 30 cm × 24 cm, with dentate to serrate, sometimes undulate margin, glabrous or with a few hyaline hairs, (greyish or reddish) green above, paler or greyish beneath, veins (midrib with 10 main laterals each side) sometimes purple or light-green, prominent beneath; leaf-blades towards flowers gradually smaller, narrower, less lobed, less coloured and less waxy, the uppermost narrowly ovate, narrowly oblong or narrowly obovate, acuminate and at least apically serrate (very seldom entire), with petioles of c. 0–5 mm.

Inflorescence a much-branched, lax, compound raceme with the open flowers below

Photograph 5. Inflorescence of *Brassica carinata* with reduced bracts.

the buds, bracteate at least apically in some of its branches, in fruit sometimes ending in a 'fruit rosette'.

Bracts sometimes formed and coloured as the highest leaves, sessile to shortly stalked, up to 35 × 5 mm, usually linear with entire margin and acuminate top, or reduced to midrib (hair-like), seldom situated on the pedicel.

Pedicels cylindrical, c. 5–6 mm long at anthesis, up to 15 mm in fruit.

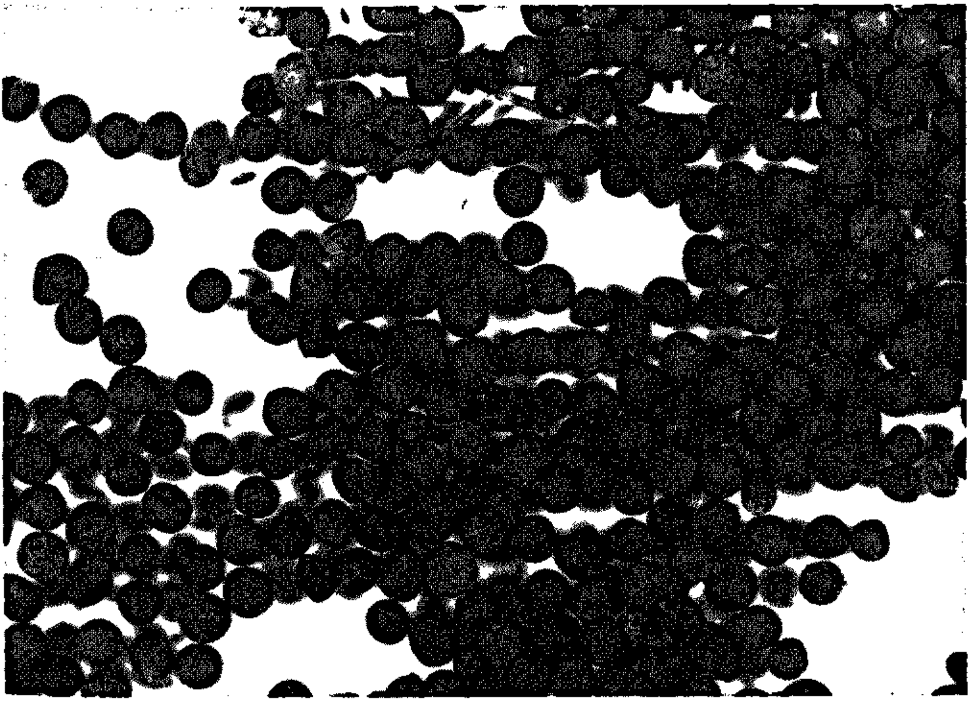
Flower (9)15–21(25) mm diam., c. 5–6 mm long.

Sepals 4, greenish yellow to light green, glabrous, erect to spreading at an angle of 45°, narrowly elliptic, ± parallel veined, midrib distinct, concave, apically obtuse to irregularly lacerate and cucculate, sometimes with an upright fleecy margin, the outer ones c. $7\frac{1}{2}$ mm × 3 mm and basally subsaccate, the inner ones c. $7\frac{1}{4}$ mm × 2 mm.

Photograph 6. Siliques of *Brassica carinata*.

Petals 4, thin, alternating with sepals, yellow or creamy white, very seldom purple veined, broadly ovate, c. 15 mm × 6 mm, entire, obtuse to truncate to shallowly emarginate and shallowly undulate at top, narrowed and concave into a nail at base, glabrous both sides, seldom slightly farinaceous on veins outside, main vein distinct up to at least half the length, at each side with c. 7 laterals.

Stamens distinct, 6, in 2 rows, outer row 2, inner row 4, with glabrous, pale yellow filaments and yellow introrse anthers, opening with 2 slits lengthwise; the outer ones up to 10 mm long with subcylindric flattened c. 7-mm-long filaments, curved at base; anthers ovate to oblong, apically obtuse to mucronulate, basally cordate, up to 3 mm long, rather erect, basifixed, thecae progressing for c. $\frac{1}{4}$ of their length along the filament, usually shortly pilose or papillose where attached; inner stamens as outer ones, but less curved at base and c. 1 mm longer.



Photograph 7. Seed of *Brassica carinata* (SL 1121; × 5).

Nectaries 4, green, 2 opposite the outer stamens, 2 alternating with these implanted between 2 inner stamens; the outer 2 erect, transversely rectangular, shallowly 2-lobed apically, flattened, c. 1 mm × ½ mm; the inner two spreading, shortly oblong to filiform, apically obtuse, c. ¾ mm long.

Ovary sessile, glabrous, (very) pale green, narrowly rectangular in outline, c. 1 mm diam., rhombic in transverse section, with 2 obvious lateral valves up to 9½ mm long, and a terete slightly oblique beak, c. 2 mm long, apically with a c. 1 mm × ½ mm capitate shallowly tangentially bilobate densely papillate yellow stigma; valvar part bilocular with a false septum; placentae 2, parietal; ovules up to 20 in 4 rows, anatropous, pendulous with dorsal raphe (descendingly epitropous), c. ½ mm diam., with a filiform funicle c. ⅓ mm long.

Fruit a beaked straight or ascendingly curved silique, at 30–45(80)°, up to 67 mm long (inclusive beak) and up to 8 mm wide. Two extreme forms may be found on the same plant: (a) strongly carinate with ± prominent seed elevations at maturity (torulose to torose); (b) less carinate and then with prominent seed elevations at maturity (torose). Wall glabrous, light brown to straw-coloured when ripe, light to medium green, sometimes variously striped or tinged with anthocyanin when full-grown but not yet ripe; valves obtuse at base and apex, with prominent midrib, other main veins seem to originate from suture (particulary obvious in strongly carinate fruits), anastomose, prominent in dry fruit; beak aspermous, slender, ± conical, apically with dry stigma, c. 3–7 mm long.

Seed diam. c. $1\frac{1}{4}$–$2\frac{1}{2}$ mm, subglobose to broadly ovate to ellipsoid, sometimes laterally compressed, sometimes shallowly grooved basally, with light-coloured hilum and a dark appressed small excrescence over the radicle, testa pitted, less so in small seeds than in large ones, in various shades of (reddish-)brown, grey, creamy and black, slightly mucilaginous.

Seedling epigeal, with a strong main root and fibrous laterals. Hypocotyl c. 2–3 cm long, cylindrical, green or purple to red. Cotyledons with semiterete petioles, above shallowly grooved, c. 1–2 cm long, purple to red, straight; blades flat, widely obovate, emarginate, basally truncato-attenuate, dull dark green, up to 23 mm × 20 mm. Epicotyl and first nodes often very short. First leaves petiolate, gradually increasing in size, flat, youngest ones wrinkled, somewhat irregularly oblong or widely so, coarsely crenate to sinuate, sometimes with 1–4 narrowly subtriangular basal lobes basally on the blade or on the petiole, glabrous or often (sparsely) pilose with stiff monocellular hairs on petioles and both surfaces, dark green above or purple to reddish at base or slightly so all over, paler beneath, midrib purple.

Notes

(1) There is great confusion on the taxonomy of the group of annual oilseed brassicas, to which *Brassica carinata* belongs. The species are morphologically often highly variable and show (wide) overlap in many characteristics. Cultivated forms from different parts of their area of distribution have sometimes been described under different scientific names. Sometimes the same scientific name has been used to describe different taxa. Oilseed brassicas often play a similar role in the agriculture of widely separated areas; different taxa may be used indiscriminately.

Some views on the correct scientific name of Ethiopian rape are mentioned below. All authors agree that *Brassica carinata, Br. integrifolia* and *Br. juncea* are closely related.

To his description of the species, Braun (1841) added that *Br. carinata* was related to some *Sinapis* species that he was not familiar with, notably *S. integrifolia* Auct., *S. juncea* Auct., *S. laevigata* Auct. and *S. brassicata* Auct. Considering Koch's criteria for distinguishing *Brassica* and *Sinapis,* however, Braun thought the plant a *Brassica* rather than a *Sinapis.*

Braun did not note the authors of the *Sinapis* species and the majority of the names Braun cited have been used more than once to describe different taxa.

Thellung (1908) believed that *Sinapis laevigata* L., *Brassica carinata* Braun and *Sinapis brassicata* Lour. non L. belonged to *Br. juncea* (L.) Czern. ssp. *juncea* (ssp. eu-juncea Thell.), while *Sinapis integrifolia* West and *S. brassicata* Griseb. belonged to *Br. juncea* ssp. *integrifolia* (West) Thell. Thellung used leaves and hairiness to distinguish the two sspp. Most of my exsiccates fit partly the one ssp. and partly the other.

Schulz (1919) distinguished a 'species collectiva' *Br. juncea,* which can be interpreted as a group of *Brassica* spp. closely related to *Br. juncea.* This species collectiva included

Br. juncea (synonyms, *Sinapis integrifolia* Schultes non Willd., Br. *juncea* ssp. *eu-juncea* Thell. p.p.), *Br. integrifolia* (West) Schulz (basionym: *Sinapis integrifolia* West; synonyms, *Br. laevigata* Burm. (nom. nud.), *Sinapis brassicata* Griseb., *Br. integrifolia* (Willd.) Rupr., *Br. juncea* (L.) Czern. ssp. *integrifolia* (West) Thellung), and two other species. Within *Br. integrifolia*, Schulz distinguished botanical varieties. One of these was var. *carinata* (West) O. E. Schultz. He based his taxa on the form of the basal leaf and dimensions of the fruit. If used on my material, the characteristics of the basal leaves would lead me generally to *Br. juncea* or to *Br. integrifolia* var. *integrifolia*, but the fruit characteristics always led me to *Br. integrifolia* var. *carinata;* the dimensions of fruit and seed in my material were often even larger than accepted by Schulz.

Bailey (1930) thought *Sinapis integrifolia* Willd. and *Br. integrifolia* (West) Rupr. were conspecific with *Br. juncea*, and that *Br. carinata* was a distinct species. Bailey distinguished *Br. juncea* and *Br. carinatà* on characteristics of the fruit. Determinations with his key place all my exsiccates in *Br. carinata*.

In the year (1930) that Bailey published his taxonomy of *Brassica*, Burkill surveyed the cultivated brassicas of the Malay Peninsula. According to him, *Sinapis integrifolia* West, *S. integrifolia* Willd. and *Br. carinata* were all conspecific with *Br. juncea* and he suggested that this was the mustard described by Sloane from Jamaica (1707), the same description as indicated by West in his description of *S. integrifolia*. Burkill's key (based on 'large' flowers and dimensions of fruit) could lead me only to *Br. oleracea* or *Br. campestris*. Other characteristics of these species (e.g. form of highest leaves) make this choice impossible and I think that Burkill's views on *Br. carinata* are useless for determinations of Ethiopian material.

Jonsell (1980) cited *Br. carinata* Braun as a synonym to *Br. integrifolia* (West) Rupr. It seems more likely to me that *Br. integrifolia* is to be reduced to *Br. juncea* (L.) Czern. and that Jonsell's view that *Br. carinata* is an incorrect name is not to be followed[1].

Thus the form of the basal leaves is not a useful character in this group. The margin of the highest leaves is mostly distinctive. Schulz (1919), for instance, indicated for both *Br. juncea* and *Br. integrifolia* that the margins of upper leaves were entire ('folia superiora integerrima') and Jonsell (1980) indicated that this was the common situation ('feuilles caulinaires à bords entiers ou crénelés', and his depiction of *Br. integrifolia)*.

I did not find bracts mentioned in any description of either species nor did I find them in the material I saw of *Br. juncea*. But I always found them in *Br. carinata*, also on Braun's specimens. The drawing of Sloane (1707), however, depicts bracts and Jonsell's drawing (1980) suggests 2 small bracts apically. The presence of bracts is thus not necessarily distinctive.

The sexual parts, notably sepals, petals, fruits and seeds, seem to be larger in *Br. carinata* than in *Br. juncea*. A characteristic related to the size of the petals is the number of side-branches of the midrib.

1. Note in press. Jonsell (1982) seems to concur (FTEA: Cruciferae, postscript on p. 69).

According to Vaughan (1976), the seed-coats of *Br. juncea* and *Br. carinata* are similar and it is difficult to distinguish the species by their seed-coat. He found both species to have a mucilaginous epidermis, which was finer pitted in *Br. carinata* because of a more regular subepidermal pallisade layer.

Bengoechea & Gómez-Campo (1975) found that the seeds of both species could be distinguished by careful measurements. They found no mucilage in *Br. carinata* but a thin layer in *Br. juncea*. My observations on the presence of mucilage confirm the observations of Vaughan.

Different chromosome number and cross-fertility are generally accepted characteristics in *Brassica* for describing relationships or for final determination of the species. The genetic background and karyological aspects of the genus are quite well agreed upon.

Japan played a particularly important role in genetic research and breeding of this genus. The break-through came with U (1935), who proposed the '*Brassica* Triangle', also known as the 'Triangle of U'. This describes the genome relationships between the commonly cultivated *Br. nigra* ($n = 8$), *Br. oleracea* ($n = 9$), *Br. campestris* ($n = 10$), *Br. carinata* ($n = 17$: *Br. nigra* × *Br. oleracea*), *Br. juncea* ($n = 18$: *Br. nigra* × *Br. campestris*) and *Br. napus* ($n = 19$: *Br. oleracea* × *Br. campestris*).

The triangle has been extended with other species (reviewed in Tsunoda et al., 1980). The validity of the relationships in the triangle has been experimentally proven several times, for instance by Frandsen (1943; 1947). Apparently Frandsen had only few accessions of *Br. carinata:* the leaf forms he depicted as typical for 'Br. pseudocarinata' (the artificial species hybrid) but not for *Br. carinata,* were also present in my *Br. carinata* material.

(2) Tsunoda et al., (1980) suggest that the kale, traditionally grown in Ethiopia is a form of *Br. oleracea,* not *Br. carinata.* This is contrary to what is mostly found in the literature on this kale.

(3) *Br. carinata* may well have originated not just once (Gates, 1953; Tsunoda et al., 1980). Berggren (1962), for instance, found subspecific differences in the seed-coats of the material she studied, suggesting hybridization between different subspecific taxa of *Br. nigra* and *Br. oleracea.*

Harberd (1972) found a wild plant orginating from Sicily to be the only one crossing freely with *Br. carinata* and having the same chromosome number. He suggested that 'Accession 45' probably needs specific recognition because it is morphologically distinct from *Br. carinata.*

(4) According to Tsunoda et al. (1980), open spreading sepals are a classical differential for the genus *Sinapis.* They seem to be unique to this genus, perhaps with the exception of some *Erucastrum* species.

From what I observed in my *Brassica* collection, it seems necessary to give a stricter definition of 'open spreading' ('patent') as opposed to 'erect' and of the stage at which the observations should be made. During most of flowering, the sepals were indeed erect but, in several plants of *Brassica carinata,* the sepals would spread to an angle of about 45° at full anthessis. In some plants of *Brassica nigra,* the sepals would even open as far as c. 90°.

(5) All my market samples were mixtures of seeds of different colours. The general impression of the coulour of a sample varies with proportions of seeds of certain colours, but there are also different colours between the samples.

Visually, the samples could be divided into five groups.

(a) The most common were mixtures that gave a reddish brown impression, often with greyish tones but never with light-coloured seeds. The bulk of their seeds more or less matched colours 174A, 177A (greyed-orange) or 199 A or B (greyed-brown) of the colour chart of the Royal Horticultural Society of London. (Samples SL 12, 18, 19, 36, 52, 60, 203, 233, 239, 245, 284, 285, 289, 330, 379, 420, 501, 503, 557, 606, 633, 679, 715, 741, 760, 848, 852, 858, 862, 896, 942, 957, 964, 983, 984, 1051, 1087, 1118, 1119, 1120, 1121, 1170, 1171, 1172, 1200, 1338, 1436.)

(b) Second-most common were reddish-grey samples, characterized by colours between 197A (greyed-green) and 199A (greyed-brown), and 165A or B (greyed-orange), seldom containing some light-coloured seeds. (Samples SL 77, 171, 194, 271, 419, 487, 488, 556, 603, 604, 605, 714, 770, 804, 929, 1088, 1240, 1275, 1343, 1388, 1410, 1427, 1464, 1489, 1537.)

(c) Greyish light-brown, characterized by colour 199A (greyed-brown), seldom with some light-coloured seeds. (Samples SL 67, 69, 130, 131, 221, 355, 985, 1336D, 1463, 1488, 1553, 1568, 1569.)

(d) Equally frequent as c: light-brown. Light-brown contains major fractions of light-coloured seeds, of colours 164B or 165B (greyed-orange). (Samples SL 112, 123, 151, 713, 806, 819, 820, 1214, 1241, 1295, 1296, 1465, 1570.)

(e) A few samples made a light-brownish grey impression. The bulk of their seeds was 197A (greyed-green) or 174A (greyed-orange). One sample (SL 1212) contained a minor fraction of black (202A). (Samples SL 1212, 1213, 1252, 1339.)

Relating colour and origin of the samples suggests that 'reddish brown' is most frequent in E and N Ethiopia but less common in the SW. The other colours are more widely distributed in S Ethiopia. 'Greyish light-brown' is relatively frequent in SW Ethiopia. I found 'light-brownish grey' only in the region of Goba (Bale).

On an oven-dry basis, the average oil contents of the different colours were found to be (number of samples investigated reported between brackets):

light-brownish grey	381 g/kg (2)	greyish light-brown	402 g/kg (6)
reddish brown	389 g/kg (17)	light-brown	415 g/kg (10)
reddish grey	397 g/kg (11)		

(6) In the Chilalo awraja of Arussi, Rydén (1972) found five different types of seed in *Br. carinata*. The seed-types were: (a) yellow, spherical-lenticular shaped, (b) yellow-brown to red-yellow, elliptical to spherical, (c) reddish-grey, spherical, (d) dull grey, spherical, (e) dull light-red, spherical.

The observations on colour of Rydén accord well with what I found (Note 5), but

I did not find a correlation between colour and form, nor did I find seeds I would dare to describe as 'lenticular'.

Rydén found no relation between seed type and plant characteristics. Plants differed in amount and pattern of anthocyanin on stem, and in colour of leaf and flower, but these differences were as common within the same seed type as between them. It was not possible to make a classification based on plant characteristics.

Rydén observed that the farmers did not usually distinguish cultivars, an observation I made too. He found only one farmer who distinguished 'white rape' and 'red rape' according to seed colour.

According to Westphal-Stevels (1975), a special-coloured form of 'gommenzer' is used for greasing the mitad. I never heard of this preference for one colour, nor did I find it mentioned elsewhere in the literature.

Apparently there is the following relation between the seed-types of Rydén (R) and of my collection (S): Ra = Sd, Rb = Sc, Rc = Sb, Rd = Se, Re = Sa.

(7) On 20 May 1974, 83 samples of *Br. carinata* were sown on a field at Wageningen, in rows 80 cm apart. Per sample, a row of 3 m was sown. After thinning twice, 10 plants per accession were left for observation and herbarium. The development of the plants was observed every 3–5 days.

The following was observed.

Germination was irregular but fast. In one week, $\frac{3}{4}$ of the accessions had germinated, after 2 weeks nearly all. Because all accessions which were older (collection WP: 1966–1967) germinated much later, it seemed that germination energy was determined by age and differences at storage and not by genetic factors.

In the seedling stage, most populations were varied in colour of hypocotyl and first leaves. Between accessions, the differences were often not larger than within accessions. The most common colours of the hypocotyl were pale-green, medium-green and blue-green, but some plantlets had dark-green, beige-green, pale-purple or red hypocotyls. Usually the base of the hypocotyl was (pale-)purple, more seldom green or red(dish-purple). The cotyledons were dull dark-green, their petiole and midrib coloured as the upper part of the hypocotyl. The youngest unfolding leaves, the heart, were often purple or reddish as well, if 'reddish' sometimes with a very light-green margin. In slightly older leaves, the venation might remain non-green. In a few cases, the petioles were the only non-green parts of the plantlet.

The very first flower buds were observed on 26 June. The data on the time from emergence until the appearance of buds suggested that part of the accessions was about a week later than the rest.

If we compare the dates of first flowering of accessions with the dates of first-observed flower buds, there is no clear relation so that accessions that were first to show buds were also the first to give flowers. Within one accession, however, the plants that first showed flower buds were usually also the earliest flowering ones. It seems that the terms 'early' and 'late' are in general more applicable to a plant than to an accession. There was a relation with the colour of the stem (p. 67).

The time to flowering after emergence showed the following tendencies: (a) accessions originating N of the line Djibouti–Addis Abeba–Asosa generally flowered earlier than accessions from S of this line; (b) accessions originating from E of the line Asmara–Addis Abeba–Chew Bahir usually needed less time to flower than accessions from W of this line. The vegetative time of most accessions form NE Ethiopia was 38 ± 4 days (mean and range), of most accessions from SW Ethiopia 59 ± 4 days. From SW Ethiopia there were also accessions flowering after 45 ± 4 days, which was also average for NW Ethiopia. Accessions from SE Ethiopia needed on average about 50 days. The accessions with the quickest development were from the area between Haik (Welo) and Robi (Shewa). In the field, they were conspicuously shorter.

The oil contents of the seeds from which the earliest flowering populations grew were on average about 2%(w/w) higher than those of which the latest flowering populations grew. There were, however, high and low oil contents in both groups (observed on 38 accessions).

With few exceptions, the accessions first to show flower buds belonged to Seed Colour a. The same applies to the accessions flowering first.

The flower was yellow, creamy, pale yellow or yellow with purple veins. Usually plants flowering with one of the three last colours formed a minor portion of the 10 plants of each accession.

Creamy flowers were found in accessions from wide spread areas of Ethiopia, particularly from the south. They were not found in accessions from Tigre and Eritrea. The accessions and, parenthesized, the number of creamy-flowering plants were: SL 18(1), 67(1), 77(3), 130(1), 151(1), 379(2), 501(4), 556(1), 603(3), 604(7), 605(3), 820(2), 929(1), 983(2), 984(1), 1172(1), 1213(2), 1214(2), 1240(1), 1241(3), 1252(1), 1275(1), 1338(2), 1339(6), 1343(7), 1410(5), 1427(6), 1436(4), 1463(2), 1465(10), 1489(3), 1537(2), 1568(4); WP 3087(1), 3277(9).

Although creamy-flowered plants were found in populations grown from samples of all seed colours, they were more frequent with Seed Colours b and e, and relatively sparse with Seed Colour a.

The accessions and number of 'light yellow' flowering plants were: SL 130(2), 379(2), 984(1), 1388(4), 1427(1); for 'yellow, purple-veined' these data were SL 679(2), 1463(2).

The origin of the last two groups was in the south. Their number was too small to demonstrate any relation between flower colour and other characteristics of the plants of the accessions. In 'yellow, purple-veined' flowers, the seedlings were red or strongly purple.

The diameter of the flowers showed variation, but was usually rather uniform within an accession. In general, there were considerable differences between and within numbers in colour, waxiness and also in the number of side-branches and their angle to the main stem. There were, however, also accessions that were rather uniform, notably the early group from the Dessie area.

Some other notes from the field were:

- plants grown from SL 271 (from Chelenko, Harergie) have a habit differing from the common picture. They possess few lateral branches
- plants grown from SL 355 (Jijiga market) have a strikingly light-green leaf and were

Photograph 8. Infructescence of 'loose' *Brassica carinata* (SL 3658).

Photograph 9. Infructescence of 'bushy' *Brassica carinata* (SL 3782).

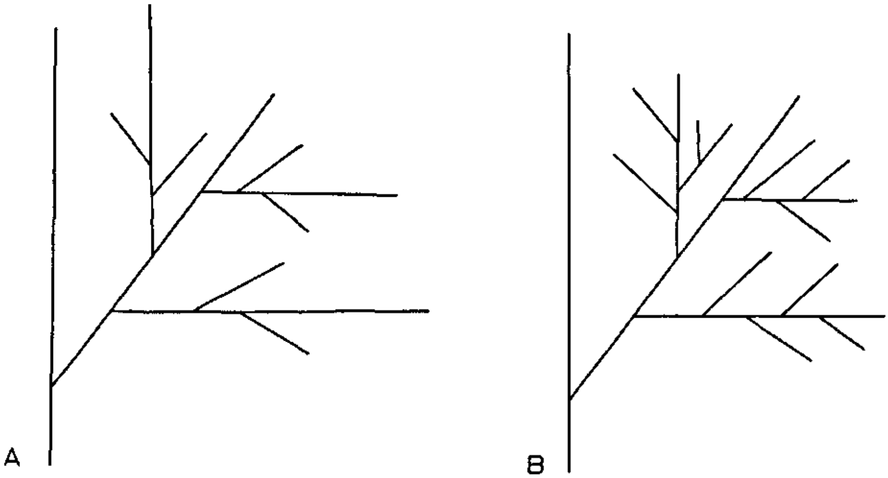


Figure 3. Branching habit of *Brassica carinata*. A. Loose type. B. Bushy type.

very late to flower
– plants grown from SL 355, 556, 1214, 1240, 1241, 1339, 1410, 1465, 1489 and SL 1568 were found to have larger leaves than average on the field; all these numbers were collected in S Ethiopia (as defined above). They never had Seed Colour a and 4 had Seed Colour b. The number of accessions is too small, though, to draw any conclusion.

(8) In a trial in a greenhouse, the different colours of the seeds of 12 seed samples were sown separately to see if the plants grown from them differed in appearance. The results were difficult to interpret, especially because only small populations (5–7 plants) could be observed. Some populations were much more uniform than the 'unsplit' populations grown in the field from the same market sample; other populations, however, remained very varied. Further study seems necessary.

(9) Although there are overlaps, I think that there are two distinguishable branching habits in *Br. carinata*. The habits are 'loose' and 'bushy'.

'Loose', the more common habit, bears usually only 2 branches of highest order at the base of the branches of the lower order of the inflorescence. On average, there are more flowers on the branches (commonly over 10) than in the other habit.

'Bushy' bears usually about 4 branches of highest order at the base of the branches of the lower order of the inflorescence (Fig. 3). Usually the number of flowers on the branches is 10 or less. The bushy effect is enhanced by the presence of a subtending 'high-leaf' at the base of each branch. This is generally larger than the bracts of the 'loose' type. Plants with this branching usually remain smaller than plants with the 'loose' branching habit.

A phenomenon found more often in 'bushy' than in 'loose' plants is the formation of 'flower rosettes', terminating some branches. I do not know whether this is a genetic property or the result of some infection with an insect or fungus.

(10) I have the impression that the following characteristics can be used in describing differences between accessions or cultivars ('descriptors'). For some of these characteristics, it will be necessary to define the stage at which they should be observed.

- Length of the growing cycle
- final height
- branching habit (Note 9)
- colour and colour distribution on stem, branches and leaves
- waxiness of stem, branches and leaves
- presence or absence of large petiolar segments in base leaves
- general outline and size of terminal segment of base leaves
- number, depth and form of lobes of terminal segment of base leaves
- apex of terminal segment of base leaves
- presence, frequency and distribution of hairs on leaves, particulary on seedlings
- margin of leaves, especially of the basal ones and the highest ones
- length of the petiole of the highest leaves
- form, frequency and size of bracts
- number of flowers (fruits) on final ramification of inflorescence
- greatest diameter of flower
- colour of petals
- upper margin of petals (slightly emarginate or not)
- angle of opening of the calyx
- apex of sepals
- form(s) and dimensions of ripe fruits, possibly also length of pedicel in fruit
- colour of unripe fruit
- number of seeds per fruit
- form, size and colour of seed
- colour of hypocotyl (and petiole of cotyledon)
- colour of first leaves of seedling.

(11) Linder (1976) reported that *Br. carinata* from different parts of Ethiopia differed in habit, size, yield, and days to maturity. This was also observed in a trial in a greenhouse at Wageningen. Plants from seeds from NE Ethiopia (Chercher, NE Shewa, Welo, E Tigre and C Eritrea) grew taller, bore more branches and leaves, accumulated more dry matter and flowered earlier than plants grown from seeds from the rest of Ethiopia (van Klinken, 1976).

The distribution of seed colours over Ethiopia (Note 5) suggests a greater vitality of plants grown from 'reddish-brown' seeds than from seed of other colours.

(12) Of several accessions in the field at Wageningen, flowering branches were bagged with water proof paper. These branches did not bear fruits, except in one plant. This result suggests that *Br. carinata* is rather strongly self-incompatible.

(13) Description was based on the following specimens.

Arussi	Butajira market: WP 3394; Sire market: SL 151.
Bale	Goba market: SL 1212–1214; Goro market: SL 1252; Kofale market: SL 1275; Robi market: SL 1240–1241.

Beghemder	Addis Zemen market: SL 60; Gonder market: SL 52, SL 858, SL 862, SL 929; Infranz market: SL 848, SL 852.
Eritrea	Adi-Caieh market: SL 896.
Gojam	Dejen market: SL 760, SL 770; Elias market: SL 804; Lumane market: SL 741; Telili market: SL 806, Sl 819–820.
Harergie	Alemaya market: SL 18–19, SL 221, SL 223; Asbe Teferi market: SL 12, SL 487–488; field 5 km E of Asbe Teferi: SL 2965; Assebot market: SL 713–715; Bedeno market: SL 330; Bedessa market: SL 679; Chelenko market: SL 239, SL 245, SL 271; Deder market: SL 379; Feddis market: SL 171, SL 194; Ghelemso market: SL 633; Jijiga market: SL 355; Karra market: SL 603–606; Kuni market: SL 556–557; Langhe market: SL 284–285, SL 289; Mulu market: SL 419–420, SL 450; Waichu market: SL 501, SL 503; Wotter market: SL 203, SL 208.
Illubabor	Metu market: SL 1488–1489.
Kefa	Agaro market: SL 77, SL 97; Bonga market: SL 1410; Chena market: SL 1427; Jemero market: SL 1436, 1463–1465; Jimma market: SL 112, SL 123, SL 129–131; Yebu market: SL 67, SL 69.
Shewa	Kuyera market: SL 1200; Robi market: SL 1170–1172; Shashemane market: SL 1295–1296.
Sidamo	Awasa market: SL 1336, SL 1338–1339; Kebre Mengist market: SL 1343; Neghele market: SL 1388, SL 1390; field 12 km SE of Sodo: WP 2954.
Tigre	Axum market: SL 942, SL 957.
Welega	Bekejama market: SL 1568–1570; Defno market: SL 1553; Dembidolo market: SL 1537.
Welo	Bati market: SL 1051; Dessie market: SL 1087–1088; Haik market: SL 1118–1121; Kembolcha market: SL 964, Sl 983–985; Robit market: SL 36.
Grown at Wageningen	SL 1599, SL 1614–1615, SL 1648–1663, SL 1668–1671, SL 1675–1689, SL 1712–1715, SL 1772–1773, SL 1776–1795, SL 1806–1807, SL 1809, SL 1818–1831, SL 1838–1839, SL 1841, SL 1853, SL 1855, SL 1859, SL 1876–1894, SL 1904–1905, SL 1923–1927, SL 1934–1936, SL 1938–1939, SL 2011–2034, SL 3309–3396, SL 3411–3416, SL 3481–3484, SL 3492–3494, SL 3504–3507, SL 3513–3515, SL 3522–3525, SL 3534–3537, SL 3546–3564, SL 3574–3597, SL 3638–3639, SL 3647–3669, SL 3706, SL 3715–3753, SL 3771–3784, SL 3801–3805, SL 3810–3828, SL 3830–3872, SL 3876.

Ecology

1. Temperature

In tropical regions, rape is mostly cultivated at altitudes of 1500 to 2500 m with average daily temperatures of 15 to 20°C (Ferwerda, 1974) and like most *Brassica* species, *Brassica carinata* needs a cool climate. It does not thrive with high temperatures (Baldrati, 1950).

In a phytotron at Wageningen, *Br. carinata* seemed to need a minimum temperature of at least 2°C for undisturbed growth (Scheltens, 1976).

Plotting the average yields of the Rapeseed National Variety Trial 1974 (Chevreau, 1976) to altitude of the stations, suggests that yield increases from 1600 to 2400 m in Ethiopia, but decreases thereafter. The data are too few, though, to be conclusive.

2. *Water*

The minimum requirements for water supply of rapeseed species are generally 200–500 mm (Ferwerda, 1974). Precipitation is not very critical for *Brassica carinata*. The plant does, however, demand some humidity of the air. In Ethiopia, it is sown from the onset of the rains until these are maximum (Baldrati, 1949; 1950).

In pure plantings, waterlogging may make resowing necessary in some areas in some years (Holovlaský, 1972). Apparently later sowing should be tried in such areas and is often practical.

3. *Soil*

Brassicaceae are generally rather indifferent to the soil (Schulz, 1919). Also *Br. carinata* has no special requirements for terrain. It grows well on almost any agricultural field. Medium-loose soils with good fertility are to be preferred, though. Good permeability suits gommenzer particularly well; this can be secured by careful soil treatment (Baldrati, 1950).

Most *Brassica* oilseed crops prefer moderately heavy, well-drained soils with pH 6.5–7.6. They are not or moderately resistant to salinity (Ferwerda, 1974). *Brassica carinata* showed moderate resistance to salinity in a comparative field trial in the Soviet Union (Sinelkova & Boos, 1978).

In an exploratory pot trial in a greenhouse at Wageningen, germination was little influenced by salt concentrations up to 1 S/m (salt: $NaCl + MgCl_2 . 6 H_20$ in weight ratios 1:1.74). In the harvest, there were, however, clear differences between accessions. Of the four accessions tested, two had little tolerance, one moderate tolerance and one complete tolerance. The latter, from Axum, still produced 300–400 kg of seed per hectare with irrigation water with electrical conductivity values of 0,9–1 S/m. The results also suggested that the earlier the cultivar, the more salt-tolerant it was. During flowering the effect of salinity was much stronger than before. Irrigating after the onset of flowering with water with an electrical conductivity of 0.5 S/m halved the average seed yield as compared to control (den Oever, 1977).

4. *Light*

Brassicas like sunny open habitats (Schulz, 1919). When intercropped in small cereal grains, this requirement will be met but, when grown within sorghum or maize, light might be lacking. I had the impression that in such fields in Harergie, the rape plants only started developing well when the rains had stopped and the cereal started ripening. At that stage, the leaves of the cereal are harvested successively, allowing the rays of the sun to penetrate. I often saw the plants (*Br. carinata* and *Br. nigra*) in flower and young fruiting stage after the cereal had been harvested.

The results of a greenhouse trial at Wageningen suggested that *Br. carinata* is day-length-sensitive. Unfortunately no further conclusions could be drawn because the plants developed abnormally because of day temperatures over 32 °C during more than half the duration of the experiment (van Klinken, 1976).

Development of the plant

According to Tsunoda et al. (1980), *Br. carinata* shows a slow steady growth like *Br. oleracea.*

Emergence of *Br. carinata* starts about 3 days after sowing and is completed 4–5 days later (Holovlaský, 1972; my observ. at Wageningen).

At Wageningen, the plants formed 5–6 leaves of increasing size, but without a rosette-like appearance, before the stem started to elongate. In my outdoors observation plot at Wageningen, this stage was reached 17–20 days after sowing (20 May).

The stem then elongated very quickly. At the same time, the leaves enlarged considerably and in some populations the first lateral branches started developing when the plants were c. 30 cm tall. Both in Ethiopia (Holovlaský, 1972) and at Wageningen, this height was reached in about 3 weeks. About a week to ten days later, the first flower buds became visible at Wageningen.

Just over a month after sowing (26 June) the very first flowers were observed at Wageningen. There was a considerable difference between populations in the time needed to reach full bloom (all 10 plants of a population in flower). In some populations this stage was reached on 11 July but other populations were generally up to about 3 weeks later. My stage 'full bloom' is comparable to the 'beginning of flowering' stage of Holovlaský's (1972). The time to reach the stage was similar in Ethiopia and Wageningen.

Both in Ethiopia (Holovlaský, 1972) and at Wageningen, plants with little anthocyanin or none within a population developed more rapidly to this stage than plants rich in anthocyanin. But on average, 'purple' reached a greated final height than 'green' ones, although the differences were small (Holovlaský, 1972; my observ.).

One population, grown from seeds from Jemero (Kefa) did not form flowers before November at Wageningen. As the plants of this population had very large leaves, it was perhaps a type of *Br. carinata* used as a vegetable rather than for seed.

According to Vasak et al. (1978), germination percentage, vigour, 1000-seed wt and seed contents of oil and nitrogen, and fraction of oleic acid in oil were highest in seed from the main stem. Yield potential, measured by number of fruits per branch and weight of seeds per branch, however, was highest in the middle branches. Similar observations were reported by Rahman & Bechyne (1972).

Lower density increases plant height, plant weight, stem diameter, number of branches, fruits and seeds per plant. At equal densities seed yield, seed oil content and 1000-seed wt are not affected by spacing between rows but they are by spacing in the row. Higher sowing rate results in higher seed yields, lower 1000-seed wt and in an unaffected seed oil content. The proportion of oleic acid in the oils was increased by higher sowing rate but was not affected by row spacing (Bechyne et al., 1976).

There is a clear difference in the attention given in Ethiopian traditional agriculture to *Brassica* grown as a green vegetable and for seed. *Brassica* as a vegetable is usually carefully tended on small specialized plots, often near houses and sometimes with irrigation (Baldrati, 1950; Selinus et al., 1971b; my observ.). The Konso cultivate it on well prepared and well kept terraces where the fields are fertilized both with dung and human excreta (Nowack, 1954).

In Eritrea (Baldrati, 1950) and in the rest of the country (my observ.), the young plants or shoots are harvested and the culture is seasonal. In the south of the country, perennial forms are cultivated, usually with a cycle of 4 years (Selinus et al., 1971b). They easily attain a height of 2 m or more (Cufodontis, 1957).

The seed-bearing brassica is mostly found in mixed stands, particularly with cereals. According to Baldrati (1950), it is especially found in tef fields, less frequently in barley. This may be true for Eritrea, but in the Chercher mountains, Kefa and Welega, I seldom saw it in tef fields, but often in sorghum and maize fields. The plants found in cereal fields are often unsown (p. 50). Kupzow (1932a) even described *Br. carinata* as a weed. Under such conditions, the plants receive the same treatment as the main crop.

In India, *Br. juncea*, a species similar to *Br. carinata* is sometimes cultivated in combination with peas. The peas find support in the brassica plants. This combination seems beneficial to both crops (Baldrati, 1950). I suggest that intercropping *Br. carinata* with peas is worth trying in Ethiopia.

Where grown in pure stands in Arussi, the seed-bed is prepared by ploughing once or twice, sometimes applying fertilizer. Sowing is by broadcasting and then ploughing the seed under (Rydén, 1972).

In experimental sowings on a farm in Chaffa, seed rates of 8–10 kg/ha were used in broadcast fields, and 12 kg/ha in row-drilled fields. Row-drilling was at a row distance of 45 cm and a plant distance of c. 4 cm resulting in c. 500000 plants per hectare (Holovlaský, 1972). The normal ranges for most rapeseed species are 200000–500000 plants per hectare and row distances of 20 to 45 cm (Ferwerda, 1974). The sowing rate at Chaffa was thus comparable to densities used in other parts of the world.

The best time for sowing is when the rains are well started until they have reached their highest intensity (Baldrati, 1949; 1950). This is somewhere between March and June for most of Ethiopia.

During the growing season, the gommenzer fields of Arussi are mostly hand-weeded twice and no other care is given to the crop (Rydén, 1972). Also at Chaffa, it was necessary to weed twice: about 3 weeks and 6–7 weeks after sowing (Holovlaský, 1972).

Brassica is sensitive to noxious insects such as aphids, particularly at young stages. Insects are a major factor causing the seed yields to vary considerably from year to year (Baldrati, 1950). As the only oilseed *Brassica* of which Schmutterer (1971) investigated the pests, he mentioned *Brassica napus*. The following are species he mentioned as harmful to *Br. napus*, oil radish, and leafy cabbages. One would expect that those species would, at least occasionally, also attack *Br. carinata*. The species are: *Brevicorne brassicae* L. (cabbage aphid, *Homoptera*), *Lipaphis erysini* Kalt. (false cabbage aphid, *Homoptera*), *Myzus persicae* Sulz. (green peach aphid, *Homoptera*), *Liscus latro* Mshl. (*Coleoptera*), *Phyllotreta mashonana* Jac. and *P. weisei* Jac. (*Coleoptera*).

Geleta (1972) investigated the effect of malathion and diazinon sprays to control 'flea beetles' and 'Bagrada bugs' on *Br. oleracea* (head cabbage and cauliflower) and on *Br. carinata*. The effects were opposite: both chemicals gave a good control of flea beetles in *Br. oleracea* but no control in *Br. carinata*, whereas Bagrada bugs were controlled in *Br. carinata* but not in *Br. oleracea*.

On average, the occurrence of diseases and pests was negligible at Chaffa, but it was necessary to spray against anther mould (*Botrytis anthophila* Bond.) to achieve acceptable yields (Holovlaský, 1972).

Harvesting is done just before the majority of the fruits start to dry because of the danger of shattering. The whole plants or branches are cut off and carried to the threshing-floor. As the length of the growing season is dependent on both genetical background (Linder, 1976: different origins 144–189 days at Kulumsa) and altitude (Huffnagel, 1961: below 2500 m 6–7 months, above 2500 m up to 11 months), the time of harvesting may be from November to March.

After a few days drying, the whole plants are threshed with a stick. The liberated seed is sieved and winnowed to achieve a greater purity.

Yields vary greatly from area to area and from field to field. The informations Rydén (1972) received from farmers in Arussi indicated a range from 150 to 4500 kg/ha, but Rydén believed that the latter figure is too high to be realistic. His opinion is confirmed by data from the National Variety Trial which were reported by Chevreau (1976).

Low yields are particularly reported from areas below 1800 m. At Melka Werer (c. 1100 m), the top yield of an irrigated rape crop was only 300 kg /ha (Melka Werer Res. Stn Progr. Rep., 1971) and at Bako (1650 m) the yields were only 21–112 kg/ha in 1969 (Bako Res. Stn Progr. Rep., 1970). Apparently the choice of the sowing material, the cultural practices and variations in climate have much influence. In 1974, for instance, the average yield at Bako was more than 1000 kg/ha and the best yielder produced 1233 kg/ha. But these yields at Bako, the lowest of all stations reported, were still least. The highest average yields were over 2700 kg/ha at Holetta (2380 m), and yields close to 2550 kg/ha were achieved at Bekoji (2750 m) and Kulumsa (2130 m). At the last station, one accession, a selection from Awasa, even yielded 3410 kg/ha (Chevreau, 1976).

The yield of brassica interplanted with other crops is impossible to estimate because of low and varying plant populations (Wolde Mariam et al., 1971).

The seed is stored in bags, pots or cans inside the house. If stored dry, brassica seeds retain their viability for 15 years (Tsunoda et al., 1980).

Brassica is certainly one of the most important vegetables in Ethiopian traditional cooking. As far as I could see, the most important vegetable in Ethiopia by far is shallots, followed by brassica and green Capsicum peppers (karia). The leaves of brassica may be cooked with meat in the wot (stew) (Kostlan, 1913), but may also be mixed with the peeled petioles and cooked in a covered pot for about 30 minutes. This is done in Sidamo Province (Selinus et al., 1971b). In Alemaya restaurants, it was mostly offered cold in an acid preparation combined with wots (hot stew), a kind of cottage cheese and karia on the teff injera (unleavened bread).

In Sidamo, the cooked leaves are usually served with enset (*Ensete ventricosum*), but also with maize bread or edible tubers. Because the brassica contains about four times as much protein as enset and because the biological value of the brassica protein is higher than that of enset protein, it is an important protein source in this region (Selinus et al., 1971b).

According to Messing (1962), brassica is considered an emergency food or poor man's food. This may be true for the 'happy (?) few', who have escaped traditional Ethiopian living, but in traditional cooking, 'gommen' is highly appreciated.

The leaves are slightly bitter, to a pleasant extent. According to an Italian at the beginning of this century, 'gommen' also suits European dishes well. It can be cooked, fried with garlic in oil to make a sauce, or combined with butter, cheese and Bechamel sauce in the oven. It is also possible to prepare a tasty salad of it. For these purposes, the flower buds were the most delicious parts, but also young plantlets and young shoots gave highly satisfying results (Bolletino, 1905).

According to Likums (1976), young greens make an excellent vegetable, which can be harvested mechanically and be processed by canning or freezing. With the recent launching of the commercial cultivar Karate on the British market, the pleasant tender taste of Ethiopian kale has become available to the European gardener. This cultivar was derived from oilseed *Brassica carinata* (Larkom, 1980).

I do not know of any specific use for the seed or its oil in Ethiopia. It is used, like most oilseeds in Ethiopia, in the wot. Crushed seeds, mostly combined with seeds of *Brassica nigra*, are served as a condiment.

Brassica seed is used to give the finishing touch to the new mitad (earthenware pan to bake the injera). If a new mitad has been baked, the upper surface should be prepared to make it usable for bread-baking.

Siegenthaler (1963) gave the following account of preparation of the mitad in SW Ethiopia. The mitad is placed over a fire and the surface is covered with a mixture of coarsely ground cotton and *Maesa* fruits. The cotton is lit. After the fire has burnt out, the charny remainders are removed, and the surface is rubbed clean. Then the mitad is covered with finely ground oilseed which remains there until dark brown. They are removed, and this treatment is repeated once or twice. The surface should be glossy black then. Crushed brassica seeds are rubbed then until the surface seems oily.

Rapeseed is also used as a detergent in Arussi (Rydén, 1972).

According to Griaule (1930), the oil is used in birth control.

Because the oil is similar to that of other oilseed brassicas, the international use is similar to those as well. The oils are excellent for lighting and for soap manufacturing; they are also used for tanning leather and for varnishes. After refining to remove the strong-tasting mustard oil, the oil has good cooking qualities (Baldrati, 1950).

Chemical and physical properties

According to Rahman & Bechyne (1971), the 1000-seed wt of *Brassica carinata* is c. 4–6 g, but Linder (1976) reported 1.5–3.0 g. These data do not necessarilly conflict. An Ethiopian farmer told me that seed size was influenced considerably by the light available to the plant during growth: small seeds were produced by plants growing in the shade, large ones by plants from sunny places. There is also an influence of branching and of plant density (p. 67).

The mass density of the seed is c. 1250 kg/m³; the seed-coat supplies c. 18.5–22.0 % of the seed weight. The latter percentage is so large that variations in the thickness of the seed-coat influence the oil contents of the whole seed, if expressed as percentage of seed weight. There is a negative correlation between the seed weight and the oil contents (Rahman & Bechyne, 1971). The bulk weight is c. 660–700 kg/m³ (Holovlaský, 1972; Linder, 1976).

Darker seed was found to have thicker testa and lower oil content than lighter-coloured seed; it had oil with lower erucic acid but higher oleic acid proportion (Bechyne et al., 1979). In my own measurements, I could not establish this relation, nor do Rydén's data (1972) give any indication of such a relation. In view of the large influence of environment, this relation is possibly only present if cultivars of different seed colours are grown simultaneously on the same field.

As there is a rather strict relation between oil contents and relative weight of plumule and cotyledons, it is possible to estimate the total oil contents of the kernel from that of one cotyledon (Rahman & Bechyne, 1971).

According to Rahman & Bechyne (1971), the oil contents range from 230 to 380 g oil per kilogram of seed. Other authors indicated values within this range (e.g. Kupzow, 1932a; Frandsen cited by Holovlaský, 1972; Tsunoda et al., 1980). In 47 samples of my collection, the oil contents varied from c. 340 to c. 475 g of oil per kilogram of seed (oven-dry basis). Even if we take into account that the other values may not have been based on an oven-dry basis and correct them accordingly, the values I found are generally higher than what is found in the literature. Also Rydén (1972) reported a sample with an oil content of 471 g/kg, well above the maximum indicated by Rahman & Bechyne.

Comparing the oil contents of the original Ethiopian seed with that of seeds grown from them in Sweden, Rydén concluded that the variation in oil contents in *Br. carinata* is highly dependent on environmental conditions during growth and less dependent on genetic differences. The data he supplied in his Appendix 5 suggest a positive rela-

Table 17. Fatty acids in oil of *Brassica carinata* as substance fraction (%). Sources: F, Frandsen, cited by Holovlaský 1972; R, Rydén 1972; SL, values found in 47 samples of my Ethiopian collection; A, Appelqvist 1970.

Acid	F	A	R	SL
14:0	2			
16:0	4	(3.0)4.0(5.1)	3.2–4.2	(2.2)3.8(5.2)
16:0	5			
18:0	2	(0.9)1.0(1.1)	0.9–1.8	(0.9)1.1(1.7)
18:1	10	(6.3)7.8(11.8)	12.3–13.3	(8.8)10.4(13.6)
18:2	21	(11.3)16.4(19.0)	15.9–18.9	(14.3)16.9(21.1)
18.3	13	(7.3)13.2(16.7)	20.6–24.4	(12.3)15.0(20.7)[1]
20:0	1	c. 0.8		(0.2)0.4(0.9)
20:1	7	(6.6)7.2(8.5)		(6.0)8.5(9.8)
20:2	1	c. 1.1		(0.7)1.0(1.4)
22:1	1	(36.0)42.0(53.2)	36.8–45.3	(32.4)41.0(44.9)
22:1	37			
22:2	8	c. 1.6		(0.5)1.5(5.2)
24:1	2	(1.8)3.0(4.3)		

1. Observed on 11 samples only.

tion between oil content and altitude (average below 2000 m 364 g/kg, above 2000 m 429 g/kg).

Frandsen (cited by Holovlaský, 1972) found the oil to have an iodine number of 118 and a saponification value of 179. Some data on the fatty acids of *Brassica carinata* oil are presented in Table 17.

A comparison of my data on oil contents and fatty acids in the oil with the average values for all samples suggested the following tendencies:
– samples with high oil contents have often a larger fraction of oleic acid (18:1) and smaller fractions of linoleic (18:2) and linolenic (18:3)
– oils comparatively high in palmitic (16:0) tend to be relatively high in stearic (18:0), oleic and linoleic, possibly also in linolenic, while their erucic (22:1) is relatively low
– correlations between stearic and other fatty acids are unclear; possibly there is a positive correlation between stearic and linolenic, eicosanoic (20:0), and eicosadienoic (20:2)
– oils rich in oleic were usually also rich in linoleic and eicosenoic (20:1), but poor in erucic
– samples high in linoleic were usually also above average in linolenic and eicosadienoic, but low in erucic
– samples above average in linolenic and eicosenoic were usually below average in erucic
– samples with relatively high contents of eicosadienoic were generally also above average in 'rest' fatty acids (22:2 + 24:1) and low in erucic.
It thus seems that an increase in the relative fraction of whatever of the other fatty

Table 18. Composition of the seed and leaves of Ethiopian *Brassica* sp. Expressed per kilogram of edible portion. Source: Ågren & Gibson, 1968.

	Seed	Leaves
Number of samples	1	10–19
Crude energy (kJ)	20209	(1088)1548(2008)
Moisture (g)	61	(840)876(912)
Nitrogen (g)	39	(4)7(12)
Crude protein (g)	244 (N × 6.25)	(16)28(48) (N × 4.04)
Fat (g)	350	(4)8(16)
Carbohydrate total (including fibre) (g)	261	(43)65(91)
Fibre (g)	78	(11)15(21)
Ash (g)	83	(11)19(28)
Calcium (mg)	3680	(1340)2600(5650)
Phosphorus (mg)	5940	(370)640(1230)
Iron (mg)	3920	(17)41(103)
β-carotene equivalent (μg)	6500	(trace)2330(5100)
Thiamin (mg)	5.4	(0.3)1.2(2.1)
Riboflavin (mg)	3.2	(0.4)2.3(4.5)
Niacin (mg)	70	(6)12(20)
Tryptophan (mg)		(1620)1650(1680)
Ascorbic acid (mg)	0	(10)200(570)

acids is particularly compensated by a decrease of the erucic fraction.

Some data on the composition of seed (gommenzer) and leaves (yebesha gommen) of Ethiopia, as found by Ågren & Gibson (1968), are shown in Table 18.

A kilogram of seed normally contains about 3 g of glucosinolates, which give unrefined oil a pungent taste (Baldrati, 1950).

After oil extraction, one kilogram of rapeseed meal contains c. 400 g of protein (in dry matter) with a well balanced amino-acid composition. It is, however, less suitable for animal feed because of the presence of the glucosinolates which yield toxic and goitrogenic cleavage products and which give the meal an unpleasant taste and

Table 19. Major glucosinolates in defatted seed meal of some *Brassica* species (mmol/kg; gas-liquid chromatography of trimethylsilyl derivatives). Source: Tsunoda et al., 1980. Abbreviations: S, sinigrin; G, gluconapin; B, glucobrassicanapin; P, progoitrin; N, napoliferin.

	S	G	B	P	N	Sum
Br. campestris	0.1	20.3	21.1	18.0	4.0	63.5
Br. carinata from Ethiopia	52.3	5.6	15.5	0.1	1.3	74.8
from Egypt	120.4	12.0	2.2	6.2	0.1	140.9
Br. nigra cv. Europe	8.2 to 150.3	0.1	0.1	0.1	0.1	82.5 to 150.7

Table 20. Nitrogen (g/kg) and amino acids (g per 16 g N) in the seedmeal of *Brassica carinata*. (Source: Harvey, 1970).

Nitrogen	74.2	Lysine	4.7
Alanine	3.6	Methionine	1.5
Arginine	7.0	Phenylalanine	3.4
Aspartic acid	6.5	Proline	5.6
Cystine	2.2	Serine	3.6
Glutamic acid	17.1	Threonine	3.6
Glycine	4.1	Tyrosine	2.4
Histidine	2.4	Valine	4.3
Leucine	5.9		
Isoleucine	3.4		

a low palatability. As yet, it is not yet practical to remove these components from the meal, and emphasis is on creating new varieties low in or free from them (Tsunoda et al., 1980).

The glucosinolate content and components of some *Brassica* spp. grown in Ethiopia for oilseed is presented in Table 19. From this table, it is clear that there may be considerable differences in contents of each component glucosinolate and as a whole in *Br. carinata* and even within one cultivar (*Br. nigra*).

The component amino acids in the protein of *Br. carinata* seed meal are given in Table 20.

The leaf is a good source of xanthophyll, carotene, lysine and other essential amino acids (Likums, 1976). Protein forms 27% by weight of the dry matter of *Br. carinata* leaf juice (Brown & Saldana, 1976). The protein is similar to that of lucerne and soya bean. In the United States, *Br. carinata* leaves yielded about 110 kg of protein per hectare. The protein production of the leaves and seed combined was 450–550 kg/ha (Likums, 1976).

2.3.1.3 Brassica nigra (L.) Koch var. abyssinica A. Br. (2*n* = 16)

'nigra': black
'abyssinica': Abyssinian: from Ethiopia

Koch in Röhling's Deutschl. Fl. ed. 3, V. 4: p. 713 (1933).
Basionym: *Sinapis nigra* L., Sp. Pl. ed. 1, V. 2: p. 668 (1753).
Type: ? (to be decided by monographer).
var. abyssinica A. Braun in Flora 24: p. 266 (1841).
Type: ? (to be decided by monographer).

Synonyms

Br. nigra 'Auct. Fl. Aethiopicae' (Fide Cufodontis, 1974): e.g. *Br. nigra* Boiss., Baldrati (1950): p. 381; possibly a misquotation of *Br. lanceolata* Schweinf. in Bull. Herb. Boiss. App. 2: p. 183 (1896), see Note 4.

Vernacular names: senafich, senafich ketel (Amarinya); sanavi, senaficciá (Gallinya); adri, amli adri, amli senafich, grumba, amli grumba (Tigrinya); kafo-dreganta (Welaminya).
Trade names: black mustard (English); moutarde noire (French).

Geographic distribution

Brassica nigra occurs wild in the Mediterranean region (Vavilov, 1951; Baccarini, 1909). In Ethiopia, it is wide-spread. Cufodontis (1974) indicated that it was not found in Gojam, Beghemder and the Ogaden. But I found it at least in Beghemder (e.g. SL 57, SL 826) and believe that its distribution in the Ethiopian highlands is similar to that of *Br. carinata.*

Description

Erect annual herb, up to 90(155) cm tall, usually with the stem loosely branched in the upper half, and a thin white taproot.

Stem up to $\frac{3}{4}$ cm diam., subcylindric, usually glabrous, seldom sparsely stiff hairy, more densely so at base, medium green, somewhat purple at base or at nodes, (slightly) waxy.

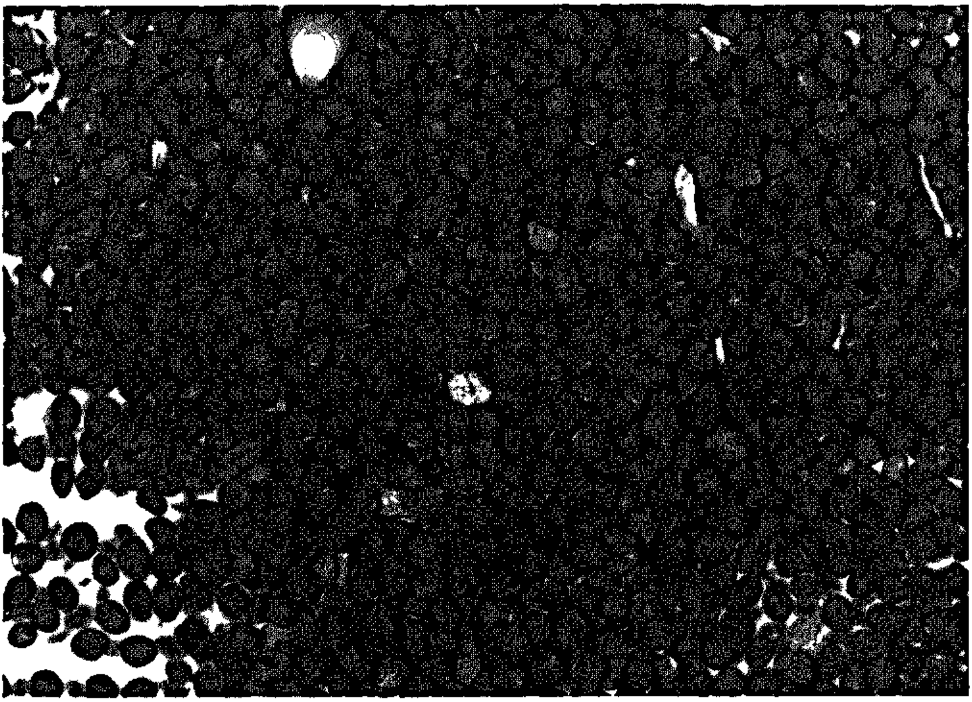
Branches thin, widely and ascendingly spreading, with many side-branches, medium green, sometimes purple at their base, slightly waxy, seldom sparsely with stiff hairs.

Leaves alternate, petiolate, membranaceous; petiole up to (10)15 cm long, semiterete, slightly flattened at base, glabrous or sometimes with few stiff hairs, green with some anthocyanin above or waxy greyish-green, with (0)2(4), $\pm$ oblong to triangular lateral foliar segments with acute top and serrate margin; blades of largest leaves up to 19 cm $\times$ 10 cm, glabrous, seldom with few stiff hairs on veins beneath, medium to dark (greyish-)green, paler beneath, with lighter midrib, ovate, lyrate to pinnatifid (seldom pinnatisect basally) with 3–9 rounded (seldom acute) lobes; lobes at base of blade deep, often oblique, sometimes $\pm$ hastate, lateral lobes usually smaller and less deep, terminal lobe largest, ovate, with obtuse (seldom acute) top and irregularly dentate margin with slightly callous teeth; higher on the plant, the leaves are smaller, less lobed and narrower; they have shorter stalks with less foliar segments, acute tops and serrate margin; the uppermost leaves are narrowly oblong and basally attenuate but with very short stalk, they are sometimes reflexed; venation apparent, pinnate, main veins prominent beneath, lateral veins rather heavily branched.

Inflorescences apically on stem and branches, with ebracteate flowers, each ramification corymbiform at onset of flowering, but with flowers not exceeding the buds, later a (strongly) elongated raceme.

Pedicel usually glabrous, in flower seldom (e.g. SL 1616) with one hair, up to $\frac{3}{4}$ mm long, in the lower half or at base (sometimes reduced to an emergence), cylindrical to filiform, c. 2–5 mm long and spreading at an angle of c. 80° during anthesis, in fruit erect, $\pm$ appressed to rhachis, growing little longer but notably thicker.

Flower 10–15 mm diam., c. 5 mm long.



Photograph 10. Seed of *Brassica nigra* (SL 1024; × 5).

Sepals 4, greenish yellow, glabrous, erectly spreading to spreading at an angle of 90°, narrowly elliptic, ± parallel-veined with 3 veins, midrib distinct, laterals anastomose, slightly concave, apically obtuse, the outer ones c. 4–5 mm × $1\frac{1}{2}$–$1\frac{3}{4}$ mm, the inner ones less concave and slightly narrower.

Petals 4, thin, alternating with sepals, yellow, glabrous, broadly ovate, c. $7\frac{1}{2}$ mm × 10 mm, truncate to obtuse and shallowly undulate at top, narrowed at base to a rather flat claw a little shorter than the limb; claw slightly widened in lowest $1\frac{1}{2}$ mm; venation pinnate in limb only, with c. 5 laterals each side.

Stamens distinct, 6, outer row 2, inner row 4, with glabrous yellow filaments and introrse yellow anthers opening with 2 slits lengthwise; the outer ones spreading, c. 6 mm long with subcylindric flattened filaments c. 4 mm long; anthers oblong, apically obtuse, basally cordate, c. 2 mm long, basifixed, thecae progressing for c. $\frac{1}{5}$ of their length along filaments, usually papillose at connective, inner stamens as outer ones but erect, apically slightly spreading, and c. 1 mm longer.

Nectaries 4, 2 opposite the outer stamens, 2 alternating with them between 2 inner stamens; the outer two erectly spreading, transversely rectangular, c. $\frac{1}{4}$ mm × $\frac{1}{2}$ mm; the inner two spreading, rounded, 3-sidedly pyramidal, apically obtuse, c. $\frac{1}{3}$ mm high.

Ovary sessile, glabrous, very light green, narrowly oblong to narrowly rectangular, rhombic in transverse section, c. 4 mm × $\frac{3}{4}$ mm, bilocular with false septum; placentae

Photograph 11. *Brassica nigra* in a field of chickpeas near Feddis.

2, parietal; ovules up to 12(14), anatropous, pendulous with dorsal raphe, c. $\frac{3}{4}$ mm diam., with a filiform funicle; style slightly thinner than ovary, cylindrical, c. 2 mm long; stigma capitate, shallowly 2-lobed, c. $\frac{1}{2}$ mm × $\frac{3}{4}$ mm, densely papillate.

Fruit a glabrous torulose straight silique, erect, almost accumbent to rhachis, seldom spreading on part of infructescence, c. 12–15(20) mm long (excluding beak), apically abruptly narrowed to the thin seedless beak of length up to 4 mm; valves strongly carinate, with prominent midrib, basally and apically obtuse, opening from base, green or green with purple or brown when immature, straw-coloured when ripe; rhachis and pedicels in fruit sometimes purple-tinged.

Seed globose, c. $\frac{1}{2}$ mm diam., usually dark rusty brown to brownish orange, very finely pitted.

Seedling epigeal with a thin main root and fibrous laterals. Hypocotyl c. 1–2 cm long, cylindrical, glabrous, pinkish to dark purple. Cotyledons with thin semiterete petioles, above shallowly grooved, c. $\frac{1}{2}$–1 cm long purplish; and flat, widely obcordate or widely obovate, emarginate, basally truncato-attenuate, green, glabrous blades up to 15 mm × 10 mm. Epicotyl and first nodes very short. First leaves petiolate, gradually increasing in size; petioles purplish tinged, scabrid, often with small triangular foliar segments; blades (dark) green with purplish veins, oblong to obovate, pinnately lobed, usually with 2–3 deep yokes basally, scabrid, more strongly so beneath.

Notes

(1) In fruit, *Br. nigra* can be distinguished easily from *Br. carinata*. *Br. nigra* has its fruits on very short pedicels normally appressed to the rhachis; *Br. carinata* usually has larger fruits on spreading obviously longer pedicels. The differences in size and colour of the flower and seed are clear too.

(2) Braun (1841) distinguished his variety *abyssinica* from the European *Br. nigra* by a laxer inflorescence and smaller leaf with only 2 foliar segments at the petiole of the largest leaves. Schulz (1919) distinguished var. *abyssinica* Braun by the same number of foliar segments of the petiole and by the longer beak terminating the fruit.

Although the presence of only two foliar segments on the petiole is most common in my material, petioles with more segments are too frequent to be ignored.

The lax raceme, as mentioned by Braun, is however present in my Ethiopian *Br. nigra*, just as the long beaks on the fruit mentioned by Schulz.

I could not make a thorough investigation of the chromosome number of my material, but think that a study of chromosome number in Ethiopian material would be worthwhile, because differences between 2*n* and 4*n* forms of *Br. nigra* from Europe as given by Frandsen (1945) lead to the following remarks.

Frandsen (1945) found artificial 4*n* material to differ from 2*n* material by a laxer inflorescence; his picture of 4*n* *Br. nigra* was much more like the plants grown from Ethiopian seeds than his picture of 2*n* plants.

If *Br. nigra* from Ethiopia were 4*n*, this fact would support the view that *Br. carinata* originated in Ethiopia.

(3) According to Schulz (1919), *Br. nigra* var. *bracteolata* (Fisch. & Mey.) Coss. was included in *Br. juncea* by some authors, the same species in which *Br. carinata* was sometimes included (*Br. carinata*, Note 1).

(4) According to Baldrati (1950), the scientific name of Ethiopian 'senafich' was *Br. nigra* Boissier. I could not trace any publication in which Boissier published '*Brassica nigra*' and think Baldrati's quotation is a mistake.

(5) Differences within *Br. nigra* leading to the distinction of botanical varieties based on macromorphological characters coincide with differences found in seed characters (Berggren, 1962).

(6) Even more than in *Br. carinata* (Note 4, and description of this species), the mode of spreading of the sepals seems to be an invalid distinction between *Brassica* and *Sinapis*.

(7) All market seed-samples were mixtures of lighter and darker seeds varying between orange, light-brown and dark reddish-brown. With differences in amounts of seeds of different colours, the total impression of the colour of the sample varied. In some samples, the presence of seeds of other colours influenced the colour of the sample in general into another tone. Other colours found were: black, grey, greyish-brown, and khaki-green. In some samples, some seeds looked grey because they had dry (dried?) slime on their testa.

The seeds often had white excrescences on their hila. I did not find black hila as described by Schulz (1919).

Black seeds were only found in samples from 'north' (see *Br. carinata* Note 7): SL 1024 (Adishow), SL 1122 (Haik). Khaki was only found from 'east': SL 1122 (Haik), SL 1253 (Goro). Numbers are too small however to be conclusive.

A relation between seed characters and general appearance could not be established, but the number of samples at my disposal was too small to arrive at any conclusion.

(8) Description was based on the following specimens.

Arussi	Swedish Mission near Asella, rape field, 2400 m: WP 3107; 4 km from Dera on road to Sire, 1680 m: WP 1544; Seed Improvement Experimental Farm at Kulumsa, 8 km N of Asella, 2200 m: WP 3117.
Bale	Goba market: SL 1215; Goro market: SL 1253.
Beghemder	Gonder market: SL 57, SL 855, SL 922, SL 929; Infranz market: SL 826.
Eritrea	Adi Caieh market: SL 886.
Harergie	Grown at Alemaya College: PJ 1595, PJ 1712, PJ 1914, PJ 2040, PJ 2778, PJ 3434, WP 240, WP 276, WP 343, WP 714, WP 759, WP 785, WP 1792, WP 1827; near Alemaya in sorghum field, c. 2000 m: PJ 7221; Asbe Teferi market: SL 9; garden near Bati, c. 2000 m: WP 384; Bedeno market: SL 323; Ghelemso market: SL 632; Langhe market: SL 286; Mulu market: SL 451.
Illubabor	Metu market: SL 1490.
Kefa	Bonga market: SL 1412; Jemero market: SL 1437.
Shewa	32 km from Addis Abeba on road to Debre Zeit, in barley field, 2080 m: WP 1957; Debre Zeit market: WP 2981; Shashemane market: SL 1288.
Sidamo	Awasa market: SL 1335; Kebre Mengist market: SL 1345; Neghele market: SL 1390.
Tigre	Adishow market: SL 1024.
Welega	Bekejama market: SL 1571.
Welo	Dessie market: SL 1091; Haik market: SL 1122; Kembolcha market: SL 986.
Grown at Wageningen	F. van Gogh 21; SL 1596–1599, SL 1613–1614; SL 1616–1621, SL 1664–1667, SL 1673–1674, SL 1690–1693, SL 1768–1775, SL 1788, SL 1796–1805, SL 1808, SL 1833–1835, SL 1840, SL 1850–1852, SL 1854, SL 1856–1858, SL 1860, SL 1895–1903, SL 1937, SL 1940, SL 3397–3409, SL 3470–3479, SL.3481, SL 3623–3625, SL 3631–3634, SL 3636, SL 3640–3643, SL 3652, SL 3762–3765.

Ecology

The conditions in which *Br. nigra* is grown are similar to those of *Br. carinata.* I had some impression that *Br. nigra* is not grown at such high altitudes as *Br. carinata.*

Br. nigra stands large amounts of N as urea much better than other *Brassica* spp., producing up to 350 kg protein per hectare (which is less than *Br. carinata,* p. 74) (Matai et al., 1972).

Husbandry

In Ethiopia, black and Ethiopian mustard are grown in the same way, and often mixed. Because the shoots and leaves of black mustard too are eaten in some regions, this species is sometimes grown on special plots (Baldrati, 1950; Cufodontis, 1957).

The seed yields of the two species are similar (Baldrati, 1950; Mulugeta, 1972; Asthana et al., 1973).

Uses

'Senafich' is used as a condiment, medicinally and as a vegetable. Which of these uses is most important depends on the region.

The use of *Br. nigra* as an oil plant is practically unknown in Ethiopia, possibly because of the pungent taste of the oil. The seeds are, however, used as a means to improve the extraction of oil from Niger seed, as are the seeds of *Br. carinata*. A small amount mixed with Niger seed makes the oil of the latter easier to extract (Baldrati, 1950).

The seed is in daily use as a condiment in most of Ethiopia, but is relatively scarce on the markets: most people grow sufficient for their own needs. It is usually mixed with seeds of *Br. carinata* and the product offered on the markets is commonly mixed. It may also be mixed with ground fresh red peppers (awaze) or with acid liquids to obtain a semi-liquid condiment. This is served with the meal, particularly with raw meat.

Crushed seed is used in preparing 'silyo', a substance particularly prepared during the fasting season of Coptic Christians. For this purpose, it is combined with water, horse-bean flour, safflower and rue. It is also used in flavouring some indigenous alco-

Table 21. Substance fractions (%) of fatty acids in the oil of *Brassica nigra*. Sources: S, Sietz (1972, a sample from Ethiopia); A, Appelqvist (1970, ranges within 7 samples); A1, Appelqvist (1970, means of 7 samples); A2, Appelqvist (1970, values of a sample of *Br. nigra* var. *abyssinica*); A3, Appelqvist (1970, values of another sample of *Br. nigra* var. *abyssinica*).

	S	A	A1	A2	A3
12:0	trace				
14:0	0.05				
16.0	3.0	3.0–3.8	3.5	3.8	3.0
18:0	1.1	1.2–1.6	1.3	1.6	1.2
20:0	1.2		c. 1.3		
22:0	0.6		c. 1.4		
24:0	0.4		c. 1.0		
16:1	0.3		c. 0.4		
18:1	10.2	6.8–8.4	7.5	8.0	6.8
18:2	16.6	13.2–17.3	14.5	15.1	14.2
18:3	15.1	14.8–23.2	16.9	16.9	23.2
20:1	10.2	5.4–7.1	6.3	6.5	6.6
20:2	1.8		c. 1.0		
22:1	36.6	35.9–43.6	40.5	38.9	35.9
22:2	0.5		c. 1.3		
24:1	1.9	2.0–2.5	2.2	2.2	2.1

Table 22. Nitrogen (g/kg) and amino acids (g per 16 g N) in the seedmeal of *Brassica nigra*. Source: Harvey (1970).

Nitrogen	73.9	Isoleusine	3.8
Alanine	3.8	Lysine	4.4
Arginine	7.6	Methionine	1.5
Aspartic acid	6.4	Phenylalanine	3.7
Cystine	2.4	Proline	6.1
Glutamic acid	17.2	Serine	3.4
Glycine	4.7	Threonine	3.7
Histidine	2.5	Tyrosine	2.6
Leucine	6.3	Valine	4.6

holic beverages.

Medicinally, it is used in the treatment of skin diseases (mixed with chicken broth, flour, other spices and butter) or in the treatment of syphilis (Griaulé, 1930), in the treatment of rheumatism (mixed with seeds of *Clematis simensis* Fresen.) (Chiovenda, 1937; Cufodontis, 1957; 1974) or as an abortive (Lemordant, 1971).

The leaves are eaten in a salad or used as pot-herb (Chiovenda, 1937; Baldrati, 1950).

Chemical and physical properties

Black-mustard seed has a 1000-seed wt between 0.6 and 1.3 g. Per kilogram, it contains c. 300–320 g of oil and about 300 g of protein. It does not contain starch (Barclay & Earle, 1974). It has generally higher contents in glucosinolates than *Br. carinata*. According to Baldrati (1950), there is about 4.25 g of them in a kilogram of black-mustard seed from Ethiopia. The contents in meal are given in Table 19 (under *Br. carinata*).

The composition of the seed and of its oil are considerably influenced by growing conditions (Schuster & Klein, 1978).

Table 23. Some characteristics of the oil of *Brassica nigra*. Source: Mensier, 1957.

Relative density (15°C)	0.914–0.924
Refractive index (20°C)	1.4720–1.4736
Saponification index	173–184
Iodine index	93–124
Acetyl number	c. 17
Hehner value	c. 95
Reichert-Meissl value	0.89
Maumené test	42–44°C
Unsaponifiable matter	10–15 g/kg
Titre	6–8°C

The seeds show dormancy, usually for about 4 months after harvest. Seed meant to be used for sowing should be stored carefully. Particularly temperatures below −5 °C should be avoided (Zimmermann, 1962).

The woody straw-coloured pericarp, which remains with the seed at threshing accounts for 25–28% of the weight of the fruit without stipe. The seed varies in diameter from 1.3 to 2.6 mm. A kilogram of the whole fruit contains about 310 g of oil (Zimmermann, 1962) whereas the seed alone has close to 500 g (Pokorný et al., 1968).

Crambe oil is used in industries such as metallurgy, rubber and plastics. The oil is extremely stable at high temperatures and is used as lubricant in steel-mills. Because of its high contents of erucic acid (c. 600 g/kg), it is not suitable for food. The presscake is toxic (Quilantán, 1976) but can be detoxified (e.g. Mustakas et al., 1976).

In agricultural literature, the common cultivated species of *Crambe* is generally called *Crambe abyssinica* Hochst. ex Fries. According to Jonsell (1976; FTEA, 1982), this name is a 'nomen ambiguum' and should better not be used. He prefers to refer such plants to *Cr. hispanica* L., distinguishing cultivated and wild forms.

I do not agree with Jonsell's opinion that *Cr. abyssinica* is a 'nomen ambiguum'. By the typification cited above, the name is linked to the most common present use.

Jonsell (1976) stated that Fries validated *Crambe abyssinica* Hochst. in 1914. This is correct. *Crambe abyssinica* Hochst. ex Fries is, however, not based on Schimper II: 1249, as claimed by Jonsell. Fries did not even mention Schimper II: 1249, but cited Schimper 513, III: 1918, Volkens 1706 and Fries 1557. He omitted to designate a type among these 4 specimens, as claimed by Jonsell.

Fries stated that a high-mountain form differed from *Cr. hispanica* L. which he recognized (inter alia) in Schimper III: 1918. This was to be recognized as a species bearing Hochstetter's epithet: *Crambe abyssinica*. Fries's validating text suggests that he was aware of certain differences among his African specimens but he decided to recognize only a single species. As a result, his description covers both *Cr. abyssinica* (length of pedicel in fruit) and what was later described as *Cr. kilimandscharica* by Schulz (1916) (reticulate-rugose fruit).

As Fries did not designate a type, it is opportune to adopt Schimper III: 1918 as the lectotype of *Crambe abyssinica* Hochst. ex Fries, leaving Volkens 1706 as an obvious contender for typification of *Cr. kilimandscharica*.

According to Jonsell (1976), the somatic chromosome number of both the cultivated and wild forms of *Cr. hispanica* is $2n = 90$, but he investigated only one specimen of each group. He was aware, however, that different chromosome numbers might occur within his interpretation of *Cr. hispanica*.

Distinction between *Cr. abyssinica* and *Cr. hispanica* is particularly common in the view of agriculturists and plant breeders. White (1975), for instance, investigating 39 accessions from different parts of the world, found three morphologically distinguishable groups which differed in chromosome number as well: $n = 45$, $n = 30$, and $n = 15$. He named those groups *Cr. abyssinica* Fries, *Cr. hispanica* L. var. *hispanica*, and *Cr. hispanica* var. *glabrata* (DC.) Coss., respectively.

White gave the following survey of relationships between chromosome number and morphological characteristics.

Chromosome number	Ratio length lower fruit segment to upper fruit segment	Leaf pubescence	Shape of basel leaf	Colour of pericarp
$n = 45$	$<\frac{1}{2}$	absent	ovate	tan
$n = 30$	$>\frac{1}{2}$	present	cordate	black
$n = 15$	$<\frac{1}{2}$	present	cordate	tan to straw

He added that the majority of these characteristics was variable and that the most reliable distinguishing characteristics between *Cr. abyssinica* and *Cr. hispanica*, so far, are the chromosome number and the shape of the lower leaves.

In 1978, White & Solt derived supporting data from another collection of *Crambe* accessions.

In my opinion, White's data show that differences in chromosome numbers do not justify any distinction of species within the *Crambe hispanica* complex but Jonsell (1976) might be correct in suggesting that *Cr. abyssinica* Hochst. ex Fries is in fact a special group of forms within *Cr. hispanica* L.; further research by a monographer is required.

2.3.3 Eruca sativa Hill

'Eruca': old Latin name for this plant.

According to Cufodontis (1974), *Eruca sativa* was found as an aromatic vegetable in Eritrea, not only grown but also naturalized.

In Ethiopia, this species is not grown as oilcrop. An experimental planting near Keren (1300 m), however, produced well on sandy soil. The oil contents of the seeds are c. 30% of weight (Baldrati, 1950).

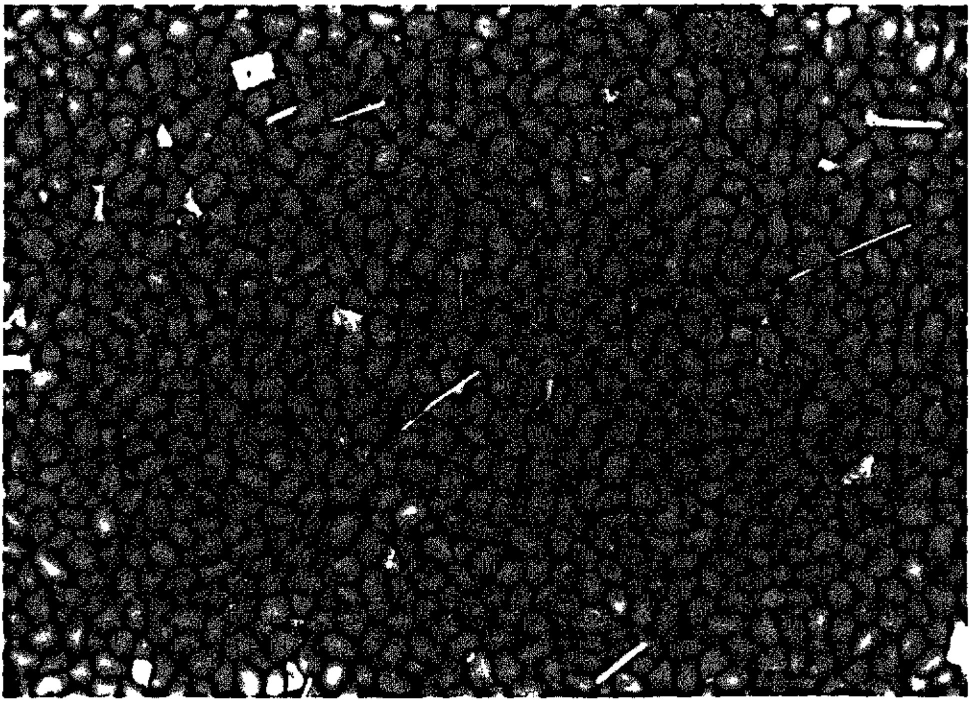
2.3.4 Erucastrum spp.

'Erucastrum': a plant similar to *Eruca*.

According to Jonsell (1976), three *Erucastrum* spp. were found in Ethiopia: *E. abyssinicum* (A. Rich.) O.E. Schulz, *E. arabicum* Fisch. & Mey., and *E. pachypodum* (Chiov.) Jonsell.

Erucastrum spp. are not important crops in Ethiopia but *E. arabicum* is occasionally grown (Cufodontis & Chiovenda, 1939: at Neghele). The species are, however, collected from the wild and are used more frequently in times of scarcity (Amare G., 1974).

Cufodontis (1974) noted 'gomanza' as indigenous name of *E. abyssinicum*. The same name is given to seeds of *Brassica carinata* and suggests similar use.



Photograph 13. Seeds of *Erucastrum arabicum* (SL 1251; × 5).

More commonly mentioned is the use of *E. arabicum*. Its leaves are used as a vegetable (Amare G., 1974) and I purchased seeds (SL 1251) of this species at the market of Goro (near Goba, Bale). The woman told me that it was called meshisha. This is also a name for *Br. carinata* and this again suggests that *Erucastrum* spp. are used like *Br. carinata*. The name 'shimpa' noted by Cufondontis (1957) and Amare (1974) is also a name for *Lepidium sativum* L. and may indicate medicinal use in some areas as well.

The seeds of SL 1215 were c. 1–1½ mm × ¾–1 mm, (greenish) pale brown, lighter on the plumule than on the folded cotyledons, brown basally. It had a somewhat variable shape: ellipsoid to (broadly) ovoid, mostly with two unequal halves, sometimes ± hemispherical, basally with the radicle protruding in a small beak. The surface was shallowly grooved lengthwise and finely shallowly bullate.

My sample contained c. 375 g oil per kilogram. The main fatty acids in the oil are listed in Table 24.

The results of a trial on date of sowing at Wageningen, suggest that *E. arabicum* needs rather low temperatures for good development. Sown outdoors in March, the seeds germinated well and produced ripe seeds within 3 months but, sown in June or in a greenhouse, they hardly germinated and seed production was practically zero.

Erucastrum pachypodum was considered a variety of *E. abyssinicum* (e.g. Cufodon-

Table 24. Main fatty acids in the oil of a sample of seeds of *Erucastrum arabicum* from Ethiopia (mmol/mol).

Palmitic	c. 34	Linolenic + eicosenoic	c. 195
Stearic	c. 10	Behenic	c. 33
Oleic	c. 44	Erucic	c. 550
Linoleic	c. 105		

tis, 1974) until Jonsell (1976) gave it its present status, and its use is probably similar to that of *E. abyssinicum*.

2.3.5 Lepidium sativum L.

Lepidum sativum (Amarinya, feto; Gallinya, shimfi; Tigrinya, shimfa) is mainly used medicinally in Ethiopia. The species was treated by Jansen (1981) in his book on spices, condiments and medicinal plants in Ethiopia.

To his data I would add that Suzzi (1904 & 1905) reported that a kilogram of the seed of Eritrean *Lepidium* contained about 219 g of oil (on fresh base) and that the oil contents of 9 of my Ethiopian collection of *Lepidium* seed were c. 240–290 g, the average being 266 g (on oven-dry base).

2.3.6 Sinapis spp.

According to Cufodontis (1974), two *Sinapis* species were found in Ethiopia, one wild and one cultivated. The cultivated species, *Sinapis alba* L. (white mustard), he found in material from C Ethiopia. I did not find it and it is certainly not widespread in Ethiopia. The vernacular name 'senafich' points to a similar use to *Brassica nigra*.

2.4 Carthamus tinctorius L. (Compositae) (2*n* = 24) Fig. 4

'*Carthamus*': Latin plant name from the Middle Ages, Latinization of the Arabic name kurthum or gurdum.
'*tinctorius*': from Latin tinctor = painter: used by painters, used as a dye.

Linnaeus, Sp. Pl. ed. 1: p. 830 (1753).
Type: Hortus Cliffortianus 394 (BM, lecto.; see note 2).

Synonyms

?*Carthamus glaber* Burm. f., Fl. Cap. Prodr.: p. 23 (1768).
Carduus tinctorius (L.) Falk, Beitr. Kenntn. Russ. Reich. 2: p. 237 (1786), non Scop. (1772).
Carthamus tinctorius L. var. *croceus*, var. *flavus*, var. *albus* } Alef., Landw. Fl.: p. 181 (1866).
Carthamus tinctorius L. var. *typicus*, var. *inermis* } Schweinf. in Mém. inst. égypt. II: p. 96, 97 (1889).

Carthamus tinctorius L. var. *angustifolius* J. v. Wiesn., Rohstoffe des Pflanzenreiches ed. 4, 1: p. 354 (1927).
Carthamus inermis Hegi, Ill. Fl. Mitt.-Eur. VI, 2: p. 987 (1929).

Literature

1932: Kupzow, Bull. appl. Bot., Genet. Pl. Breed., Ser. 9, 1: p. 99–181. (tax.)
1960: Ashri & Knowles, Agron. J. 52: p. 11–17. (tax.)
1961: Hanelt, Die Kulturpfl., Bdg. 9 : 114–115. (tax.)
1963: Hanelt, Feddes Rep. No. Reg. Veg., Bd. 67(1/3): p. 41–180. (tax.)
1971: Weiss, Castor, sesame and safflower: p. 529–760. (agric.)
1971–1975: Ashri (et al.), Evaluation of the world collection of safflower I–V, several journals. (agric.)

Vernacular names: shuff, ssuf, suf (Amarinya, Tigrinya); yahaya suf (Amarinya); sufi (Gallinya); borda (Konso); astur (Somalinya); kurtum, usfar, usfur[1] (Arabic).
Trade names: safflower (plant and flower), safflower seed, safflower oil (English); carthame (plant), safran bâtard (flower), graine de perroquet (seed), huile de carthame, huile de safre (French).

1. According to Chavan (1961), the word 'safflower' may derive from the word 'usfur' in the following way: usfur (Ibn Baithar, 1200 AD), affore (Pergoletti, 1343 AD), asfiore, saffiore, safflower. The Ethiopian 'suf' seems very closely related to 'usfur' too.

Geographic distribution

The genus *Carthamus* L. is almost confined to SW Asia, N–NE Africa and S Europe (Kupzow, 1932). In California, some species are found as introduced weeds (Chavan, 1961).

Carthamus tinctorius is a warm area crop, which can be found cultivated between latitudes 45°N and 45°S. At the equator, it is mostly cultivated at altitudes of 1600–2200 m (Weiss, 1971). It is not known in wild state and its widespread dispersion has obscured its origin (Weiss, 1971). De Candolle concluded that Arabia was the area of origin, but modern research rather points to the Palestinian area as possible homeland of the species (Note 4).

Cultivation spread to India (which with more than 500000 ha at present has the largest area under this crop), China, the East Indies, Iran, Caucasia, Arabia, Ethiopia, Spain, and more recently to the United States and Australia. Although interest in the crop is still increasing, especially after cultivars were developed producing oil of different composition, safflower is still a minor crop in terms of total production and world trade. Through history, it was a 'cottage industry' crop, commercial scale production only taking place in the United States, Australia and the Soviet Union since World War II (Weiss, 1971).

It is assumed that Arabs introduced it into E Africa. Any local production is quickly purchased by local Arab and Indian traders for their personal use. The history of the crop in Ethiopia is obscure, although the country is considered to be a secondary centre of variability of the species. It is well known and wide-spread in Ethiopia and has been cultivated for centuries, but documentary or other evidence of its early history is not available (Chavan, 1961; Weiss, 1971).

In Ethiopia, the distribution of safflower is closely associated with the distribution of tef (*Eragrostis tef* (Zucc.) Trotter) and barley, with which it is mostly intercropped. Because of the sensitivity to wet weather at ripening, it is only found in regions with a very distinct dry season; the south-west is therefore mainly excluded. I noticed the most important production areas in Ethiopia in the E and C provinces, notably Harergie, Sidamo, Shewa, Arussi, Welo and Tigre, and the adjoining areas of Gojam and Beghemder. I did not visit Eritrea extensively, but according to Baldrati (1949) safflower was sparser in Hamasen (Asmara region) than in Tigre and Welo.

The total cropped area in Ethiopia is difficult to assess as the crop is normally grown in small patches scattered throughout the cropland and then usually in mixed crops. According to Weiss (1971), the area in Ethiopia in 1966 was estimated at 56000 ha. With this area, safflower ranked fourth among Ethiopian oil-seed crops. For the same period, Statistical Abstract Ethiopia (1970) indicated an area of 57200 ha, at the same time presenting an increase to 61 100 ha in 1970.

Description

An erect almost glabrous annual herb, 70–100(180) cm tall, heavily branched from 25–35(45) cm upward; each branch rather straight and ending in a flowering head. Branching usually no further than third order.

Photograph 14. *Carthamus tinctorius*: achenes without pappus (SL 30; × 5).

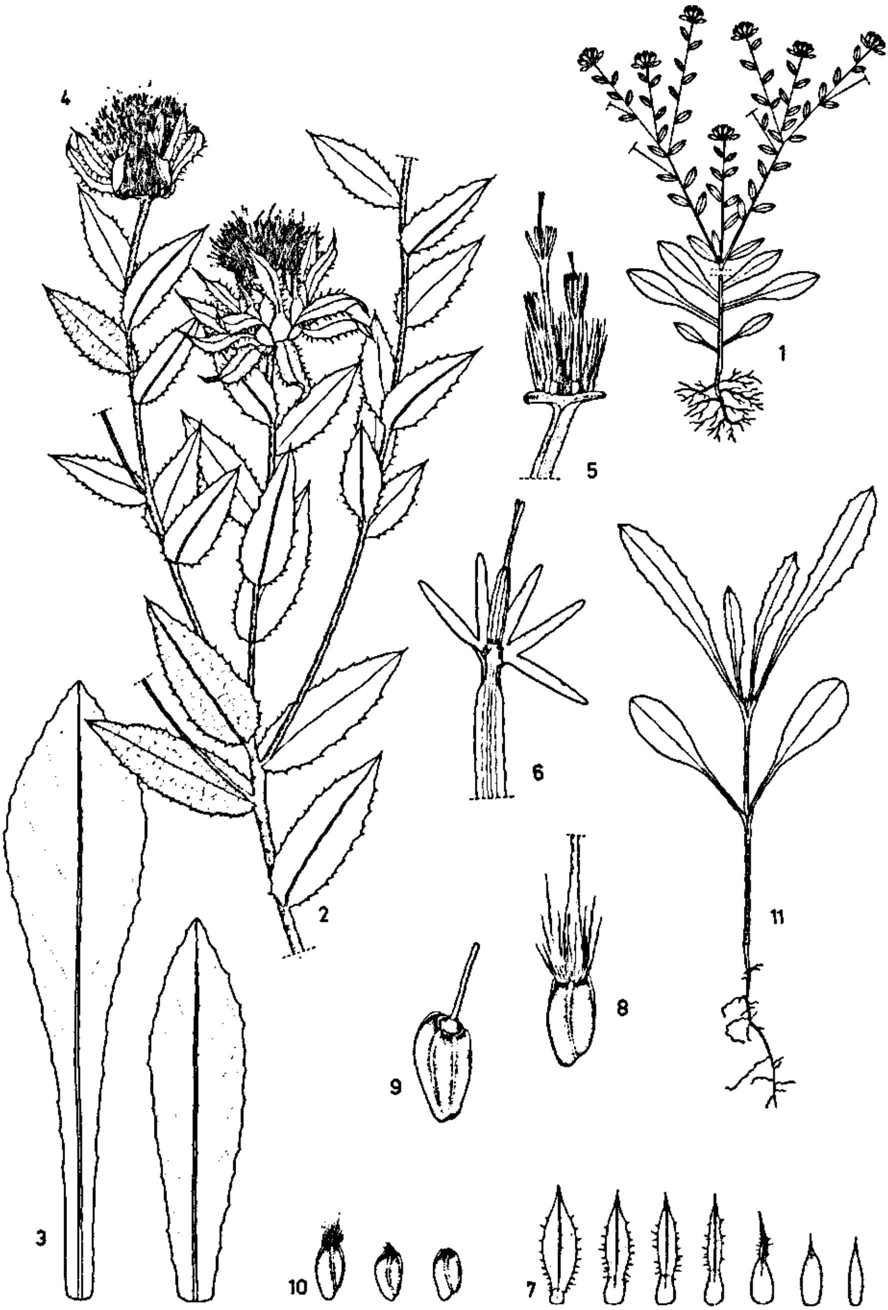


Fig. 4. *Carthamus tinctorius* L. 1. Growth habit. 2. Flowering branch (× ½). 3. Basal leaves (× ¼). 4. Capitulum cut lengthwise (× ½). 5. Detail of capitulum (× 1). 6. Apical part of floret slit open (× 2). 7. Involucral bracts; left, an outer one; right, an inner one; in between, intermediate forms (× ½). 8. Ovary with pappus (× 2). 9. Ovary without pappus, flower tube removed to show implantation of style (× 2). 10. Achenes with varying pappus (× 1). 11. Seedling (× ½). 1, SL 1711, SL 1748; 2–9, SL 1748; 10, SL 98; 11, SL 3889.

Photograph 15. *Carthamus tinctorius*: achenes with pappus (SL 1435; × 5).

Root system well developed, brownish to greyish; taproot rather thick and fleshy; main laterals firm.

Stem cylindrical, woody near base, solid, with soft pith, glabrous, striate, greenish-white.

Leaves spirally arranged on stem and branches, sessile, exstipulate, oblong to lanceolate, from 20 cm × 5 cm in the lower leaves to 4 cm × 1 cm in the upper ones, herbaceous when young, firmer and rather stiff later on, dark green above with almost white midrib, paler beneath with pale green midrib, glabrous; top acute, lower leaves with a long gradually tapering base; margin spinulose-dentate in the lower leaves to spinose-spinulose in the upper ones, spines creamy; venation pinnate with c. 7–10 main lateral nerves on each side in the lower leaves to almost palmately 3–5-nerved in the upper ones.

Inflorescence: an urn-shaped terminal head with disk florets only, c. $2\frac{1}{2}$–3 cm diam., $3\frac{1}{2}$–4 cm high; involucral bracts numerous, spirally arranged, the outer ones oblong, constricted above the base, c. 3–7 cm × 0.5–1.6 cm, the upper part leafy and spinescent, erect or spreading, not appressed against the head, with long hairs on the lower margin, lighter green than the leaves, the lower part appressed, whitish-green, long-hairy outside, especially on the margin, glabrous inside; towards the centre of the head, the constriction becomes less apparent and the leafy part disappears, the lower part forming the bract; the innermost bracts lanceolate, c. 1.8–2.5 cm × 0.15–0.35 cm with

Photograph 16. *Carthamus tinctorius*: field after harvest of the interplanted cereal.

a spinescent ciliate apex. Receptacle flat to conical, with abundant erect whitish bristles 10–20 mm long.

Florets numerous, c. 20–80, hermaphroditic, a few marginal ones sterile, sessile, actinomorphic, epigynous, sometimes yellow, mostly orange-red becoming dark red during flowering, c. 38 mm long, glabrous. Corolla 5-lobed, tube 18–22 mm long, lobes spreading, narrowly oblong to linear, c. 7 mm × 1 mm. Stamens 5, epipetalous, inserted at the mouth, filaments 1–2 mm long, often bent, in the middle wider than on the ends, a few papillae on both sides of the central part; anthers almost basifixed, connivent, opening apically, c. 5–5½ mm long, pollen yellow. Ovary ellipsoid, one-celled, with one ovule, c. 3½–4½ mm long; style slender, c. 28–30 mm long, glabrous; stigma bifid, yellow, short-haired, c. 5 mm long; discus on top of the ovary.

Fruit an achene, obovoid, often obliquely so, 5½–8 mm × 3–5 mm, 4-angled with clearly visible ribs, glabrous, pericarp white, often pale brown near top, sometimes with a pappus. Pappus variable from head to head and from fruit to fruit, generally the innermost fruit in a head bears the biggest pappus, the outermost none; when fully developed, the pappus consists of several complete, dense circles of paleae clasping the scar of the corolla-tube. Paleae narrowly oblong to linear, obtuse to acute at top, glabrous with hirsutely ciliate margin, flat, bent inwards at base, 6½ mm × ¼ mm, white like the pericarp.

Seed exalbuminous.

Seedling with epigeal germination. Strong taproot; hypocotyl greenish-white, cotyledons leaflike, obovate, c. 3 cm × 1 cm when plumule starts growing, c. 6 cm × 1½ cm when fully grown, greyish pale-green, when young with darker green dots; first leaves lanceolate with tapering base.

Notes

(1) *Carthamus* L. (Compositae) is closely related to the genus *Carduncellus* Adans., from which it is difficult to distinguish (Dittrich, 1969). Linnaeus described six species; some were later placed in other genera.

Bentham & Hooker (1873) were the first to describe *Carthamus* L. within the present boundaries. The subdivision of the genus currently adopted corresponds largely with the division De Candolle made (1837), although the rank of the taxa distinguished by him is often lowered (Hanelt, 1963).

(2) Hanelt (1961) chose the plate of L. Fuchs (1542, p. 409–410) as lectotype of *Carthamus tinctorius* L. He reasoned that this plate formed the basis of the plates of some of the authors cited by Linnaeus. As such it could only be taken as 'typotype'.

Although Fuchs's work is present in Linnaeus's library (Heller, 1959), Linnaeus did not annotate it (Savage, 1940) nor did he cite it. If a plate be chosen, it should be one that can reasonably be supposed to have been studied by Linnaeus. On the other hand, Sheet 394 • Carthamus 1α of the Herbarium Cliffortianum fits the description 'Carthamus foliis ovatis integris serrato-aculeatis' very well (pers. commun. Dr F. J. Breteler), while the material in LINN is insufficiently a match to Linnaeus's description. I thus choose sheet 394 • Carthamus 1α in Herbarium Cliffortianum as lectotype.

(3) Most of the specimens I examined carried heads of which the outmost florets bore slender ovaries, which did not develop into achenes. Hanelt (1963) stated that this is anomalous in *C. tinctorius* and I suggest that a closer investigation whether this loss of fertility may be more frequent in Ethiopia than elsewhere could be of interest.

(4) The majority of the species of *Carthamus* occur in the E Miditerranean and in the area from Turkey to W Iraq. It contains some wild species which are often considered to be close relatives of the cultivated *C. tinctorius*, notably *C. lanatus* L., *C. oxyacanthus* Bieb., *C. palaestinus* Eig and *C. persicus* Willd. The old view (e.g. De Candolle) was that both *C. lanatus* and *C. oxyacanthus* were involved in the development of *C. tinctorius*. This view was based on the morphology of the three species and the presumed area of origin of *C. tinctorius*, the Middle East, the region where the natural areas of *C. lanatus* and *C. oxyacanthus* overlap (Chavan, 1961; Kupzow, 1932).

More recently, the genus has been divided by Hanelt (1961, 1963) on the basis of morphology and by Ashri (1975) on the basis of cytology and fertility of F_1 and F_2 plants from crosses between plants of different species. The cytological division resulted in 4 sections, respectively with (a) $2n = 20$, (b) $2n = 24$, (c) $2n = 44$ and (d) $2n = 64$.

The species *C. tinctorius*, *C. oxyacanthus*, *C. palaestinus* and *C. persicus* all belong to the section *Carthamus* with 24 chromosomes somatically (b). They cross easily and form often fully fertile F_1 and F_2. *C. lanatus* has 64 chromosomes somatically and thus belongs to another section. Crosses with *Carthamus tinctorius* usually fail and when successful produce a sterile progeny.

According to Ashri & Knowles (1960), all species of the section *Carthamus* (b) crossbreed, with inbred-depression after selfing. The differences between species are often based on a few genes only; they are closely related and in some crosses even heterosis has been found.

The hypothesis that most of our cultivated crops are no evolutional products of one or another wild relative but that the evolution of wild and cultivated species took place simultaneously from common ancestors, e.g. by intercrossing, seems to be particularly evident in section *Carthamus*. *C. oxyacanthus*, *C. tinctorius*, and *C. persicus* all have their natural habitat closely associated with human activities and lost some of their 'wild' characteristics, while *C. palaestinus* kept those characteristics as it did not share its habitat, the desert, with man (Imrie & Knowles, 1970). From Ethiopia, no other species is known that forms fertile hybrids with *C. tinctorius*, but in India the freely crossing *C. oxyacanthus* is a common weed. This situation explains why *C. tinctorius* in Ethiopia has a much smaller variability than in India (pers. commun. Ashri, 1976).

In the literature on safflower, one often finds the term 'variety' used in different meanings: sometimes equivalent to a selection, sometimes referring to a specimen from a certain region or origin, and often these taxa are named by their provenance. In fact, there are no pure lines in safflower. Selections are mostly mixtures of similar plants, either out of a segregating population or out of a natural population in a limited area. This could be expected as up to 60% of the seeds may be the result of natural crossing (Weiss, 1971).

Kupzow (1932) concluded that safflower had two centres of variability: Ethiopia and Afghanistan. Hanelt (1961) considered the Afghan-Indian area as primary centre of variability and the Ethio-Egyptian area as secondary centre. Knowles (1969) concluded from field studies and observations in the nursery that divergence had taken place in safflower and suggested the concept of 'Centers of Culture' with a predominant type in each. Consequently, many of the introductions from each centre resemble one another. Knowles (1969) defined seven such centres. Ashri (1975) later extended this number to ten by defining 3 areas within the 'Middle East' of Knowles and by adding Kenya. He thus recognized as 'major pools': 1, Far East; 2, Indian subcontinent; 3, Iran-Afghanistan; 4, Israel, Jordan, Iraq, Syria; 5, Turkey; 6, Egypt; 7, Sudan; 8, Kenya; 9, Ethiopia; 10, Morocco, Spain, Portugal, France.

In Ethiopia, an orange-flowered spiny type is the commonly established taxon (Ashri, 1975).

(5) Professor Ashri (Hebrew University) has examined the Wageningen Ethiopian collection and stated that many of the achene samples are different from samples from most other origins in three characters mainly: the form and size of the pappus, the

strong ribs, the brown coloration of the upper area near the apex (the 'shoulders'). The last character he knew only from achenes of F_1 of the interspecific cross *C. tinctorius* × *C. palaestinus* (pers. commun., 1976). *C. palaestinus* is not known to occur in Ethiopia.

(6) For the morphological variability of *C. tinctorius* within Ethiopia, considered as a secondary centre of variability of the species, literature is often difficult to compare because the authors distinguish taxa with different delimitations. I never heard of Ethiopian farmers distinguishing cultivars within this crop, and Rydén (1972) made the same remark.

It is, as yet, impossible to give any standard characteristics with which cultivars could be distinguished within safflower (pers. commun. Ashri, 1976).

Kupzow (1932) mentions 2 kinds of *C. tinctorius* for Ethiopia: one tall, the main type, and one short. The latter, he stated, was represented mainly in populations from the regions of Addis Abeba and Lake Tana. I only encountered the tall kind and was unable to demonstrate a clear distribution between tall and short safflower. Similarly, all other authors (e.g. Knowles, 1969; Weiss, 1971) mention that all introductions from Ethiopia were late, tall, and strongly branched.

According to Weiss (1971, p. 561) the degree of spininess of the outer involucral bracts is a characteristic of a cultivar and a 'spine index' has been designed. This index can be calculated by multiplying the number of spines on the outer involucral bract by the length in millimetres of either the longer spines or the estimated average. Within the species, the number spines varies from 0 to 24, the length of the spines from 1 to 6 mm.

According to Ashri (1975) the 25 Ethiopian samples he compared with safflower of other origins all bore involucral bracts richly provided with spines; I found the same. The distribution he found for those spines, though, is different from what I found. In 24 groups, he found the spines all along the margins, in 1 only near the tip and a few basally. In my material, the normal distribution of the spines was rich in the lower $\frac{1}{2}$–$\frac{2}{3}$ of the leafy part and absent in the upper part, except for a spiny tip. Only in 2 of the specimens and then only on some of the bracts, 1 or 2 spines were present in the upper parts of the margins.

On the colour of the florets of Ethiopian safflower, there are also different views. Ashri (1975) distinguished 4 different colours in his Ethiopian material. He described for all 4 groups the fresh flower as 'yellow'. A distinction was to be made according to the amounts of orange on some of the parts and in the dry flower. Wu & Jain (1977) stated that 70% of their Ethiopian material was yellow, the rest white. In my material, I found the following descriptions of the floret colour: bright orange + yellow orange + yellowish orange 22 (PJ 2788, 2789, 3087; SL 1711, 1727, 1728, 1740, 1741, 1742, 1743, 1747, 1748, 1763, 1764, 3896, 3897; WP 7444, 7447, 7450, 3010, 3011; WdeW 8468), orange-red 4 (Ash 1378; PJ 3088; WP 2897; WdeW 9716), tube orange and lobes yellow 2 (PJ 3504; SL 1746), yellow 2 (SL 1765; WP 3121).

Unfortunately some of the characteristics of Ethiopian safflower as described by Ashri (1975) (e.g. leaf colour, shape of the primary head, implantation of the branches) could not be investigated with sufficient precision from my herbarium material to allow comparison. His findings on late rosette leaves, shape of upper stem leaves, angle of branches to stem agree closely with my own findings. However all my specimens carry upper stem leaves with dentate-serrate margins. In Ashri's collection, this was only the case in about ⅓ of the material.

Wu & Jain (1977) concluded that the variability of 18 characteristics of Ethiopian safflower is, on average, clearly less than that of safflower from other parts of the world. In view of the growing interest in safflower, the different findings, and the commonly rather small number of samples from Ethiopia, a special study of the geographic and physiological variability in the country seems necessary.

(7) In the literature on safflower, the terms 'wild safflower' or 'different species of safflower' are used regularly. These neglect the meaning of the vernacular species name safflower and the botanical genus name *Carthamus*. They often involve confusion of wild *C. lanatus* ('saffron thistle'), *C. oxyacanthus*, and cultivated *C. tinctorius*.

(8) The terms 'specioid' and 'provar', used by Hanelt (1961) are based on a publication of Mansfeld and not on the International Code of Nomenclature of Cultivated Plants.

(9) In those parts of the world where safflower is mainly cultivated for the production of dye, a non-spiny form is cultivated (Chavan, 1961; Weiss, 1971).

(10) Description was based on the following specimens.

Arussi	field at Kulumsa: WP 3132; SW shore of Lake Langano: J. W. Ash 1378.
Bale	market at Goba: SL 1210.
Beghemder	market at Gonder: SL 54, SL 56, SL 926, WP 4997.
Gojam	market at Dejen: SL 780.
Harergie	market at Alemaya: SL 223; market at Bedeisa: SL 677; market at Dire Dawa: WP 120; market at Harer: WP 59; market at Jijiga: SL 351; market at Kuni: SL 555; garden Alemaya: WP 275, WP 351, WP 744, WP 761, WP 3010, WP 3011, WP 3040, PJ 2788–2789, PJ 3087–3089, PJ 4058, PJ 4503.
Illubabor	market at Metu: SL 1484, SL 1485.
Kefa	market at Agaro: Sl 98; market at Jimma: SL 118, WP 3282.
Shewa	market at Robi: SL 1153, SL 1174; market at Shashemane: SL 1292; along road Awash–Welenchite SL 0.
Sidamo	market at Awasa: Sl 1342; field 18 km NE of Soddo: WP 2892.
Tigre	market at Adishow: SL 1019.
Welega	market at Dembidolo: SL 1538.
Welo	market at Bati: SL 1052, WP 4012; field near Bati: WdeW 9716; market at Dessie: SL 1086; field near Lalibela: WdeW 8468; market at Robit: SL 30, SL 32.
Grown at Wageningen	SL 1711, SL 1727–1728, SL 1740–1743, SL 1746–1748, SL 1763–1765, SL 1906–1918, SL 3881–3897, WP 5817–5818, WP 6050–6051, WP 7141, WP 7443–7451.

Ecology (data mainly from Weiss, 1971)

Safflower is a crop of semi-arid areas with warm climates and a pronounced dry period at ripening. The main production areas of the world are usually below 900 m altitude. Near the equator, it is mainly found at higher altitudes. In Ethiopia, it is mostly cultivated at altitudes of 1700–2200 m. If grown for dye production, the range can be much greater as the seeds are not required to mature.

It seems likely that cultivars can be bred for a wide range of climatic conditions (Weiss, 1971).

1. Temperature

The temperature requirements of safflower are correlated with its development. To induce germination, a temperature of more than 2.5 °C is necessary, a condition met all over the cultivated area of Ethiopia. The optimum temperature for even and quick emergence on the seed-bed is around 15 °C. Emergence then takes 4–7 days. The main safflower-producing areas of Ethiopia have an average diurnal temperature of c. 16–20 °C during the months of sowing. The temperature of the wet soil thus might well be near this optimum.

In its early stages, the plant is rather cold-tolerant and can even withstand some degrees of frost. Cold tolerance decreases with the developmemt of the plant. In budding, flowering and seed-set, frost can cause heavy damage. In Ethiopia, frost can only be expected in some areas during the night at the time the plant is drying in the field. Frosts then mainly influence the quality of the seed.

In years that the frosts come early, they may cause severe damage. The safflower in the National Orientative Trial on Oil Crops at Alemaya (2000 m altitude), for instance, was killed off by frost in November 1970 after a growing period of c. 17 weeks (Brhane G. K., 1971).

Average temperatures of 17–20 °C seem to be best for safflower. Provided enough water is available, short periods of very high temperatures seem to have no noticeable effect on the crop. Prolonged periods of high temperatures, on the other hand, may be detrimental. The American cultivar Gila grew best at a day temperature of 18 °C but died after c. 40 days at constant day temperatures over 30 °C and high night temperatures. High temperatures also markedly reduce rate of accumulation of dry matter, period till flowering, period of flowering, head size, seed-set, seed size and composition. A bad setting of seed is probably due to arrest of growth of the pollen tube at high temperature. The duration of the morning cool period and the length of the style therefore seem to be of influence. The effect can be aggravated by water stress (Weiss, 1971).

The areas of Ethiopia where safflower is grown lie between 1600 and 2400 m. There the monthly average maximum temperatures during the growing season are generally about 21–26 °C, the average diurnal temperatures about 16–20 °C (Mesfin, 1970, Maps 18–21; Adugna Z., 1971). The temperature requirements of safflower are thus well met in Ethiopia.

2. Water

Safflower has acquired the reputation of being drought-resistant and a suitable crop for dry or semi-arid areas. This is only true if there is sufficient soil moisture for growth. With its deep root, safflower can extract water from much greater depths than the majority of annual crops. If the soil at planting can store sufficient moisture for the season's growth in the upper 3–4 m, the plant can develop roots rapidly enough to extract deep subsoil water. This leads to nearly maximum yields, and so the plant becomes practically independent of rain. In this respect, it is probably superior to most other annual crops.

Commercial production is hazardous if the water requirements of the plant can be met only from rain falling on the crop during growth. If about two-thirds of the total requirements is available as soil moisture, the rest may be supplied by rain with no major depression of yield.

The plant is sensitive to excess moisture of any type, be it rain, high humidity or standing water. Moist soil increases the incidence of root rot, high humidity of the air causes fungal attacks and standing water or waterlogging is fatal. Because of this high sensitivity for excess water, irrigation of safflower is difficult. As a moist subsoil is wanted, subsoil irrigation gives best results. When too much water is applied or small amounts too often, the plant becomes vulnerable to a variety of damaging root diseases.

High rainfall during flowering causes low seed-setting and badly filled or empty discoloured achenes ('seeds'). After the seed has developed, rain may induce germination in the head.

The seed-bed should be at field capacity to a depth of $1\frac{1}{2}$–3 m at sowing. The seed should be placed in moist soil, even if this means planting at a depth of 10–15 cm. These specific seed-bed requirements can be explained by the growth habits of the plant, combined with the high susceptibility to fungal attacks in wet conditions. After germination, early growth is mainly of the root system. A fungal attack or a hindering of root growth depresses yield considerably. A short time after emergence, safflower is rather tolerant of water shortage; drought at this stage does not appear to have any major effect on subsequent growth and yield. However water shortage during later stages of development markedly reduces growth and prolongs the growing season. Moisture shortage during flowering and maturation lowers yield considerably and reduces oil content.

Water requirements are difficult to define in the usual terms of water required to produce a crop, since safflower has greater capacity to extract water than most crops. Therefore the data vary greatly with soil type and area. Most data for minimum rainfall are around 500–600 mm. Water consumption ranges from 520 mm to 930 mm, of which 430–880 mm is used by the plant (Stern, 1965; Luebs et al., 1965; Fisher et al., 1967).

The most important safflower areas in Ethiopia have a rainfall of 600–1100 mm (Mesfin, 1970; Rydén, 1972). The sowing time is usually in the second half of the rainy season when the rains are starting to wane so that the water requirements, both in amount and distribution, are rather well met.

Safflower is rather sensitive to soil environment, quite apart from the moisture it may contain. Wherever safflower is particularly successful, soils are deep, fertile, well drained and neutral in reaction (Knowles, 1958; Weiss, 1971). Grown commercially, it prefers sandy loams with no major horizon near the surface but, grown by small cultivators, it may be planted on a variety of soils. The pH (H_2O) then usually ranges from 5 to 8 and is of little importance with such crop husbandry. Irrespective of their fertility, shallow soils seldom produce high yields, because of insufficient moisture capacity. Dense subsoil or a layer of impermeable clay will retard root growth. Under such conditions, yield may be substantially reduced, even if the subsoil stores enough water. Acid soil can increase the incidence of root rot.

Sticky soils require careful treatment. The stickiness is bothersome, especially during weeding of the young crop; damage is unavoidable if the soil is wet. However, if the climatic conditions are favourable, good yields can be obtained.

Safflower is considered to be salt-tolerant, ranking just below cotton in its ability to produce profitable yields when grown in saline soils. It is especially tolerant of sodium salts but less tolerant of salts containing either calcium, magnesium or both. A comparison between safflower and some other arable crops is shown in Figure 5. The indicated values apply to the periods of rapid plant growth. Salinity delays initial emergence which, subsequently, tends to be irregular. Very high salinity also reduces germination. Safflower is only half as tolerant to salinity in the germination stage as in later growth stages. At a salt concentration corresponding with an electrical conductivity of extract of 700 mS/m, emergence time is doubled.

Salt makes the plant smaller, thicker and darker green. It makes the branches grow

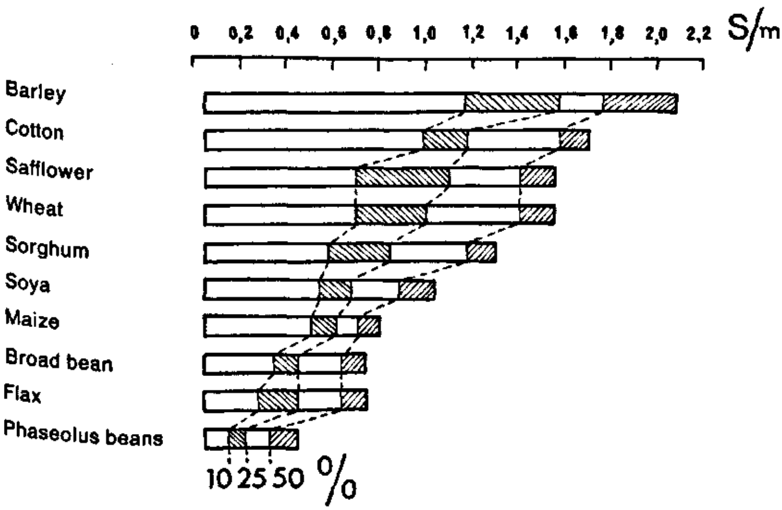


Fig. 5. Comparison of the relative reduction in yield (%) of safflower and some other field crops (Weiss, 1971) in relation to electrical conductivity (S/m) of the soil extract at 25 °C.

more appressed and it accelerates both flowering and maturity, the former by a few days, the latter up to several weeks.

Under irrigation, each conductivity increment of 300–400 mS/m reduced the time to maturity by about a week. Yield decreases by a reduction of the number of heads per plant, the number of seeds per head remaining constant. Seed yield per head decreases by a reduction of the weight of the individual seeds. In a trial with 4 cultivars in the United States, the oil content was found to be depressed by 0.4% for every 100 mS/m, but the composition of the oil was not affected. The protein content was lower and the content of hull higher under saline conditions. Under highly saline conditions, the seeds of the tertiary head were found to have the lowest oil content, while those of the primary head had the highest; under non-saline conditions the reverse was found.

Sodium, as distinct from salinity, was stated to be beneficial in the early stages of growth. Exchangeable Na^+ up to 30% resulted in greatly increased growth; higher levels were detrimental.

The extent of the fertilizer response is related to soil moisture reserves, soil conditions and climatic influences (de Geus, 1973). Phophate requirements are moderate. If there is a shortage of P, 15–29 kg/ha is a normal dressing (de Geus, 1973).

Response to nitrogen is generally more pronounced than to other fertilizers: it promotes the vegetative growth after which a larger number of heads per plant is found, especially tertiary. Nitrogen alone has little or no effect on seed weight or composition, but when associated with phosphate and potash, the nitrogen content of the seed can increase. Higher applications of nitrogen may cause a slight reduction in oil content and iodine value. Excess nitrogen may reduce yield (Weiss, 1971) but no reduction in safflower yield has been observed from excess nitrogen under moist conditions (de Geus, 1973).

Under more intensive growing conditions, N dressings of 30–60 kg/ha are recommended for unirrigated crops; for irrigated crops, the amounts are about double. In trials at the University of Arizona, safflower responded in yield with N dressings up to 168 kg/ha. Yields were 1717 kg/ha without N, rising to 2899 kg/ha with 56 kg/ha, 3314 kg/ha with 112 kg/ha and 3755 kg/ha seed with 168 kg/ha. High dressings of nitrogen should be applied half at planting and half as topdressing (de Geus, 1973). Topdressings with ammonium sulphate had no significant effect on safflower grown in red clay soils in Kenya but, on more sandy soils in Tanzania, it increased the yield by about 30% (Weiss, 1971).

Potash had no effect at low levels KCl in East Africa, but at higher levels there was a slight decrease in yield. Applications of minor nutrients like zinc and boron do not generally show a favourable effect.

In Ethiopia, the soils in the regions where safflower is cultivated are mostly dark to dark reddish brown clayey loams with a moderate to good drainage. They have a slightly acid, neutral or slightly alkaline reaction and are usually moderate to poor in phosphorus and rich in potassium (Rydén, 1972; Westphal, 1975; my observations).

4. Light

The flowering behaviour of safflower is that of a typical long-day plant. Growing under short days, the plant has a longer vegetative stage and develops more vigorously. It produces more heads per plant if sowing be done with wide spacing, as in Ethiopia.

In the United States, a light phase of about 14 h is considered to be required for flower initiation. The temperature, however, has a very great influence. High temperatures during early growth accelerate flowering: they can reduce the time from emergence to flowering by more than a month.

A provisional out-door sowing-date test in Wageningen, conducted with four samples from different parts of Ethiopia, showed that safflower planted on 24 June, came to flower 68 days after sowing at a plant height of 60 cm; safflower planted on 25 April, needed 97 days to reach the flowering stage at a plant height of 100 cm. These results may be taken to support the influence of day-length combined with temperature.

5. Other factors

Safflower is sensitive to direct damage by strong winds and hail during the stages of quick elongation and flowering.

Development of the plant (data mainly from Weiss, 1971)

After emergence, the safflower plant in many parts of the world forms a rosette. The Ethiopian type lacks this habit: it grows on immediately (Kupzow, 1932; my observation). When the plant is 20–40 cm high, lateral branches start to develop, their place and number depending on environment and genetic factors. They reach final length at about the same time as the main stem and terminate their growth by forming flowering heads. In Ethiopian plants growing under favourable circumstances, branches form of second and sometimes also of third order. The size of the heads decreases with increasing order of branching.

The basal leaves of the plant are rather soft and not spiny. The leaves towards the top become shorter, stiffer and spiny. Along the ultimate branches, they are borne closer together, and at the top they become superimposed, as involucral bracts.

As soon as the secondary branches have completed their growth and have formed their flowering heads (75–100 days after sowing), florets begin to appear in the head which terminates the main stem of the plant. Successively, the heads on the branches of first, second and third order come to flower, the highest branches first. According to Weiss (1971), the number of heads per plant within the species can vary from 5 to 50 and there is also a close relation between the planting distance and this number. The number of heads in Ethiopian safflower cultivated in the traditional way with wide planting is mostly in the higher part of this range.

The total flowering period usually takes about 3–4 weeks but may be as short as

10 and as long as 40 days, depending on the number of heads per plant and weather conditions. The flowering period of the plant tends to be prolonged with wide planting, when the number of secondary and tertiary heads is high. The opening of the florets proceeds from the margin to the centre of the head and is mostly complete after about four days. The florets open mainly in the morning and remain open for 1 to 2 days (Chavan, 1961; Weiss, 1971).

Anther dehiscence takes place while the elongating style pushes the stigma through the anther tube. By the time the elongation process is complete, the style is usually well covered with pollen of its own floret but the stigma is mostly free from pollen. Movements of the florets because of wind and insect activity make geitonogamy possible in this situation. In some florets, the anthers open before the extrusion of the stigma so that conditions are present for self-fertilization (Chavan, 1961; Weiss, 1971). Indeed even in dense plantings, more than 60% of the seeds resulted from self-fertilization. This result was obtained in fields open to visiting insects. On the other hand, populations have been found with 100% cross-fertilization (Claassen, 1950).

Barbier & Nadir (1976) found that the presence of many honey-bees induced the development of more but smaller seeds per head. Those seeds had a higher oil content and showed a higher germination energy than seeds developed after selfing. The final germination percentage, though, was equal in the two groups. Weiss (1971) mentioned an investigation with fields from which insects were excluded. The fields yielded 785 kg/ha of clean seed, whereas fields accessible to insects yielded 1700 kg/ha. Because of this insect activity, a spatial isolation distance of at least 200 m is considered necessary for breeding purposes in the United States and South Africa.

Ashri et al. (1974) found that the most important seed-yield component in safflower is the number of heads per plant. The number of seeds per head (in their collection, Ethiopian plants had the lowest number of seeds per head) and seed weight are, however, far less important. The oil content of seeds of plants with many heads was slightly lower than that of plants with less heads. But also the oil yield of the former group was larger: there was even no correlation between the oil content of the seeds and the yield per plant. There was also no correlation between the length of the vegetative growing season and the yield per plant.

Cultivars differ in the rate of accumulation and the period during which accumulation takes place. In general, 'seed' reaches its maximum dry weight four weeks after flowering. Oil content, germination percentage and iodine value are then also maximum, the percentage of weight of the hull minimum. Seeds from different positions on the plant and from different plants within one cultivar may differ considerably in composition (Weiss, 1971).

Husbandry (data mainly from Weiss, 1971)

Land preparation as for small grains is quite suitable for safflower. If present, compact horizontal layers within the root zone should be fractured and the seed-bed should be free from clods. On the other hand, in a trial in the United States, highest yields were obtained with minimum cultivation. Land preparation with smallholder crops is normally traditional in the area and varies little for local rain grown annual crops. Because of the slow initial growth of safflower, special care should be taken to destroy weeds.

In Ethiopia, safflower is almost exclusively grown in mixed cultivation with small grains, especially with tef. According to Baldrati (1949), the stiff safflower plants prevent the tef from lodging. Only in Northern Arussi and the adjoining areas did I sometimes see fields of grain planted with a border of safflower.

The preparation of the seed-bed starts with ploughing the fields towards the end of the dry season. After the rains have begun, the field is ploughed 2–3 more times. The plough used is the 'marasha', a breaking plough.

In Ethiopia, the farmers select big and healthy looking seeds for sowing. These are stored apart from the bulk which is used for consumption. In general, seed quality influences the yield of the crop so much that it is economically feasible to cultivate special seed for sowing. Seed size can considerably influence the percentage of emergence: large seeds emerge faster and more regularly than smaller ones, and may be sown deeper. Seed disinfection is often highly profitable: in Central Tanzania, seed dressing increased emergence by 30%.

Because temperature at flowering and the amount of water available for growth can affect seed weight, oil content and even oil composition, the best time for sowing ought to be carefully considered.

Cultivation mixed with other crops requires 5–12 kg of 'seed' per hectare, pure stands require usually 28–34 kg of 'seed' per hectare. The spacing is mainly related to the influence on growth habit and the availability of water. If grown mixed with tef or other small grains, the planting distance in Ethiopia is usually 70 cm or more; in the border plantings, the distance was 30–40 cm. This rather wide spacing and the comparatively low stand of tef allow the safflower plants to grow bushy with many branches of varying lengths and seed-heads at many levels. Close spacing will result in taller plants with thinner stems and their heads mainly near the top of the plant.

When grown as a peasant crop, safflower is sown by the most convenient method and, in fact, is usually hand-planted or broadcast as part of a mixed crop. There is seldom any particular planting equipment. In regions where equipment for grain sowing is available, this can usually be adjusted to sow safflower. Safflower should, preferably, not be sown deeper than c. 5 cm.

In Ethiopia, small grains are broadcast over the field, which immediately thereafter is trodden. During treading, the sparse safflower seeds are planted individually, as are border plantings.

The initial slow growth habit of safflower makes it extremely susceptible to weed competition after emergence, and two to three weedings may be required before the crop can compete. In this requirement, safflower and tef are similar. The combination of those two crops in Ethiopia is thus very logical. Fields with small grains in Ethiopia are cleaned by hand-picking the weeds. This is usually done 2–4 times. The small grains, particularly tef, develop slowly at first too and do not compete too strongly with safflower.

Safflower can be attacked by a large number of pests and diseases, but control measures are not normally required nor feasible, especially in smallholders mixed crops. Mostly diseases and pests of safflower, though present, will become important only in large pure stands. Ashri (1971) found that Ethiopian safflower was mostly hardly susceptible or even resistant to attacks by rust (*Puccinia carthami* Cda.), leaf-spot (*Ramularia carthami* Zaprom. and *Cercospora carthami* Sund. & Ramak.), powdery mildew (*Erysiphe cichoracearum* DC.), and phyllody caused by a mycoplasma. Castellani (1940) reported that attacks of *P. carthami* in the Ethiopian Highlands are never such that special precautions are necessary. But according to him, attacks of *Cercospora carthami* can be violent and of economic importance in Ethiopia.

De Lotto & Nastasi (1955) mentioned *Dactynotus compositae* Theob. as a damaging insect in Eritrea. The same insect was found on safflower by Hill & Tesfaye (1965) at Alemaya and by Schmutterer (1971) at Bako. Other insects feeding on *Carthamus*, as reported by Schmutterer, are *Heliothis peltigera* Schiff. and *Acanthiophilus helianthii* Rossi.

Jannone (1952) reported that the aphid *Macrosiphum solidaginis* F., or at least a species very close to it, was extremely damaging to experimental, almost pure stands of safflower near Feddis (Harergie). It almost completely destroyed the crop. In these experimental plantings, a wide distance was used: 50–60 cm in the row, 60–70 cm between rows. Castor was interplanted at 2 m × 2 m. The aphids attacked the leaves, stalks and involucral bracts in all stages and caused the plants to dry for the lower two-thirds before ripening. Spraying the safflower with an aqueous extract of castor, which was not attacked at all by the aphids, had no result.

Safflower appears to be very susceptible to nematode attacks. The temperature for the heaviest attacks coincides with optimum temperatures for the parasites (c. 32°C) (Harold et al., 1963; Lear et al., 1966).

In Ethiopia I saw as a rule rather healthy-looking safflower but I was told that farmers in several regions believe that sowing a field purely with safflower means crop failure (pers. commun. Dr Amare G., 1972).

Harvesting safflower is comparatively simple. The crop does not lodge or shatter and is relatively resistant to insect attack and bird damage. When mature, the crop may be left standing in the field for up to a month with small loss. Only wet and warm weather in this period may cause damage by germination of the seed in the head. Harvesting can take place when the seeds separate easily from the head by squeezing; this is normally 35–40 days after maximum flowering. The most common method for harvesting is to cut the whole plant, let it dry completely and then to thresh it on any hard smooth surface. For mechanical harvest, most equipment used for small grains may be easily adjusted to suit safflower, but the bristles can cause problems by blocking air-inlets and radiators.

Pure crops grown under dryland conditions yield 200–1500 kg of seed per hectare; under irrigation, maximum yields of 5500 kg/ha are possible. In Ethiopia, unirrigated pure stands of safflower have yielded more than 3500 kg/ha at Debre Zeit, with an average rainfall of 1115 mm per year (Asrat Felleke, 1965). Even higher yields are reported from Bako in 1968 (Bako Res. Stn Progr. Rep., 1970 and 1971). The best results were obtained with the same indigenous cultivar in both years in both places.

Irrigated culture is, to my knowledge, not practised in Ethiopia. But safflower might be an interesting alternative crop for such irrigated schemes as Tendaho, where rice and sorghum are eaten by birds (Kline et al., 1969).

It is difficult to assess an average yield for mixed crops as it is closely correlated with the portion of each crop in the mixture.

Huffnagel (1961) indicated that safflower is sown in July or August in the lowlands, and harvested in February or March. In the highlands, it is sown from June to August and harvested in October and November. These periods are well in accordance with what I saw.

In Ethiopia, the grain is harvested around the time that the safflower starts to ripen. The safflower remains on the field and is later harvested by hand as described above.

The seed is stored in clay pots. In general, moisture and high temperatures, especially in combination, are harmful during storage. In fact, the most important factor for safe long-term storage is the moisture content of the seed. It should preferably be 40–80 g/kg. Data from Morgagni (1939) show that Ethiopian safflower can contain less than 35 g/kg.

Uses (non-Ethiopian data mainly from Weiss, 1971)

In Ethiopia, pounded seed wrapped in cloth is used to grease the 'mitad' (injera pan). Decorticated seed is pounded finely and made into a stimulating beverage or into 'fitfit', a porridge-like mixture of injera, spices and pounded oilseeds. The beverage and fitfit are eaten especially on fasting days. Roasted seed as such or mixed with other oilseeds or grains is sometimes offered as a snack. Safflower oil is produced in the home by cooking cracked seeds with water. The floating oil is skimmed off.

As in other countries, safflower oil is appreciated, but sesame oil is preferred in regions where sesame can be produced.

The threshed plants and the kitchen left-overs are discarded in the field where they are eaten by the ever present goats and cattle.

The oil contents of safflower achenes are not very high: 200–300 g/kg (Chavan, 1961; my own findings) but new cultivars with c. 400 g of oil per kilogram have been bred (Weiss, 1971). The oil may be extracted or pressed any common way, leaving quite a lot of presscake. Decortication of the achenes before pressing gives a better quality of oil as well as of presscake (Chavan, 1961).

In India, the traditional uses of the oil are for cooking, lighting and soap manufacture, and to dilute other, more expensive, oils and fats (Chavan, 1961). In Ethiopia I only encountered the culinary uses. Medicinally the oil can be used internally as a mild purgative, charred oil externally for the treatment of sores and rheumatism (Chavan, 1961).

The use of the oil for human comsumption is traditional in several countries with a peasant agriculture, but it is rather recent in industrial countries, where it was known mainly as a drying oil for paints and varnishes. The use for human consumption there rose strongly as a result of the considerable publicity given to the suspected relationship between high intake of saturated fatty acids and cardio-vascular diseases. Safflower oil contains a low percentage of saturated fatty acids and a high percentage of polyenoic fatty acids. It is now used for the preparation of oils of the 'salad dressing type', cooking oil, margarine and some imitation dairy products.

A disadvantage of safflower oil is the oxidative instability which reduces storage life of the edible products, especially in hot climates. New cultivars producing an oil with a much higher oleic and a much lower linoleic fatty acid content have been developed. This oil is much more stable at high temperatures, as it is more saturated (Knowles, 1971). Heating the oil in the presence of such spices as red pepper, turmeric or dry ginger improves the keeping quality quite effectively (Chavan, 1961). Hydrogenation of the oil to give it greater stability rendered it too hard in consistency for cooking oil (Chavan, 1961). On the other hand, the oil is particularly suitable where a high stability and added flavour at low temperatures are desired.

The technology of the oil and its uses have been studied intensively in recent years. In drying quality, the oil is intermediate between soya and linseed oil. The high content of linoleic acid and the absence of linolenic acid make it especially suitable for protective coatings (Weiss, 1971: a detailed account).

Use of the presscake for animal food is possible. It is especially suitable for ruminants because of the high proportion of hull. If given to dairy cows, it does not impart any objectionable flavour to the milk. Stored under dry conditions the cake keeps rather well. It is possible to prepare a flour for human consumption from it (Chavan, 1961). The flour is acceptably light-coloured but has a bitter taste. The bitter principle can be extracted with ethanol. The final product contains about 700 g of protein per kilogram of presscake.

If excess presscake is available, it may be used advantageously as a fertilizer. Although it requires a long time to decompose, it has excellent effect on structure and water-retaining ability of the soil (Chavan, 1961).

The florets, which are also thought to have some medicinal properties (stimulant, sedative, laxative, depending on the amount administered) have been the source of two dyes through the ages. The yellow dye, carthamidin, is very soluble in water and is used as a food colour ('false saffran'). The second dye, carthamin, confers red colours to clothing, the hue depending on the way of preparation (pH!). According to Chavan (1961), the main reason for safflower cultivation in Ethiopia was for the dye. When I was in Ethiopia, this was certainly not so. Perhaps the typical orange-red cotton head-shawls of the Kottu women from the Chercher Highlands were coloured with safflower. They are nowadays largely replaced by factory-made printed cloths.

The young plant may be eaten as a pot-herb or as salad. It contains a fair amount of iron and some carotene. In older stages, the plant forms a valuable cattle feed, including as silage. In India, it is sometimes specially grown for this purpose. It may produce 10 Mg/ha of fresh fodder (Chavan, 1961). I never heard of these uses in Ethiopia.

Statistics on the production, area and trade in safflower are difficult to obtain because the crop is usually included in 'minor crops' or 'other oilseeds'. The sparse data are often conflicting. According to Asrat Felleke (1965), safflower was produced solely for local consumption in Ethiopia. The production of Ethiopia was then estimated to be 90 Gg. Given the average yield in Ethiopia of 550 kg/ha (Westphal, 1975), this would mean that at least 164000 ha must have been planted under safflower in that year. Weiss (1971, p. 537) indicated that Ethiopia's production increased from 16 Gg in 1960 to 46 Gg in 1968, and that 56000 ha was being sown to the crop in 1966. With the earlier quoted average yield of 550 kg/ha, this would only have yielded c. 31 Gg. Still according to Weiss, there is some export from Ethiopia through Djibouti.

Chemical and physical properties (data mainly from Weiss, 1971)

Safflower fruits can be up to 9 mm long, and up to 5 mm thick and wide (Mensier, 1957). In my Ethiopian material, 8 mm was the maximum length. The fruit weight can vary from c. 35 mg to c. 75 mg (Weiss, 1971). Commercial safflower fruits usually consist for 60-70% of their weight of kernel, the rest being hull (Weiss, 1971). But higher proportions of hull have been reported by Mensier (1957) and for Ethiopia by Morgagni (1939). The reserve material of the safflower seed is chiefly in the form of oil and protein; in the dormant seed, no starch was found (Chavan, 1961; Weiss, 1971).

Chavan (1961) mentioned 200–300 g/kg for the oil content of whole fruits of Indian safflower; new cultivars in the United States contain about 400 g/kg (Knowles, 1958; Weiss, 1971). Twenty-one samples from my collection from Ethiopia, investigated in the Netherlands, had a range of (134)240–300(326) g of oil per kilogram, the mean value being 275 g/kg. The kernel contains c. 500 g/kg (Mensier, 1957), but Morgagni (1939) and Ferrara (1943) reported c. 600 g/kg for Ethiopian safflower. A complete survey of Morgagni's and Ferrara's observations is given in Table 25. The food value of Ethiopian safflower fruits, as given by Ågren & Gibson (1968) is surveyed in Table 26. The protein content of safflower fruits is mostly around 120–150 g/kg (Weiss, 1971) but Ågren & Gibson (1968) indicated lower values for Ethiopian safflower. Differences in oil and protein content are usually the result of different percentages of hull. Such differences are induced by genetic and ecological factors (salinity). The protein content is influenced by such ecological factors as temperature and fertilizers.

The oil is pale yellow. The colour is probably associated with pigments such as β-carotene, which has been reported in a quantity of 21.6 mg/l (Weiss, 1971). Some characteristics of the oil are surveyed in Table 27.

The percentages of the composing fatty acids may vary greatly in seed samples from different origins but almost always the two main ones are linoleic and oleic acid. A survey of the composing fatty acids from the literature and 21 of my Ethiopian samples is given in Table 28. According to Weiss (1971), ecological factors during fruit formation may influence the quality of the seed to such extent, that technically different oils are obtained from the same cultivar.

Table 25. Physical and chemical analyses of samples of safflower fruits from Ethiopia by Morgagni (1939)(the first values) and Ferrara (1943) (values between brackets; the other values given by him are exactly the same as those of Morgagni, 1939).

Origin of sample	Harer	Galla & Sidamo	Gonder	Addas (Shewa)	Addis Abeba	Forli
Physical properties						
Mass density (kg/m³)	550 (432)	542	520	542	532	530
Average length (mm)	7.29 (7.60)	7.67	7.36	7.75	7.53 (7.75)	7.45
Average width (mm)	3.26 (3.37)	3.36	3.26	3.26	3.30 (3.26)	3.30
Average weight (mg)	45 (40)	45	40	45	50	50
Kernel (g/kg)	500	445 (444)	500	444	500	480
Chemical composition of kernels (g/kg)						
Moisture	55 (33) (35)	33	34	34	36	35
Ether extract	621 (592)	591	586	636	598	618
Crude protein	257 (190)	231	234	220	252	246
N-free extract + cellulose	63 (162)	124	. (124)	88	107	103
Ash	22	22	. (22)	22	21	21
Oil in whole fruits	310 (290)	263	293	283	299	279

Table 26. Food value of Ethiopian safflower fruits. (After Ågren & Gibson, 1968; all data per kg).

	Range		Range
Crude energy (MJ)	16.9–23.347	Calcium (mg)	520–2270
Moisture (g)	26–89	Phosphorus (mg)	1730–4970
Nitrogen (g)	15–29	Iron (mg)	76–215
Protein (g)	75–143	Thiamin (mg)	2.8–5.1
Fat (g)	88–436	Riboflavin (mg)	0.5–1.1
Carbohydrate (including fibre; g)	359–726	Niacin (mg)	6–26
Fibre (g)	214–351	Tryptophan (mg)	1240–1270
Ash (g)	16–34		

Table 27. Some characteristics of safflower oil. (After Weiss, 1971, and Mensier, 1957).

Acetyl value	12.5
Acid value	0.4–10.0
Hehner value	95–96
Hydroxyl value	1–12
Unsaponifiable matter	5–15 g/kg
Iodine value (Wijs)	129–151
Polenske value	0.1
Refractive index at 25°C	1.473–1.476
at 40°C	1.467–1.470
Reichert-Meissl value	0.0–2.5
Relative density at 15°C	0.925–0.938
at 25°C	0.919–0.924
Saponifacation value	186–203
Thiocyanogen value	82–87
Titre	7–17°C

With the high percentage of linoleic acid, di- and tri-linoleoglycerides form a large proportion of the glycerides present. According to Chavan (1961), 63% is oleo-dilinoleic glyceride, and 15% is dioleo-linoleic glyceride.

Seeds from heads at different positions on the plant vary in several important characteristics. Considerable variation will be found not only between different heads on a single plant, but also between heads at similar positions on different plants within one field. This makes representative sampling difficult. Usually, seeds from primary

Table 28. A survey of composing fatty acids in safflower oil. Data from Weiss (1971), Chavan (1961) and Mensier (1957) compared with 21 Ethiopian samples from my own collection (SL)[1]. (Data as substance fraction, %).

Source	Weiss	Chavan	Mensier	SL	
				Range	Mean
Saturated	5–10	6.0	6–9	7–10	8.7
Palmitic	6–7	3.0	.	(5.3)5.7–6.8(7.0)	6.2
Stearic	2–3	1.0	.	1.8–2.3(2.9)	2.1
Arachidic	0.2	0.5	trace	trace	–
Myristic	.	1.5	trace	trace	–
Lignoceric	.	trace	trace	trace	–
Unsaturated	90–95	94	91–94	90–93	90.2
Oleic	12–14	33.0	16–25	9.3–15.7(19.4)	12.5
Linoleic	76–78	61.0	63–72	(70.3)74.2–81.9	78.7
Linolenic	nil	nil	0.1–6.0	nil	–

1. Methods: see castor or sesame.

Table 29. Contents of amino acids in protein (g/kg) of safflower: a, unprocessed meal; b, processed meal; c, FAO provisional recommended reference pattern for amino acids. (After Weiss, 1971).

	a	b	c		a	b	c
Isoleucine	39	40	42	Valine	49	57	42
Leucine	55	62	48	Histidine	20	24	.
Lysine	27	31	42	Arginine	78	93	.
Phenylalanine	53	44	28	Glycine	.	58	.
Tyrosine	.	31	28	Aspartic acid	.	98	.
Total sulphur amino acids	.	33	42	Glutamic acid	.	194	.
Methionine	15	17	22	Serine	.	44	.
Threonine	29	33	28	Proline	.	41	.
Tryptophan	12	16	14	Alanine	.	58	.

heads have the highest weight and the lowest oil content; the reverse accounts for seeds of tertiary heads (Weiss, 1971).

Weiss (1971) indicated that vitamin E, which is a mixture of α, γ and δ-tocopherol, is present in the following proportions in oil: total tocopherol 0.89 g/kg, consisting of α 51.5%, γ 21.9%, and δ-tocopherol 26.6%.

Content of protein in the presscake from undecorticated seed is 200–220 g/kg and of hull in presscake 600 g/kg. After removal of the hull and the bitter principle, content of protein was 700 g/kg and of α-tocopherol 0.8 mg/kg. Table 29 gives some data on the composing amino acids. The protein is of a rather high biological value; only lysine is critically limiting, while methionine and isoleucine are borderline. The biological quality of the protein changes only slightly by the processing of the meal (Weiss, 1971).

From amino acid data, the correct multiplication factor for calculation of the protein content from the nitrogen content is 5.42 for safflower (Weiss, 1971).

Chavan (1961) and Weiss (1971) give detailed accounts on the colouring agents in the florets of safflower, and their preparation.

2.5 Cordeauxia edulis Hemsley

A very interesting plant is *Cordeauxia edulis* Hemsley. The Somali call the plant gut or guda, the seed jeb or jeheb (yicib) (Marassi, 1939; Cufodontis, 1955). It belongs to the *Leguminosae* (*Caesalpinioideae*), and is indigenous in a limited area in Somalia and the adjoining region of Ethiopia (Bally, 1966).

It is a densely branched evergeen shrub, up to 3 m high but usually lower, with very hard wood. The leaves are exstipulate, paripinnate, and 3–5 cm long. The leaflets, mostly in four pairs, coriaceous, ovate to oblong, 1–2.5 cm long, 1–1.5 cm wide, olive-green above, lighter with many red glands beneath. Flowers in few-flowered corymbs at apex of the branches, hardly exceeding the leaves, 2.5 cm diam., bright yellow.

Sepals 5, basally connivent, oblong, about 1 cm long, green with red glands. Petals 5, almost equally spoon-shaped, c. 1.5 cm long, with a nail. Stamens 10, straight, free, the filaments hairy below the middle. Ovary shortly stipitate, biovulate, densely glandulate, at least the style, with a terminal obtuse stigma. Legume coriaceous, slightly compressed ovoid, 4–6 cm long, curvate, apically beaked, dehiscent, bivalvate, very often with one seed only. Seed ovoid, 3.5–5 cm long, exalbuminous; germ with thick fleshy cotyledons, a small radicle and a late-developing plumule (Hemsley, 1907; Brilli & Mulas, 1939; Bally, 1966).

The local population distinguishes two forms: 'sulei' and 'mogollo'. Sulei has smaller leaves and fruits than mogollo, its habit is more open and erect (Brilli & Mullas, 1939).

The plant is found in hot dry climates with average daily temperatures over 25°C and an average annual rainfall of less than 100 to about 300 mm (Bally, 1966, distribution map; Mesfin, 1970, Maps 21, 26). Under more humid conditions, the plant does not produce fruits: it is never found near water (Brilli & Mulas, 1939).

Cordeauxia prefers stoneless, reddish, sandy, siliceo-ferruginose, non-calcareous soils (Brilli & Mulas, 1939). It has been suggested that the limited geographic distribution might be explained by special soil conditions. Analysis brought out nothing but the very poor character of the soil (Bally, 1966, soil analysis).

The plants are very long-living: according to Somali sources, more than 200 years. Flowering starts just before the first rains fall. Depending on the amount of rain, the fruit can develop in less than 2 weeks. As soon as the rains cease, fruit formation stops immediately, but the ovaries are not shed; they remain dormant for 4–5 months. At the first rains, the fruits attain maturity in about a week (Brilli & Mulas, 1939).

Both, leaves and seeds are used. The seed is eaten raw, roasted or cooked. It has a sweetish agreeable taste (Bally, 1966), and a high nutritive value (Brilli & Mulas, 1939). From the leaves, a tea is brewed and the extract is also used as a dye. No therapeutic use is known (Brilli & Mulas, 1939).

The plant is no good fodder and induces intestinal disorders in goats (Brilli & Mulas, 1939), which seem to be fond of the leaves (Bally, 1966).

The seeds have been investigated several times. Some data are summarized in Table 30.

The oil is yellow and has an acid value of 1.93 (Brilli & Mulas, 1939).

Table 30. Composition of the seed of *Cordeauxia edulis* Hemsley (g/kg); data from Brilli & Mulas, 1939; Marassi, 1939; Bally, 1966.

Moisture	80–100	Reducing sugars	23–53
Crude oil	100–120	Sucrose	116–216
Total N	25	Ash	22–37
Crude protein	110–160	Nutrient ratio	1:6.5
Cellulose	27–33	Tests for alkaloids	
N-free extract	610	and glycosides:	negative

2.6 Cucurbitaceae

Several *Cucurbitaceae* are grown in Ethiopia, and their fruits or seeds are found on many markets. The seeds play only a minor role in exports of Ethiopia (Asrat Felleke, 1965: 26 Mg).

Pumpkins have the widest dissemination (Amharic: duba, baharkel, yequara-arag. Gallinya: dabakula. Gumuz: patue. Kaffinya: buko, bukeh. Konso: dahanta. Tigrinya: wushish). They are offered on most markets in and east of the Rift Valley (Westphal-Stevels, 1975), and are an important crop in the Lake Tana region (Ufficio, 1938).

Ethiopian pumpkins belong mainly to two species: *Cucurbita maxima* Duch., the commoner; and *C. pepo* L. They are mostly lumped under the same vernacular names (Westphal, 1975, p. 211). The fruits are variable in shape and size, but usually globular to ellipsoid, dark green, mottled with light yellowish green, often with orange parts, also all orange. The pulp is eaten as a vegetable in the wot and the oil-rich seeds are roasted and consumed as a snack. The seeds are also used as a vermifuge. For the latter purpose, whole seeds are used since the active principle is located in the seedcoat (Schuster, 1977).

As oil crop, they have the disadvantage that they have very much pulp in relation to the amount of seed. Large-scale separation of the seeds is therefore expensive (Chevalier, 1949).

In Eritrea, seeds of *Cucumis* sp. are actually used to prepare oil. The Baza people plant a melon (according to Chiovenda: *Cucumis melo* L. cv. Chate) in their sorghum fields as oil crop (Chiovenda, 1929).

In the region between Tessenei and Keren, seeds of 'shobob' or 'sanat' are a commodity on markets. This is seed of a *Cucumis* sp. collected from the wild but also cultivated. The fruits, usually 18–20 per plant, are 10–14 cm long and 5–6 cm thick; while ripening, the pulp vanishes, leaving the seeds in a brittle pericarp, out of which they can easily be removed (Baldrati, 1950). According to Baldrati (1950), the scientific name is *Cucumis melo* L. var. *agrestis* Naud., but according to Jeffrey (1967) this variety is hardly useful in describing the actual pattern of variation of *C. melo*, and should not be distinguished. When cultivated, it is usually sown with sorghum, but sometimes with cotton (Baldrati, 1950).

The seed is very similar to that of a melon, but it is smaller. One litre of the seeds weighs 650 g, and one kg of it contains 334 g of oil. The oil has a nice yellow colour (Suzzi, 1904/1905).

Suzzi found the following characteristics for the oil:

mass density (15°C)	922.2 kg/m^3
solidification range	−1 to −5°C
acid value (as oleic)	0.23
saponification value	190
iodine value (Wijs)	118

Photograph 17. Seeds of *Cucurbita pepo* (SL 587; × 3).

Besides its oily seeds, shobob deserves interest for its habit, which renders it a good plant to combat erosion (Baldrati, 1950).

If the shobob is indigenous to Ethiopia, pumpkin is not. There are different views on the origin of the species: some authors think them all to originate in Tropical America, whilst others think them to be Asiatic (Greenway, 1944). There are also authors that think *Cucurbita pepo* and *C. moschata* Duch. ex Poiret to be American, but *C. maxima* to be Asian (Schuster, 1977). The etymology of the Amharic name 'baharkel' might indicate a rather recent introduction ('bahar' = sea, commonly used for foreign; 'kel' = calabash).

The common way to grow cucurbits in Ethiopia is to sow them in a field of tall growing cereals, particularly sorghum. Their growing cycle is similar to that of long-cycle sorghum so that sowing is done at the onset of the rains and harvest lasts through December. It is also common to sow pumpkins near the house, the soil may be fertilized with dung or compost (Nowack, 1954; Brooke, 1959).

The scarce literature on cucurbits from Ethiopia is mainly related to pests and diseases (e.g. Jannone, 1940; de Lotto & Nastasi, 1955; Stewart & Dagnatchew, 1967; Schmutterer, 1971).

Per kilogram whole seeds, most cucurbits contain 300–350 g of an oil with a pleasant taste and colour (Baldrati, 1949; Schuster, 1977). Nine samples of my Ethiopian collection contained about 350–420 g/kg (on dry basis). Ågren & Gibson (1968) gave the following average composition of pumpkin kernels from Ethiopia (data are per kilogram edible portion).

Food energy (MJ)	(18.910)20.960(22.320)
Moisture (g)	(56)71(96)
Nitrogen (g)	(17)40(50)
Crude protein (g)	(278)300(318)
Fat (g)	(327)374(402)
Carbohydrate total, inclusive fibre (g)	(201)271(394)
Fibre (g)	(193)227(263)
Ash (g)	(35)38(40)
Calcium (mg)	(620)740(930)
Phosphorus (mg)	(7170)8410(9290)
Iron (mg)	(106)217(443)
β-carotene equivalent (μg)	trace
Thiamin (mg)	(1.7)2.9(4.0)
Riboflavin (mg)	(0.9)1.2(1.5)
Niacin (mg)	(25)49(67)
Rubbish in sample as purchased (g)	(40)110(180)

In my Ethiopian collection of cucurbitaceous seeds, I found clear differences in size and colour. The length and width varies from 16 to 25 mm and from 9 to 13 mm, respectively. Within a sample, width is generally more constant than length.

Four distinct colour groups were present:

1. 'White', white (Royal Horticultural Society Colour Chart 155D) to yellowish white (RHS-CC 158D), margin greyed-yellow (RHS-CC 161D). With 23 samples, it was the largest group (*Cucurbita maxima* Duch.).
2. 'Chamois', 3 samples, greyed-orange (RHS-CC 165B-C), lighter at margin (*Cucurbita pepo* L.).
3. 'Dirty white', 1 sample, greyed-orange (RHS-CC 161A), darker at margin (RHS-CC 164D) (species?).
4. 'Black', 1 sample, very dark brown (RHS-CC 200A) to black (RHS-CC 202A), slightly lighter near apex and at margin (*Cucurbita ficifolia* Bouché).

Three samples contained both 'white' and 'chamois' seeds. One mixed sample was purchased at Debre Zeit market, all other non-white samples originate from the Chercher region.

Sowing five market samples at Wageningen gave the following observations:

- The vegetative parts of all (11) plants showed little variation.
- Most plants formed roots at the nodes.
- There were considerable differences in the length of the growing cycle.
- The form and colour of the fruits was highly variable.

2.7 Glycine max (L.) Merr. (Leguminosae, Papilionoideae)

Soya is a Chinese crop, whose cultivation was limited to China and the adjoining area up till the end of last century. Until World War II, production was mainly in

China, Korea, Indonesia and Japan. Only after the War did the crop spread to other areas of the world (Hittle, 1975).

Soya has been tried in Ethiopia since the fifties (Hammar & Haraldson, 1975), particularly because of its valuable proteins. The Ethiopian Nutrition Institute has a programme on the development of recipes for use of soya beans in traditional dishes (Hiwot, 1975).

A pilot study on how to introduce the crop to local farmers was started in 1975. Simultaneously farmers' wives were taught how to prepare soya beans and fit them into local diet and food habits (Hammar & Haraldson, 1975).

The crop has given varying results but in some areas it can be produced profitably. In the first years after its introduction to Ethiopia, soya was considered well adapted to the Jimma (1700 m) area with yields over 2500 kg/ha (Siegenthaler & Wilson, 1958), but the yield potential in Debre Zeit (1680 m) was insufficient at that time (Agric. Ethiop., 1964).

Around 1970, yields of 1600 kg/ha were achieved at Chilalo Awraja Development Unit (CADU) (2100 m). This was considered promising and an introduction programme was launched. New introductions have shown yields of 3 to 4 Mg/ha (Hammar & Haraldson, 1975).

The highest yields seem to be achieved at altitudes between 1300 and 1700 m. Good yields were sometimes obtained at 1900 m, while no acceptable yields were achieved at altitudes over 2000 m (Hammar & Haraldson, 1975).

In 1976, Wolde Amlak Araya gave the following survey of soya productivity in Ethiopia.

Cultivars	Locality	Soil	Altitude (m)	Yields of best yielders (kg/ha)	Average yield (kg/ha)
Mid-season cvs	Neghelle (Arussi)	clay-loam	1860	c. 1400–1600	1526 (10 cvs)
(National Yield Trial)	Awasa	loam	1600	c. 1750–2300	1995 (7 cvs)
	Deneba	loam	1680	c. 2150–2400	2256 (9 cvs)
	Didessa	red	1650	c. 1650–2640	1958 (7 cvs)
	Gambela	sandy	450	c. 1250–1500	1252 (8 cvs)
Late-season cvs	Bako	red	1650	c. 950–1100	989 (7 cvs)
(National Yield Trial)	Jimma	black	1700	c. 750–1500	1031 (8 cvs)
	Jimma	red	1700	c. 2100–2450	2206 (8 cvs)
International	Bako	red	1650	c. 2700–3200	2992 (15 cvs)
Soybean Variety Trial	Deneba	loam	1680	c. 1800–2100	1949 (17 cvs)
	Debre Zeit	loam	1860	c. 2000–2750	2106 (15 cvs)
	Jimma	red	1700	c. 1700–2100	1754 (16 cvs)

Mid-season cultivars needed (103)110–125(154) days to maturity and were in general little to moderately heavily attacked by bacterial blight. Late-season cultivars had a cycle to maturity of (138)151–169(170) days. They were generally heavily attacked by rust and showed very different levels of bacterial blight attack.

Downy mildew, purple stain and viruses have been observed, but have not done real damage to the crop so far (Hammar & Haraldson, 1975).

Soya seems to produce best on clayey soils in Ethiopia, probably because of the water-retaining capacity (Hammar & Haraldson, 1975).

Inoculation of the soil with *Rhizobium* sp. has not significantly increased yields, but P fertilizer (17.5–22 kg/ha) on soils poor in this nutrient has given very good results (Hammar & Haraldson, 1975).

Soya cultivars have a very strong reaction to differences in daylength. Most are therefore adapted for full-season growth in a band usually not wider than 150–250 km from north to south (Hittle, 1975).

Trials have indicated that a seed ratio of 70 kg/ha should be used and a spacing of 40 cm between the rows (Hammar & Haraldson, 1975), but at Bako the highest yields were reached at sowing densities of 60 cm × 3.3 cm (Wolde Amlak Araya, 1976).

2.8 Gossypium spp. (Malvaceae)

Vernacular names: tit (the plant, the fibre), tiftirre (the seed) (Amarinya, Gallinya); duht (Tigrinya, northern Amarinya); othbe (Saho); udbe (Somalinya); garatita, futota (Konso); girbi (Gallinya); cotton (English), coton (French); algodón (Spanish).

In most of the warmer and drier regions of Ethiopia, different species of *Gossypium* can be found, both cultivated and wild. Cultivation is mostly for the fibre, but the seeds are used for oil and are a common commodity on many Ethiopian markets. Cotton has been one of the more valuable and extensively grown crops of Ethiopia for a very long time. An old and well established 'cottage industry' in handspinning and weaving cotton also exists. It involves thousands of people all over the country (Nicholson, 1960; my investigations).

When cotton first came to Ethiopia is not exactly known, but most probably it was grown there already in the earliest centuries of our era (Nicholson, 1960). There is a theory that a primitive *Gossypium herbaceum* L., ancestral to the 'race' *africanum* and to the known cultivated Old World cottons, was developed in SW Ethiopia. Cotton, on the other hand, was grown at Mohendjodaro (India) as far back as 3000 BC (Wrightly, 1960).

Genetic research so far leads to the conclusion that Old World cotton is of African origin. As the species must have had an agricultural evolution before it reached Mohendjodaro, cotton must have been grown in Africa before 3000 BC, and probably long before. Even then, although cotton may have been grown for its oil long before its lint was spun, it is not likely to have been among the first African plants to be domesticated (Wrightly, 1960). The early history and origins of spun cotton are still far from being satisfactorily understood.

The cultivated cotton in Ethiopia belongs to the following species: *Gossypium barba-*

dense L., *G. hirsutum* L. (notably *G. hirsutum* var. *punctatum* (Schumacher) Hutchinson), and *G. herbaceum* L. var. *acerifolium* (Guillaumin & Perrottet) Chevalier. There are many infraspecific hybrids in *G. hirsutum* (Nicholson, 1960; Bigi, 1969). Formerly *G. arboreum* L. was cultivated to a lesser extent in the lower regions of the west of the country (Bigi, 1969).

Neither *G. arboreum*, nor annual *G. herbaceum* occur in recent collections. In these collections, the most widespread species by far, undoubtedly is *G. hirsutum* var. *punctatum*, while *G. herbaceum* var. *acerifolium* now only occurs in areas in the south and south-west of Ethiopia and in the Webi Shebelle area of the Ogaden (Nicholson, 1960). In Herbarium Vadense, Ethiopian *Gossypium* belongs to *G. hirsutum* var. *punctatum* and *G. barbadense*, only (respectively Anonymous: Abessinia; Anonymous, Sennaar, Abessinien; SL 1744, SL 1920–1921, SL 1951, SL 1994–1995; WdeW 9756, and F. G. Meyer 8732; SL 1922, SL 1993).

Perennial introduced cottons from the New World (*G. barbadense* and *G. hirsutum* var. *punctatum*) are clearly spreading rapidly in peasant cultivation (Nicholson, 1960), and even in remote areas in the south-west, *G. herbaceum* var. *acerifolium* and *G. hirsutum* var. *punctatum* are often encountered in mixed stands (Cufodontis, 1957).

Seed samples of the two most common species can be distinguished easily. Seeds of *G. barbadense* have no fuzz when the lint is pulled off, except for a turf at one end. Seeds of *G. hirsutum* are covered all over with fuzz after removal of the lint.

With some exceptions (but as regards the recent introductions of *G. hirsutum* and *G. barbadense* without exception), all cottons in Ethiopia are perennial. The perennials are grown for 3 to 5 years or more.

Traditional cotton growing in Ethiopia is usually at altitudes between 1000 and 2000 m, but in Eritrea usually between 900 and 1800 m. It is a perennial culture under dryland conditions, associated with other crops, especially with cereals. The first 2–3 years, a mixture of cotton and cereals is grown, after which another 2–3 years of pure cotton may follow. The traditional cultivars are short-linted; according to Nicholson (1960), *G. hirsutum* seems to be especially well adapted to the highland conditions.

The altitudes at which rain-fed cotton is grown in Ethiopia, are determined by the incidence of frost and related to the onset of the wet season. At altitudes over 1500 m night frosts occur in many regions of Ethiopia during October and November, just after the rains. They coincide in most areas with a stage of the cotton plant sensitive to frost (Huffnagel, 1961). In the north, frosts retard growth to such an extent, that even introduced annual cultivars are grown on a biennial cropping basis (Nicholson, 1960). On places with an early wet season or where irrigation is available, earlier sowing allows earlier harvesting and cotton can be sown at higher altitudes (Huffnagel, 1961).

The most suitable areas for rainfed cotton are situated at altitudes of 1000 to 1400 m, with an annual rainfall of c. 630 to 760 mm. Because of the occurrence of malaria, peasant farmers avoid these areas. By far the most successful method of growing cotton in Ethiopia at altitudes above 1000 m on a plantation basis is use of supplementary irrigation (Huffnagel, 1961).

In S Ethiopia, the climatic conditions are such, that there is no marked effect on growth in the coldest months of the year. Perennial cotton can be grown under these conditions, but pests and diseases are severe in this region, and the tendency is to grow cotton at high altitudes to escape them. At those altitudes the same problems arise as in the north (Nicholson, 1960).

There are several areas in Ethiopia where cotton might be grown commercially, either with natural rainfall or under irrigation. Estimates of the total area, suitable for cotton without a reduction in the production of other crops, of 500000 ha have been made (Nicholson, 1960). In a few, notably in the Awash valley, W Eritrea, Beghemder and Gemu Gofa, this is practised already (Nicholson, 1960; Bigi, 1969; Kline et al., (1969).

Commercial cotton growing is done at altitudes of 750 to 1100 m, mostly with purely foreign annual cultivars (Huffnagel, 1961; Bigi, 1969). In these lowland conditions, long-staple Egyptian types of *G. barbadense* seem to adapt well (Nicholson, 1960).

This modern cultivation is rather novel for Ethiopia. The first trials were by the Italians between 1900 and 1910 in Eritrea. They also built a de-linter and an oil-mill for processing the seed. They were successful to some extent and introduced cultivars were tried (Lavelli de C., 1909; Bigi, 1969).

The large increase of commercial cotton production in Ethiopia started only in the 1950s and the area showed a spectacular growth from nearly 50000 ha in 1966 to more than 83000 ha in 1970 (Statistical Abstract, 1970). A large area of unirrigated or partially irrigated cultivation of cotton (30% of the surface), rotated with sorghum (45%) and sesame (25%), came into existence near Homera (Beghemder) and attracted peasants from all over Ethiopia. On the Tendaho River, the Awash River and near Tessenei and Arba Minch, large irrigated projects were developed. In most of the projects, a system is practised combining machines and hand labour. In 1966, the Institute for Agricultural Research started an experimental station for research on irrigated cultivation of cotton, maize and peanuts at Melka Werer, on the Awash River at an altitude of 750 m, and with an average annual rainfall of 540 mm (Bigi, 1969).

Eight de-linters were present in Ethiopia in 1969, each with a capacity of 20000 to 120000 kg of lint per 24 hours. The biggest was at Tendaho, while there were four in Addis Abeba and three at Asmara (Bigi, 1969).

Pests, noted on cotton in Ethiopia are, for instance: *Diparopsis* sp., *Earias insulana* Boisd., *Platyedra gossypiella* Saund., and *Podagrica puncticollis* Wse. (de Lotto & Nastasi, 1955). *Fusarium* wilt and *Empoasca* spp. are present in many areas of Ethiopia too (Nicholson, 1960). Many more pests and diseases attacking cotton in Ethiopia are reported by Bigi (1954a, b).

In addition to a (partial) insensitivity to the local pests and diseases, the variability of climate and altitude also requires a wide range of adaptability within and between the local cultivars. The perennial species and cultivars of Ethiopia, therefore, are likely to be a good source of desirable characters for breeding (Nicholson, 1960).

Around 1970, c. 60 Gg of lint were produced in Ethiopia (Bigi, 1969). According to Kline et al. (1969), 62% of the weight of the harvest was formed by seed weight at Tendaho. A combination of these data leads to a seed yield of c. 98 Gg in Ethiopia in 1970. Other sources give different figures. Data from FAO are surveyed in Table 31.

Besides the use for cloth, the following uses are made of the cotton plant in Ethiopia (Nicholson, 1960):

- cottonseed oil may be prepared, but is rarely used for cooking
- leaves, flowers and roots are used medicinally, both internally and externally
- in the south-west, a fermented cake, containing cottonseeds, is sometimes prepared for consumption
- lint may be used in magic and rituals.

Observations at Wageningen

- The flower in 4 accessions of *G. hirsutum* var. *punctatum* from Ethiopia was creamy yellow, usually turning pink during anthesis. The plants grown from sample SL 254 from Chelenko (Harergie) could be identified as *G. barbadense*. Their petal colour was similar to that of the other numbers, but purple at the base.
- Germination was slow (t_{max} 30–32 °C; t_{min} 17–20 °C).
- SL 1081 had the weakest vegetative development but the largest number of fruits: the shortest cycle and the largest yield. It was the only daylength-neutral entry.
- The following is a survey of some other observations.

Collection number (origin)	Germination	Weeks from sowing to flowering at 10 and	13 h daylength	Leaf form	Hairs on stem	Petal colour	Anther colour	Weeks from sowing to ripeness	Fruit size (cm)	Number of carpels
SL 254 (Chelenko)	moderate	10	–	large, deeply cleft	absent	creamy with purple base	yellow	16	4–6	3
SL 776 (Dejen)	moderate	14	–	small, not deeply cleft	absent	creamy yellow	creamy	22	<4	4
SL 849 (Infranz)	bad	12	–	small, not deeply cleft	present	creamy yellow	creamy	20	<4	4
SL 861 (Gonder)	bad	14	–	small, not deeply cleft	absent	creamy yellow	creamy	21	<4	4
SL 1081 (Dessie)	moderate	9	9	small, not deeply cleft	present	creamy yellow	yellow and creamy	15	4–6	5

Chemical and physical properties

Cotton seeds are 7–9 mm long and 3–5 mm wide; they weigh c. 700 g/l (Mensier, 1957). The seeds have a brown to blackish hard hull, and are covered with long hairs. After removal of this lint, they are in some species (partially) covered with short hairs (fuzz).

Table 31. Area, yield and production of cotton seed in Ethiopia (source: FAO Production Yearbooks).

Year	Area (10^3 ha)	Yield (kg/ha)	Production (Gg)	Year	Area (10^3 ha)	Yield (kg/ha)	Production (Gg)
1965	34	200	7	1973	135	578	78
1966	40	360	14	1974	120	550	66
1967	49	330	17	1975	130	554	72
1968	53	420	22	1976	120	600	72
1969	53	420	22	1977	110	409	45
1970	53	420	22	1978	110	409	45
1971	97	505	49	1979	165	455	75
1975	99	515	51				

Depending on species, growing conditions and cultivar, the kernel forms 44–60% of the seed weight; oil content of kernel is 340–390 g/kg and of hull less than 10 g/kg. On average, whole seed has the following composition (Mensier, 1957; data in g/kg):

moisture	110
crude protein	200
lipids	200
N-free extract	230
crude fibre	210
ash	38

The oil can be extracted after a thorough removal of the hull with its remaining fibre. The hulls are rich in phosphorus and potash; they are therefore good fertilizer fresh or burnt (Ubbelohde, 1920). Because expelling leaves much oil in the cake (see below), solvent extraction is to be preferred.

Unrefined, the oil is not usable for direct consumption, but when refined it is of good quality (Ubbelohde, 1920). This is because the kernel contains gossypol (4–12 g/kg), a brownish toxic substance, which is partly extracted or expelled with the oil (Mensier, 1957).

Freshly extracted cottonseed oil is red to dark brown. The colour is mainly caused by resins and pigments, less so by gossypol. It has an unpleasant odour and an acrid taste. The gossypol makes the oil toxic (Mensier, 1957).

Refining is done by heating in the presence of a small amount of caustic soda. After decoloration and deodorization, a thin transparent, light yellow, almost tasteless and odourless oil is obtained, perfectly edible (Mensier, 1957).

Some characteristics of the oil are (Ubbelohde, 1920, Mensier, 1957):

relative density (15°C)	0.913–0.932
saponification value	190–198
solidification range	4–0°C
free fatty acids	7.5–80 g/kg
Hehner value	c. 96

refractive index $n_D(20\,°C)$	1.4668–1.4720
iodine value (Wijs)	101–117
acetyl value	20–22
sulphocyanogenic value	61–65
unsaponifiable matter	5–15 g/kg

Table 32. Composition and digestibility in vitro of pressed cottonseed cake from Ethiopia after Chichaibelu et al. (1977).

	(g/kg)		(mg/kg)
Dry matter	960	Na	80
Crude protein	410	Co	4.33
Crude fat	130	Ca	16.79
Cellulose	89	Mn	21.67
Estimated total digestible dry matter	812	Mo	2.45
		Se	0.29
Estimated total digestible nutrients	927	Zn	75.83
Ash	66		
Ca	2.5		
K	14.6		
Mg	6.8		
P	12.8		
S	4.4		
Fe	1.0		

Table 33. Average amino acid composition of the protein of 4 *Gossypium* species as mass fraction (%) of the total nitrogenous matter other than NH_3 (source: Otoul & Marechal, 1975; authors did not indicate cystine).

Amino acid	*G. herbaceum*	*G. arboreum*	*G. hirsutum* var. *punctatum*	*G. barbadense*
Aspartic	10.38	10.44	10.01	10.24
Threonine	3.56	3.78	3.86	3.47
Serine	4.42	4.53	4.50	4.36
Glutamic acid	22.67	23.30	22.52	23.49
Proline	3.99	4.03	4.12	3.98
Glycine	4.59	4.63	4.92	4.53
Alanine	4.38	4.59	4.78	4.24
Valine	4.90	5.12	5.21	4.99
Methionine	1.41	1.50	1.84	1.53
Isoleucine	3.56	3.71	3.77	3.50
Leucine	6.38	6.62	6.71	6.26
Tyrosine	3.03	2.91	2.96	2.93
Phenylalanine	5.53	5.59	5.24	5.58
Lysine	4.66	4.95	5.55	4.60
Histidine	2.86	2.75	2.94	2.79
Arginine	13.66	11.51	11.07	13.60

According to Mensier (1957), about a quarter of the fatty acids of cottonseed oil is saturated, the bulk (c. 9/10th) being palmitic, the rest mainly stearic with traces of myristic and arachidic. The unsaturated fatty acids are oleic and linoleic, the latter forming only a slightly larger fraction. In nine samples from my Ethiopian collection, I made the same observation as far as the saturated fatty acids are concerned, but the amount of linoleic was about double that of oleic. In summary, my observations (mass fractions) were:

oil in dry whole seed	c. 175–270 g/kg
palmitic	c. 20–25%
stearic	c. 2.5–3.3%
oleic	c. 20–25%
linoleic	c. 50–55%

(methods see sesame p. 279)

The extracted flour forms, after detoxification, a feedstuff rich in protein; expelled presscake contains also more oil than other oilseed presscakes.

Cottonseed presscake has the following average composition (data in g/kg; source, Ubbelohde, 1920).

moisture	100
crude protein	430
crude fat	160
N-free extract	160
crude fibre	80
ash	70

Chichaibelu et al. (1977) investigated the composition and digestibility in vitro of Ethiopian expelled cottonseed cake. Their values are summarized in Table 32.

The results of investigations of Otoul & Marechal (1975) on the amino acid composition of the protein of some *Gossypium* species are listed in Table 33.

2.9 Guizotia abyssinica (L.f.) Cassini (Compositae) (2*n* = 30) Fig. 6

'Guizotia': named after François Pierre Guillaume Guizot, French historian and statesman (1787–1874).
'abyssinica': from Abessinia, Abessinian, Ethiopian.

Cassini in Dict. Sci. Nat. 59: p. 237, 248 (1829).
Basionym: *Polymnia abyssinica* L.f.
Type: LINN 1033.5, from Hortus Upsaliensis (cf. Baagøe) (microfiche!).

Synonyms

Polymnia abyssinica L.f., Sp. Pl. Suppl.: p. 383 (1781).
Polymnia frondosa Bruce ex Murray, Travels ed. 2, 7: Tab. 15 (1805); ibid. ed. 3 (1813).

Parthenium luteum Spreng., Novi Prov.: p. 31 (1819).
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Ramtilla oleifera DC. in Wight, Contr. Bot. Ind.: p. 18 (1834).
Guizotia oleifera (DC.) DC., Mém. Soc. Hist. Genève 2, 7: p. 271 (1836).
Guizotia abyssinica (L.f.) Cass., the following varieties: var. *baldratiana* Cif., [Rass. econ. Afr. ital. 30: p. 116 (1942)]; Atti Ist. bot. Univ. Pavia, Ser. 5, 2(2): p. 140 (1944); var. *candussioana* Cif. (l.c.); var. *caulirufa* Cif. (l.c.); var. *corgevinii* Cif. (l.c.); var. *negriana* Cif. (l.c.); var. *pichlsermollii* Cif. (l.c., ort. mut. for *pichisermollii*); var. *sciarapovii* Cif. (l.c.).

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1974: Baagøe, Bot. Tiddskrift 69(1): p. 1–22. (tax).
1976: Prinz, Untersuchungen ..., 210 p. (agric.)

Vernacular names: nug, nook, nuk (the plant), nehigue (the oil, Amarinya); nehuk, neuk, nuhk, nehug (Tigrinya, Sahinya); nuhuk (Tigray); nuga, nughi (Gallinya, Orominya); hada (Kottinya); nughio (Kaffinya); gizkoa (Gumuzinya); nihig (Eritrea); elhongui (Bilin: Arbashiko); ghelghele (Ghinda); ram-till, kala-till, karala, sarguja, werrinuwa (India).
Trade names: niger, Niger seed, Niger-seed oil, ramtil oil (English); guizotia oléifère, nigèr (French); semen guizotiae oleiferae (medical).

Geographic distribution

Niger is cultivated as an oil crop in Ethiopia, India, Tanzania, Uganda and Sudan (Baagøe, 1974); in Zimbabwe it has been grown as a green manure and for silage (Vaughan, 1970). The plant is occasionally reported as a weed from places remote from the area of cultivation, probably because of the use of Niger seed in bird food, e.g. Belgium (Henin, 1941), United States (McCarty, 1980).

It seems that niger had a larger distribution in Europe during the 19th Century than now. Several authors mention it and, on a sheet of niger in the Paris Musée National, it is noted that the plant was cultivated in Württemberg (Prinz, 1976).

Niger is the most important oil crop of Ethiopia, and Ethiopia has a larger production and export of niger seed than any other nation. According to Schäfer (1964), the amount produced in 1962 was about four times the production of safflower, sesame, peanut, linseed, rapeseed and mustard seed together. I think this situation has not changed very much since then.

Around 1968, Ethiopian production was, with more than 200 Gg, twice as much as that of India, the second largest producer; it was still increasing (Vegetable Oils and Oilseeds, 1970).

According to Bridges (1960), the 'nug' area of Ethiopia in the fifties was about 200000 ha and it had increased to 400000 ha in 1970. The production in 1970 was estimated to be 258.6 Gg (Statistical Abstract, 1970).

In 1977, the Provisional Military Government indicated that the production of Ethiopia was only 24 Gg. I think that this was an underestimate, because some of the areas where I saw niger were excluded from the survey, e.g. Tigre (Selinus et al., 1971a: near Makalle the commonest oilseed is niger), Harergie (notably the Ghelemso area), and Eritrea. It was stated that niger was mainly produced on farms of 2 to 10 ha surface, where about 3% of the area was assigned to the crop. There was also a small area on state and cooperative farms. The data per province are as follows.

Province	Estimated area (× 1000 ha)	Estimated yield (kg/ha)	Estimated total production (Gg)
Arussi	0.5	197	0.10
Beghemder	42.6	180	7.67
Gojam	39.8	175	6.97
Kefa	1.5	753	1.13
Shewa	8.9	436	3.88
Welega	23.0	181	4.16
Total/weighed average	116.3	210	24.42

Ethiopian exports of Niger seed vary from 0 to 20 Gg annually (Yantasath, 1975).

The natural distribution of the species is difficult to determine. Baagøe (1974) thought that it was native to the Ethiopian Highlands, north of latitude 10°N. According to her, this assumption is difficult to prove but there are four pointers. Firstly, the highest concentration of *Guizotia* species is found in that region. Secondly, the species has been collected in Ethiopia both as a crop plant and as a weed, and in natural localities, whereas in the Indian subcontinent it has never been collected in natural localities. Thirdly, similar distribution patterns may be found in other genera containing cultivated species. Fourthly, the long-existing trade between the Horn of Africa and India explains how the seeds may have travelled from Africa to India.

In my opinion, the second pointer is weak. The combination of the very common use, the great mobility of the population, the often primitive means of transport and packing of products, together with the dimensions of the seed makes it doubtful that 'nug' really grows wild in natural localities (a term not defined by Baagøe). I have the impression that niger mostly grows in rather humid habitats outside agricultural fields. This was also observed by Chevalier (1949) and Cufodontis (1968). The sheet Ash 1300 even notes that the plant was collected rooting in a brook.

Concerning the fourth point, it is curious to note an old tradition of the region of Wolcait reported by Baldrati (1950). According to this legend, an Ethiopian queen had occupied a vast territory in India in the very remote past. She made groups of Ethiopians emigrate to India. How far this story has historical background is unknown but it is striking that there are so many similarities between the crops of traditional agriculture in Ethiopia and India, and that there are groups at Jaferbad in Kathiawar, that consider themselves to be of Ethiopian origin.

As niger does not have special requirements, it is found cultivated all over the country if conditions are favourable, i.e. in regions between c. 500 and 2600 m altitude with enough rain. The areas where I saw most of it are E Gojam, Beghemder and between Ghelemso and Asbe Teferi (Harergie). In the Himalayas, it can be found up to c. 1700 m (Bhardwaj & Gupta, 1977).

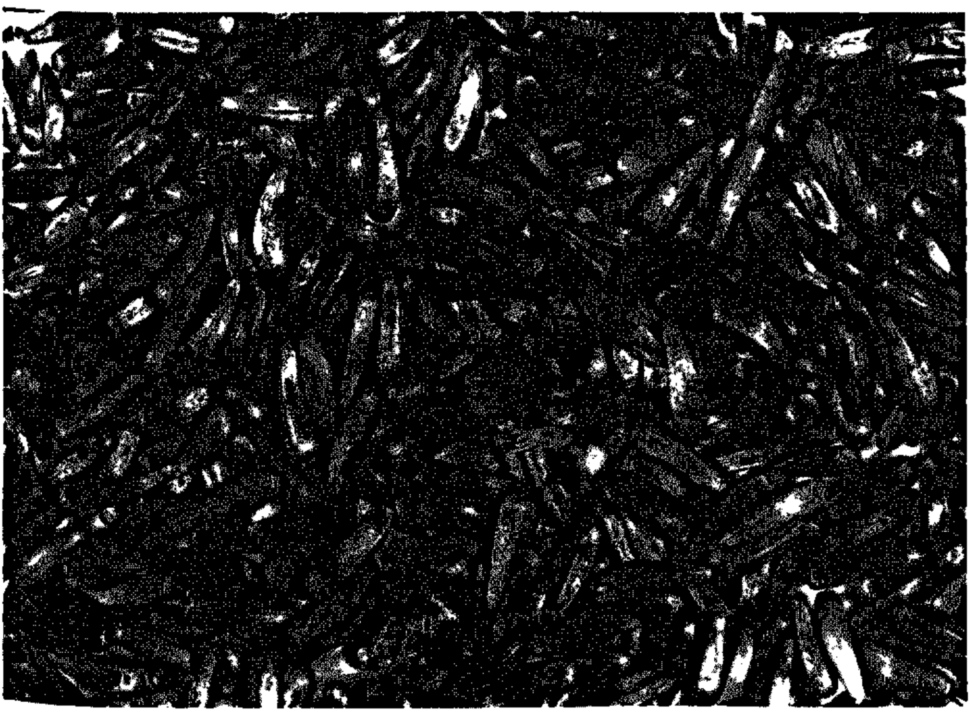
Description

An annual, stout, erect, leafy, moderately to well branched, smooth to slightly rough (scabrid) herb, 35–150 cm tall or more.

Root system well developed, strong quickly tapering taproot with many firm main laterals, especially in the upper 5 cm; brownish.

Stem firm, up to c. 1.5 cm in diameter at base, hollow, light green, often purple stained or dotted, especially near base, puberulous to pilose with multicellular white hairs.

Leaf herbaceous; opposite sometimes appearing perfoliate, clasping half the stem (hemi-amplexicaul), sometimes alternate in uppermost leaves subtending the inflorescence; lanceolate to narrowly ovate or obovate, last leaf under flower head sometimes ovate; (2.5)10–17(23) cm × (0.7)2.5–6 cm; apex tapering; base truncate to cordate; margin entire to serrate, ciliate (cilia c. 0.1 mm); sparsely puberulous on both sides,



Photograph 18. Achenes of *Guizotia abyssinica* (SL 1435; × 5).

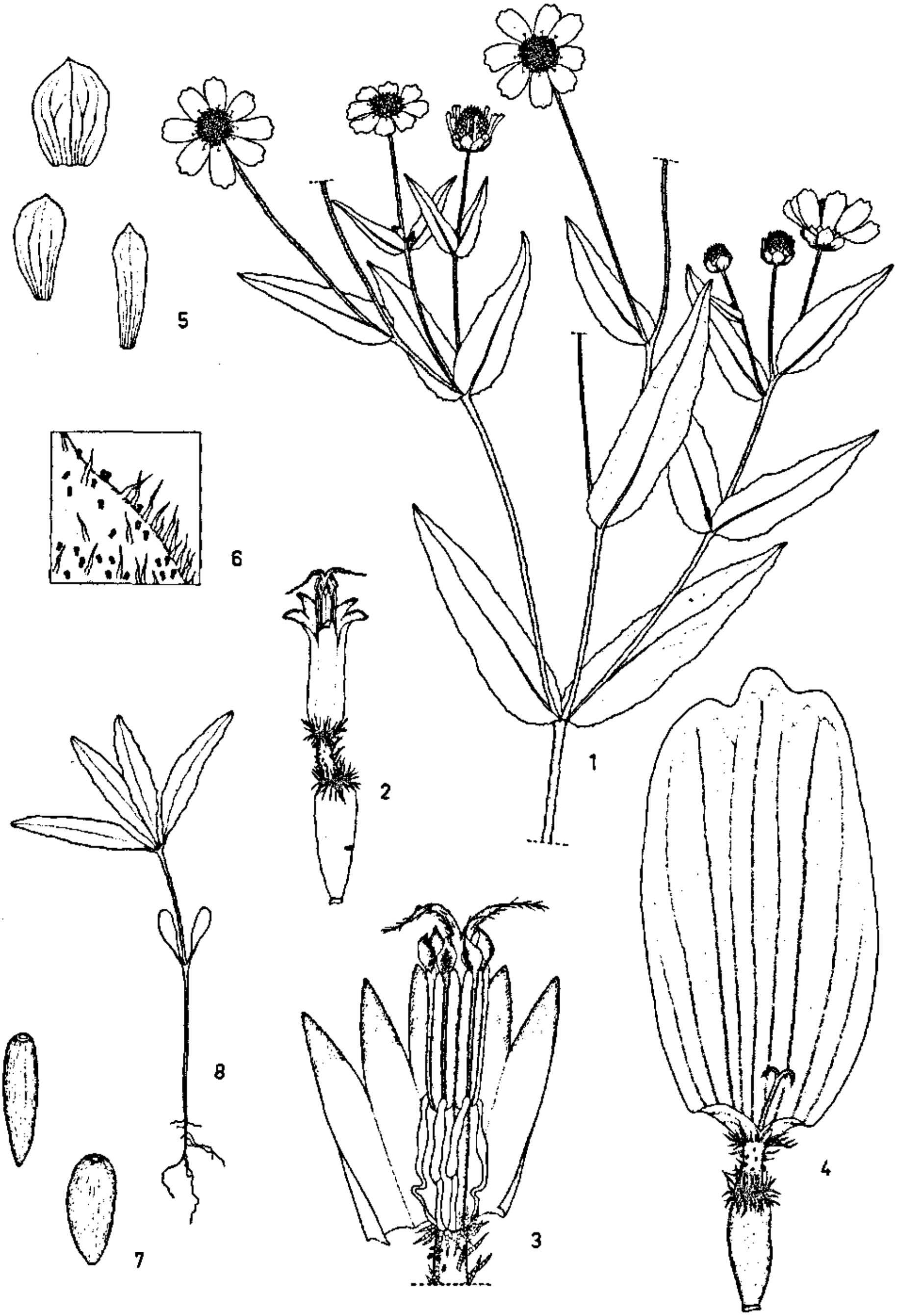


Fig. 6. *Guizotia abyssinica* (L. f.) Cass. 1. Flowering branch (× ½). 2. Disk floret (× 4). 3. Detail of disk floret, the apical part of the tube laid open (× 8). 4. Ligulate flower (× 4). 5. Involucral bract and paleae (× 4). 6. Upper margin of palea (× 20). 7. Achenes (× 4). 8. Seedling (× ½). 1–6, PJ 4075; 7, SL 44; 8. WP 474.

beneath also with small yellow drops of oil; venation pinnate, with c. 8–13 main laterals on each side.

Inflorescence a cupshaped axillary or terminal head with ray and disk florets on a flat to hemi-spherical receptacle; c. 1.0–2.2(3.0) cm diam. (measured over the involucre); c. 0.8–1.5 cm high; stalk (0.8)2.5–5(14) cm long, densely pilose near the head. Outer involucral bracts 5(6), leafy, broadly ovate to elliptic to obovate, 0.7–1.3 cm × 0.4–0.7 cm, 5–9-nerved, nerves slightly hairy, broadly attenuate, cuneate or obtuse at base, (acuminate to) acute to obtuse at apex, margins entire, ciliate, scarcely pilose, more densely so towards the base. Inner involucral bracts scarious, (narrowly) obovate, c. 5–9 mm × 2–5 mm, 7–9-nerved, apex obtuse to acute (to acuminate), base broadly cuneate to truncate, margin entire, ciliate especially near the apex, glabrous (to slightly puberulent) inside, outside with one-celled stiff hairs, in the apical part mixed with more-celled and club-shaped glandular hairs. Receptacular paleae like the inner involucral bracts, c. 10–12 mm × 1.5–3 mm. Ray florets 6–8, fertile, female only; ovary narrowly elliptic to narrowly obovate in outline, c. 4–4.5 mm × 1–2 mm, glabrous with 4(5) longitudinal ribs, greyish transparent with dark top; corolla tube cylindrical, abruptly widened at base, c. 2 mm long, c. 0.5–1.0 mm diam., brownish yellow, densely pilose with c. 1–2.5 mm long multicellular colourless hairs, especially on widened base, lower implanted hairs appressed to the ovary, higher implanted hairs appressed to the tube, with club-shaped glandular hairs on the side facing the centre of the head (adaxial) except for the widened base; ligule (narrowly) obovate to rectangular in outline with three teeth, c. 14–21 mm × 5.5–6.5 mm, 7–9-veined, yellow, glabrous above, beneath with sparse, often brown, globular protrusions and short hairs on veins; style cylindrical, glabrous, (2)4–7 mm long, c. 0.2–0.3 mm thick, yellow, seldom purplish; stigma with two branches c. 2 mm long, curled, slightly grooved inside, edges densely papillate, yellow to orange. Disk florets up to 40, usually in three whorls, hermaphrodite; tube with a distinct upper and lower part, yellow to orange; ovary narrowly obovate in outline, 4-ribbed, c. 3.5–4.5 mm × 1–3.3 mm, glabrous, greyish-brownish transparent with dark top; lower part of the tube 1–1.5 mm long, as in ray florets but with many more club-shaped glandular hairs, the multicellular hairs being restricted to the side facing the outside of the head (abaxial); upper part of tube (limb) slightly campanulate, hairy at base, 2–3 mm × 0.5–1 mm; lobes 5, acute, densely papillose above, yellow; stamens 5, inserted at the base of the limb; filaments flattened, c. 2 mm long, glabrous, bent twice near anthers, sometimes strongly so, yellow; anthers orange, seldom black, syngenesious, more or less basifixed, with apically a glabrous, erect, concave, acute appendage; anther + appendage c. 2.5–3.0 mm long, appendage c. 0.5 mm; style cylindrical, at base where clasped by discus thin, above discus slightly thickened, c. 5 mm long, glabrous except a bit papillose just below the stigma branches; stigma densely hairy underneath, above basal two-thirds grooved with papillose border, upper third flat and hairy, c. 1.5–2.0 mm long.

Fruit (mostly called seed) an achene, obovoid, club-shaped, elongate or narrowly so, mostly bent or oblique (3)4(5)-angled on transverse section, scar of tube often surrounded by a minute ring, c. 3.0–5.0 mm × 1.5–2.0 mm, striate, glabrous, glossy (brownish) black with white to yellowish scars on top and base.

Seed exalbuminous, greyish white.

Seedling epigeal. Root wel developed, laterals develop early and strongly, white. Hypocotyl very pale green to brownish or pale violet, becoming darker green and brown spotted when older. Cotyledons slightly succulent, medium green, sometimes purplish beneath, ovate, base attenuate and paler green, apex obtuse (to slightly acute), 7–25 mm × 3–7 mm. The cotyledons stay on the plant for a long time and may grow considerably after germination. First leaf-pair shaped as regular leaves but smaller and less dentate. Successive leaves gradually becoming larger, the dentation being the regular already in the second pair. All leaves rather pale green.

Notes

(1) The present genus first became known in Europe by its cultivated species, now known as *Guizotia abyssinica*. Because this species is grown both in Africa and in India, botanists specialized on African and Indian flora treated the taxon independently for a long time (Baagøe, 1974).

The first valid name was *Polymnia abyssinica* L.f. (1781). It was accompanied by a good description but the specimen on which it was based was not mentioned. The Linnaean Herbarium at London holds a specimen, matching the description of Linnaeus filius with the note '*Polymnia bidentis*', probably written by the older Linnaeus, and the note '*abyssinica*', added in J. E. Smith's handwriting. As no other specimen belonging to this taxon is present in any of the herbaria that were available to Linnaeus filius, this specimen is considered the type of *Polymnia abyssinica*. The specimen originates from the Hortus Upsaliensis and was probably raised from seeds Jussieu sent from Paris to Linnaeus from seeds he had received out of Bruce's Ethiopian collection (Baagøe, 1974).

Another plant, probably also originating from Bruce's Ethiopian collection, was described by Cassini as *Heliopsis platyglossa* in 1821. Eight years later Cassini realized that this taxon was identical to *Polymnia abyssinica* L.f. He described the new genus *Guizotia* and typified it by the species *Guizotia abyssinica* (L.f.) Cassini (for details, see Baagøe, 1974). The name *Guizotia* Cassini was entered in the list of conserved generic names (The Code).

Botanists studying the Indian flora used several names. De Candolle, first unaware of the conspecifity of the Ethiopian and Indian plants, described the new genus *Ramtilla* in Wight (1834). He named the typifying species *R. oleifera* and described two varieties. Two years later De Candolle recognized that his *Ramtilla* was the same as Cassini's *Guizotia* and, by the principle of priority, made the new combination *Guizotia oleifera*. This combination is still found here and there in agricultural publications. De Candolle knew of the older epithet '*abyssinica*' but, thinking that the plant was native to India and not to Ethiopia, he kept his own '*oleifera*'. Oliver & Hiern correctly reduced De Candolle's *G. oleifera* to *G. abyssinica* in 1877 (Baagøe, 1974).

(2) Upon the introduction of the concept of type species at the Cambridge Congress

in 1930 and the enumeration of type species for already conserved names, *G. abyssinica* (L.f.) Cass. was proposed as the type species of *Guizotia* Cass. It was conserved against the name *Werrinuwa* of Heyne.

No arguments for the conservation of *Guizotia* Cass. have been published, but as *Werrinuwa* is a vernacular name, and not a generic one validly published by Heyne, the conservation is superfluous, as noted by Ricket & Stafleu (Baagøe, 1974).

(3) Pollen within the genus *Guizotia* turned out to vary but little. It is tri-colporate, (oblate-)spheroidal, spiniferous, equator diam. including spines 32–41 μm, not including spines 23–31 μm, tectum between the spines granulate by nanospinules. It conforms to Stix's 'Helianthus Type' (Baagøe, 1974).

(4) Although herbaceous annuals, Niger plants seem to exhibit anomalous regrowth (Chavan, 1961).

(5) *Guizotia abyssinica* can almost certainly be derived from *G. scabra* (Vis.) Chiov., probably from subspecies *schimperi* (Sch. Bip.) J. Baagøe. It has apparently obtained its specific characters during selection in cultivation (Baagøe, 1974). Ciferri (1944) even included *G. scabra* ssp. *schimperi* in *G. abyssinica*, and Candussio (1941) mentioned a plant from the neighbourhood of Adua being most probably a natural hybrid.

The two species are easily distinguishable, though (Baagøe, 1974).

G. abyssinica	*G. scabra* spp. *schimperi*
Fruits 1–3 mm long	Fruits 3½–5 mm long
Paleae with sessile glands at apex	Paleae with multicellular glandular hairs at apex
Paleae obtuse	Paleae apiculate
Paleae mostly 5-nerved	Paleae mostly 3–4-nerved

(6) The use by Baagøe of the subspecies rank for the taxa within *Guizotia scabra* (Vis.) Chiov. does not conform to traditional use of this rank, as the distribution of the two taxa show an overlap.

(7) Within Ethiopia, one can see very large phenotypic variation between regions of cultivation. However plants grown at Wageningen from seed from different parts of Ethiopia showed many different types within the populations but they were the same in the different populations. Similar observations were made by other observers of Ethiopian Niger plants (e.g. Candussio, 1941; Maugini, 1946b; Siegenthaler & Melak, 1960; Agric. Ethiop., 1964; Linder, 1976). Chavan (1961) reported the same observation from India and stated: 'From an agricultural point of view, no distinct local varieties are met with in niger', and that types, possessing diverse botanical characters can be isolated by selection.

The most striking differences are those in branching, size and form of leaves, dentation of leaf margin and stem pigmentation.

Maugini (1946b) made a detailed study on the phenotypic variation of flowering plants at Florence. The variation she described I also observed in my material, but I did not make a special study of the heads. Her findings are reported below.

– *Branching*. The branching was most commonly erect with a rather sharp angle to the stem, rendering the plant a rather obconical shape. Less common is a more open habit.

– *Stem pigmentation.* In Maugini's collection, the most common stem colour was green with sparse violet dots, particularly near the base. These spots may be small and sparse but in other plants large and protruding, wart-like. In my collection, the most common stem was uniformly pale-purple-stained, a coloration found second in frequency by Maugini. Finally there are plants with all-green stems.

– *Leaves.* The leaves are normally lanceolate; some plants have narrowly or widely lanceolate leaves, but the character is also variable on one plant.

– *Dentation of leaf margin.* Maugini found that most plants had a very light dentation and that only plants with narrow or wide leaves had a more apparent dentation. In my collection, most plants had a clearly visible or even coarse serration and no correlation was found between leaf form and margin dentation.

– *Flower colour.* Maugini found three colours: yellow, yellow distally greenish, and orange distally yellow greenish. I did not encounter really 'orange' heads, but heads with orangish yellow ray-florets and yellowish orange disk-florets.

– *Dimensions of heads.* Differences in size of heads and of the ligules of ray florets on individual plants were found both by Maugini and by me, but the range Maugini found was wider. She indicated that all her measurements showed a normal distribution within the following limits: diameter of head 15–50 mm, length of ray florets 5–20 mm.

– *Form of the receptacle.* According to Maugini, three forms of the receptacle are distinguishable. In 1120 flowers of different plants, she found the following forms and distribution:

47.58% subglobose receptacle
27.94% flat or subconcave receptacle
14.46% subconical receptacle.

She did not report whether this character was different from plant to plant or from head to head. She only added that the form of the receptacle is a useful character in distinguishing different flower forms in niger.

Besides these characters, the presence, number and distribution of hairs on the vegetative organs and the form of the outer involucral bracts are variable among plants, and thus useful in its description.

In Wageningen, there were some differences among the populations in the maximum height reached and the time from sowing to full flowering, but the populations were too small (6 plants) to base conclusions on them. The observations concerning these characters are summarized as follows.

Population	Provenance	Time to flowering (weeks)	Height (cm)
SL 13	Asbe Teferi	9½	180–200
SL 37	Robit (Welo)	9	180
SL 74	Agaro	9½	200
SL 147	Sire (Arussi)	9	200
SL 215	Wotter	9	180
SL 361	Jijiga	10	200
SL 429	Mulu	8½	180
SL 502	Waichu	9	180
SL 558	Kuni	9	180
SL 602	Karra	9	180
SL 734	Lumane	10	200
SL 749	Dejen	10	180
SL 802	Elias	10	200
SL 824	Worata	10	200
SL 850	Infranz	9½	200
SL 924	Gonder	9½	200
SL 963	Kembolcha	9½	200
SL 1085	Dessie	9½	180–200
SL 1160	Robi (Shewa)	9½	180–200
SL 1237	Robi (Bale)	8½	180–200

These data might suggest that the 'proles *praecox*' and 'proles *serotina*', described by Ciferri (1944), have an ecological background rather than a genetic (taxonomic) one.

(8) Both in Ethiopia and in India (Nayakar, 1976), niger populations are very heterogeneous. In Ethiopia, very little work has been done to improve the crop (Linder, 1976) but in India good results have been achieved by selection (Chavan, 1961).

Candussio (1941) observed that, under the same environmental conditions, plants with large leaves formed less branches than plants with narrow leaves. He indicated that plants with more branches form more heads and had higher yields. If his observations were right, it could be an easy criterion for selection for higher yields.

(9) Description was based on the following specimens:

Ethiopia sine loco	Dillon & Petit 1838/43 (L), R. F. Hohenacker 384 a (L; WAG), Schimper 1931 (L), Schimper 3841 (L).
Arussi	Sire market: SL 147.
Bale	Goro market: SL 1249; Robi market: SL 1237.
Beghemder	Addis Zemen market: SL 62; field near Debre Tabor: SL 824; Infranz market: SL 846, SL 850; Gonder market: SL 51, SL 923, SL 924, SL 929A, WP 4983; along road to Bahr Dar, 33 km S of Gonder: JdeW 7161.
Gojam	Bahr Dar market: WP 4961; Dejen market: SL 749; Elias market: SL 802; Lumane market: SL 734; Telili market: SL 805.
Harergie	Alemaya market: SL 219, WP 3008; EELPA campus near Lake Alemaya: WP 280, WP 364, WP 747, WP 2219; campus of the College of Agriculture, Alemaya: PJ 1596–1597,

	PJ 2081, PJ 2784, PJ 3117, PJ 4074–4075, WP 1902–1903, WP 3997; field along the road from Alemaya to the College of Agriculture: WP 3954; Asbe Teferi market: SL 13; Deder market: SL 374; Dire Dawa market: Bos 8368, WP 134; Ghelemso market: SL 642; Harer market: Bos 8041, WP 73; Jijiga market: SL 361; Karra market: SL 602; Kuni market: SL 558; Mulu market: SL 423–424, SL 429; Waichu market: SL 502; Wotter market: SL 215.
Illubabor	Jemero market: SL 1435, SL 1466; Metu market: SL 1482–1483; along the road to Bedelle, 1 km from Metu: Friis, Getachew, Rasmussen & Vollesen 1703.
Kefa	Agaro market: SL 74, SL 82; Jimma market: Bos 8633, SL 117, WP 3289; 15 km E of Jimma: WdeW 7667.
Shewa	Near Addis Abeba: Rousseau s.n. (L); Gerfersa reservoir, 33 km W of Addis Abeba, 2850 m: J. W. Ash 1300; Debre Zeit Station collection: WP 4866–4872, WP 4874–4880, WP 4882; field 26 km from Nazreth along road to Mojo: WP 1929; Robi market: SL 1160, SL 1175; Shashemane market: SL 1291.
Sidamo	Awasa market: SL 1340; Neghele (Borana) market: SL 1387.
Tigre	Fields near Adua: Schimper 340 (L), Schimper 957 (L); fields near Axum: Schimper 1519 (L); Axum market: SL 952.
Welega	Defno market: SL 1554.
Welo	Bati market: SL 1054–1055, WP 5011 B; Dessie market: SL 1085; Gude Beret market: SL 50; Haik market: SL 44, SL 1115; Kembolcha market: SL 963, SL 973–974; Robit market: SL 29, SL 37.
Grown at Wageningen	SL 1601–1607, SL 1623–1635, WP 5852–5853, WP 7000, WP 7438–7442.

Ecology

1. Temperature

In Ethiopia, the principal regions of niger production have an altitude of 1700 to 2200 m. The crop may be found both higher and lower but, as far as I could see, growth is then less prolific, particularly when grown higher. Saville & Wright (1958) indicate that the crop is cultivated with good results at altitudes of 2000 to 3000 m in Kenya but that it gives fair results at lower altitudes.

Comparison of the relief map with temperature maps and tables of Ethiopia leads to the conclusion that the average daily temperatures of the regions where niger is grown is from 16 to 20°C during the growing season. In the rainy season, the average daily maxima are around 22–24°C with absolute maxima usually 25–28°C, average daily minima around 12–14°C and absolute minima 6–8°C. The crop is harvested at the beginning of the dry season. During the period before harvesting, the average daily maxima are about 3°C less and the corresponding minima 3–6°C less. Night frosts occur occasionally.

Prinz (1976) studied the reactions to different temperatures of 12 plant populations from Ethiopia and 12 from India in a phytotron with a 12-h light period. Ethiopian niger showed a much slower development at all temperatures and had a lower optimum temperature than Indian niger. He made the following observations.

Temperature (°C) light period	Temperature (°C) dark period	Time to flowering (d)	
		Ethiopian niger	Indian niger
28	23	164	118
23	18	149	120
18	13	162	136

Prinz (1976) also found that Indian plant populations flowered more profusely and reacted much more uniformly than Ethiopian material. Under cooler conditions, Ethiopian material remained shorter, showed more main branches, and more flowering than under warmer conditions, differences not seen in Indian material. Dry matter accumulation in Ethiopian niger had larger variation and was on average twice as large as in the Indian. It was influenced significantly in all populations, but only in the Ethiopian material were the differences between the populations significant.

After additional experiments with different daylengths, Prinz (1976) came to the conclusion that temperature influences the generative induction of Ethiopian niger considerably, but not of Indian niger.

Temperatures around 18 °C retarded growth, but accelerated generative development of Ethiopian niger while the optimum day temperature was around 23 °C. Both temperatures are in or close to the common range of day and night temperatures for the Ethiopian Highlands during the growing season of niger. The species thus seems well adapted.

Higher temperatures had a clear positive correlation with ultimate plant height and with dry matter production in Ethiopian material, but not in Indian.

The minimum temperature that niger could stand during growth was close to 0 °C (Prinz, 1976). According to Prinz (1976), Abebe found a temperature of $1\frac{1}{2}$ °C as minimum. Indeed a late-sown crop can completely fail because of night frost (Brhane, 1971).

The effect of chilling was explored by Scheltens (1976) at Wageningen. In a greenhouse, plants were grown from seed from different parts of Ethiopia in 10-litre pots, at day/night temperatures of 25/15 °C. At a certain stage, they were transferred to phytotron cells with a regime of 20/10 °C as day/night temperatures, and a daylength of 12 h. In the last three hours of the dark period, the temperature in 3 of the 4 cells was lowered to 6, 2 and −3 °C, respectively, The carbon dioxide concentration was not regulated and the relative humidity was c. 50% during the light period. The treatment was given for 18 days. The investigated stages were: seedling, young vegetative (c. 1 month old), and old vegetative to young flowering (c. 2 months old). Notes were made on changes of colour, mortality, growth in length, and differences in fresh and dry weight.

All stages were killed or heavily damaged in the regime with −3 °C. Of the 16 seedlings, only 2 survived the experimental period, both of seed from Axum. Of the 16 plants in the young vegetative stage, 1 survived, of seed from Neghele (Borana). About half the plants of this stage was killed by the first chilling period, and only a quarter was still alive after three nights. The plants in the oldest stage seemed most sensitive: the first night gave severe damage and the second night was mostly fatal. One plant of seed from Defno (Welega) started to form new shoots at the end of the experimental period.

Younger plants that were dying turned black, the stem of flowering plants sometimes reddish and the leaves yellow.

The preceding results suggest increasing sensitivity to night frosts of niger during development until flowering.

The differences between the other treatments on dry matter weight and growth in length were not very large. The seedlings usually gave slightly more dry matter in the regime with 6 °C, while growth in length in the older stages was slightly depressed in the 2 °C regime.

All results combined suggest that the night temperature for niger should not fall below 2–6 °C.

2. Water

Niger only grows well if soil water is constantly available. This is particularly important during the first two months (Saville & Wright, 1958). The highest seed yields are obtained with moderate rainfall. It is not cultivated in regions with heavy rainfall (Chavan, 1961; Linder, 1976). According to Baagøe (1974), this is so because it grows too vigorously and produces less under such conditions. Prinz (1976), however, found that the amount of water available has only slight influence once enough is available, but that the supply of nitrogen influences the development of Niger plants very much in the way described by Baagøe.

In a pot trial in sand with two levels of nitrogen (N1 = 15 kg/ha; N2 = 70 kg/ha) and two levels of water (W1 = pF 1.3; W2 = pF 1.0) Prinz found the following:

	Relative yield of dry matter in aerial parts	Relative number of heads
N1W1	1.00	1.00
N1W2	1.11	1.12
N2W1	1.40	1.03
N2W2	1.70	0.67

So soils poor in nitrogen should be chosen for crops in high rainfall areas.

A precipitation of c. 1000 to 1300 mm is best suited to the crop, but also lower levels suffice (Chavan, 1961). Precipitations indicated in some publications concerning niger in Ethiopia have similar values, e.g. Ufficio .. Amara (1938): 1000–1400 mm, Tozzi (1943): 700–1000 mm, Baldrati (1950): 400–800 mm. Niger is rather resistant to waterlogging (Prinz, 1976).

A comparison of the rain distribution per month in most of the important Ethiopian areas of niger cultivation with the growing cycle of the plant leads to the conclusion that rainfall is most abundant in the first 3–4 months. That period is usually followed by 1–2 months with less rain. Then the dry season starts. Translated into the cycle of the crop, the water supply is rather abundant from germination until the start of flowering. During flowering, the water supply is less but still regular, whereas after flowering the plant has to sustain itself on the remaining soil moisture.

Prinz (1976) studied the reaction of niger to different levels of available water. He remarks that the behaviour under very wet conditions (pF = 1.0–0.2) was unexpected. Dry matter production and number of heads were only slightly less than under 'optimum' conditions, and the plant formed aerenchyma and respiratory roots. At high pF, there was a direct correlation between dry matter production and water supply.

Prinz observed that if more water became available to the plant, there was an increase in height of the plant and of the lowest implanted branches, in stem diameter, in the daily dry matter accumulation, in the ratio of dry matter in aerial parts to subterranean parts, and in the number of heads, but the number of florets per head or the length of the stem below the lowermost green leaves were not affected.

Total accumulation of dry matter and fresh matter increased on all soil types with more water available up till a quarter higher moisture content than at pF 1 in sand; higher water contents induced a small decrease (Prinz, 1976).

Drought periods of 20 days showed surprisingly little influence on growth in all stages of the plant; only during the period of maximum flowering did the number of heads decrease (Prinz).

3. *Soil*

Niger does not show a clear preference for particular soil types, as long as they are not very loose (Baldrati, 1950) or very heavy (Chavan, 1961). If the field is well tilled, niger accepts also compact soils, such as the black soils from the weathering of basalts in the highlands of Ethiopia. It also grows well on lateritic soils and adapts itself to coarse stony soils. If assisted by favourable weather, steep sloping terrains are suitable too. Best are moderately light, deep, cool soils (Baldrati, 1950).

The prime factor in vegetative growth of niger is the amount of water available to the plant. The soil, therefore, influences growth according to its water-holding capacities and the volume available for rooting (Prinz, 1976).

In Ethiopia, niger is mostly sown in areas with a rather poor soil (Linder, 1976).

Traditionally no fertilizer is used and the literature indicates variable results. Tiwari & Bisen (1965) reported that phosphorus was the most important nutrient, nitrogen only being effective in combination with phosphorus. Patil & Ballal (1964) and Singh & Verma (1975), however, reported that nitrogen alone gave considerable increases in yield.

Weiss & Gosnel (1965) reported from Kenya that single and triple superphosphate

(134 kg/ha) induced very good growth. Ripening was extended to such a long period that harvesting became impracticable. In view of the higher physiological variability in Ethiopian niger than in Indian niger, the Indian results can not be taken as applicable to Ethiopia, and situations similar to those described for Kenya may be expected.

In Germany, Yantasath (1975) investigated the influence of nitrogen on growth of niger in pots and waterculture in the greenhouse and in the open. He found that nitrogen at 30 to 60 kg/ha favoured growth; larger dressings were not absorbed. The strongest reaction was at the lowest level (10 kg/ha), the following steps giving less reaction. The form in which nitrogen was applied ($(NH_4)_2SO_2$, $NaNO_3$, NH_4NO_3, urea) had hardly any influence. Growth and nitrogen intake were better under neutral to slightly alkaline conditions than under acid ones. The beneficial effect of liming of acid soils for niger on a field scale was reported, for instance by Bhattacharya (1976) and Sarkar (1976).

Niger seems to have a considerable ability to extract phosphorus from the soil (Graw, 1978). It is almost certain that this ability is improved by certain mycorrhiza, because inoculation of the soil with soil in which niger had been growing for some time resulted in a considerably increased growth, while no nitrogen fixation was found in the rhizosphere (Yantasath, 1975).

A micro-organism that is involved as mycorrhiza is *Glomus macrocarpus*. Its efficiency is influenced by pH (Graw, 1978), temperature, humidity in the soil and composition of the soil (Sieverding, 1979).

The mycorrhiza symbiosis also influences the water supply of the plant and possibly also the efficiency of water use (Sieverding, 1979).

Niger is more salt-tolerant than flax or sesame. It shows a marked decrease in days to flowering with increasing salinization (Mesfin, 1972), and its germination is relatively little affected (Mesfin, 1971). Abebe (1975, seen in abstr. 1977) describes niger as semi-tolerant of salinity. It is more sensitive to $CaCl_2$ than to NaCl. In his experiments the roots functioned best at temperatures of 17 to 25 °C. The plants were then capable of extracting water at osmotic potentials up to 45 kPa before exhibiting a 50% reduction in dry matter accumulation.

Niger was extraordinarily resistant to poor oxygen supply in the soil (Abebe Abstr. 1977). This could probably be explained by the presence of aerenchyma and the ability of the plants to form respiratory roots (see p. 135).

4 Light

Maugini (1946a) was the first to publish on the reaction to daylength of Ethiopian niger. She indicated that plants grown under a 12 hours photoperiod had their first flowers on average 42 days after sowing, while those grown under the natural daylength of Florence (c. 15 h during the trial) had their first flowers three weeks later. Only a few plants produced their flower quicker in the natural daylength.

In Wageningen, only 1 out of 160 plants grown outdoors from 4 batches of seed from markets produced flowers. It had been sown on 24 March and showed its first flowers on 11 August. The plants grown from 20 batches of Ethiopian seed in a greenhouse with 10-h daylength started flowering in the eighth week (p. 131).

These results show that Ethiopian niger is a short-day plant with daylength-neutral individuals.

Prinz (1976) studied the reaction of niger to short daylength (10 h, 12 h) and to long ones (natural summer daylength of Germany). His observations were done in a phytotron and in a greenhouse. He found considerable differences in the reactions of niger from Ethiopia and from India. He made the following observations.

- Flower induction with 12-h daylength reached maximum after 12 days in both Ethiopian and Indian niger.
- Ethiopian niger showed best induction at low temperatures (in phytotron 18°C/13°C); at higher temperatures, most plants were not induced by the 12-h daylength. At the highest temperatures (28°C/23°C), whole populations started flowering with 10 h of light, but with 12 h only a third of the plants initiated flowers. Summarized: in Ethiopian niger, flowering was strongly delayed at daylengths of more than 12 hours and temperatures over 23°C.

  The influence of temperature on flower induction in Ethiopian niger was also observed by Eenink (1968). He observed two Ethiopian samples in daylengths varying from 10½ to 13½ h in a Wageningen greenhouse in the summer of 1968. the minimum temperature in the greenhouse was 20°C, the maximum temperatures ranged 40–43°C and no flowering was achieved.
- The influence of temperature on flower induction was not present in Indian niger.
- The number of heads in a given mass of dried crop was more dependent of daylength than of temperature in Ethiopian niger.
- In both Ethiopian and Indian niger, a longer daylength increased vegetative period and height.
- Longer daylengths induced higher dry matter accumulation. In short daylengths, the accumulations of Ethiopian and Indian niger were similar, but at longer daylengths Ethiopian niger accumulated much more dry matter than the Indian.
- Differences from 10 to 12½ h resulted in a slight and insignificant increase in the number of heads. In Ethiopian niger, this was only so at low temperatures. At 14½ h, it decreased by 75%, mainly because many plants were not induced at all.
- The stage of highest sensitivity to induction of the plants was different in Ethiopian and Indian niger. Short daylength a month after sowing gave no induction at all in Ethiopian niger, but gave full induction in Indian niger. Ethiopian niger was fully induced with short daylengths 55 and 75 days after sowing.
- It was possible to induce some of these reactions in plants grown under natural daylength after short days for 11–12 days when the plantlets were c. 7 weeks old. Plants treated this way showed some of the differences between Ethiopian and Indian niger better than in the phytotron, e.g. more vigorous growth, higher dry matter accumulation, and longer vegetative cycle. Without the treatment at 7 weeks of age, Ethiopian niger did not flower at all.

Yantasath (1975) also reported that plants of niger, once they are induced, remain induced even in long day. Cuttings of flowering plants produced flowers immediately.

Prinz (1976) concluded that Ethiopian niger is borderline between quantitative and qualitative short-day plant. There is considerable influence of temperature on induction: long day and high temperature work in the same direction and additively. Indian niger, on the other hand is a typical quantitative short-day plant.

Development of the plant

Under favourable conditions, niger germinates in a few days. The cotyledons and first leaves are small at first but keep growing for some time. The plants grow immediately to their erect habit and in the stage with 6–8 leaves the first side-shoots may develop. The plants are then usually c. 30 cm high. If the plants have enough space, the branches reach an ultimate height about equal to that of the main stem. At closer spacing, as often found in Ethiopian traditional agriculture, the lower branches stop growing and die off. Normally the plants have three primary branches.

Usually two to three heads are formed close together at the top of the branches. This happens at about the same time at the top of the stem and on the side-branches. Simultaneously small shoots develop in the axils of the leaves under the one bearing the first heads. These develop into short branches, usually with 2–3 heads again. The length of the latter branches makes them often grow higher than the primary heads. This process of shoot-bud formation may be repeated several times but generally stops with branches 3rd to 4th order. A single plant thus mostly bears 20 to 40 heads, sometimes (many) more.

In Ethiopia, flowering may start 2 months after sowing by opening of the first heads, but mostly starts 1–3 weeks later. Flowering of a head usually lasts c. 8 days, the individual florets starting to dry after c. 3 days. Flowering of a field lasts 4–6 weeks. This long period induces uneven ripening and causes losses by shattering at harvest.

At opening, the ligule of the ray florets is bright yellow. Later it turns more golden-yellow and finally, as it fades, brown. The disk florets are slightly darker during all stages.

The florets open about 2 h after sunrise. The disk florets liberate their sticky pollen immediately, after which process the stigma protrudes through it in such a way that the receptive part only rarely touches the pollen of the floret. With this flowering mechanism, cross-pollination is to be expected, both with florets of the same plant and of neighbouring plants. Indeed it was proven that cross-pollination by insects is common although seed, formed after selfing has a normal viability (Chavan, 1961).

From the flowering stage, it usually takes 45–55 days for seed development in Ethiopia. One good head produces about 30 ripe seeds.

The total growing period is 5–7 months in Ethiopia.

One author (Corni, 1938) states that niger requires good terrain and suffers from weeds. All others indicate that niger is a hardy rain-fed crop. If grown as a pure crop, it often receives little attention in preparation of the seed-bed, weeding and manuring. It is rather indifferent to the kind of crop it is preceded by; only another niger crop or maize showed unfavourable influence. It is a good precursor for tef (Bako Res. Stn Progr. Rep., 1971).

The plant is not adapted to fertilizer levels common for other crops. Such levels increased vegetative growth enormously and induced lodging resulting in a relative loss of seed yield of 37%. Reports from other experimental sites in Ethiopia showed only negative effects, if any, of fertilizing (Yantasath, 1975). Low levels of fertilizer are sometimes beneficial and there are considerable differences in reaction to fertilizer between niger from different parts of Ethiopia (Bako RSPR, 1970). Positive reports are mainly from India (e.g. Patil & Joshi, 1978).

According to the Provisional Military Government (1977), 1% of the Ethiopian niger area received chemical fertilizer, and 3.8% received dung. I suppose that most of the fertilized area is on experimental stations or in situations where the crop is grown together with a fertilized main crop.

Because the seedling is small, it is important that the field is even and free from clods (Saville & Wright, 1958; Chavan, 1961).

In the Tana region, I saw it mostly in pure stands whereas in Harergie, it was generally grown at the margins of fields or as strips 1 to 2 m wide in them. The fields were mostly planted with cereals, especially tef, or beans, but also with spices, particularly tikur azmud (*Nigella sativa* L.). Both systems can be found all over the country, but there are, apparently, local preferences for one of the systems.

The productivity of niger in pure stands is generally much lower than in strips. When grown on strips, the seed-bed is prepared the same way as that of the main crop. Particularly in combination with tef, fertile fields, often the first two years after fallow, are chosen, so that growing conditions are better than on fields planted with niger alone. Such fields are common the last year before fallow (Baldrati, 1950). Only if a field is very weedy may it be sown with niger earlier in the rotation. This is because niger overgrows and stifles weeds. It emerges quickly, develops and grows densely. Therefore the field is quickly covered and remains so until ripening (Baldrati, 1950; pers. commun. Dr Amare G., 1972).

Sowing in Ethiopia is done from May to July, from the beginning to the middle of the rainy season, depending on length of the growing season (depending on altitude) and annual precipitation. The time of sowing should be chosen such that the time of ripening is short, because the small seeds are easily shattered (Tozzi, 1943).

In traditional agriculture, the seed is always broadcast, but sowing on rows, 25–40 cm apart, as is done in India, is generally advantageous.

In India, Mukerji et al. (1961) compared 4 treatments: broadcast with or without fertilizer, and row sowing with or without fertilizer. The fertilizer was ammonium sulphate with N $22\frac{1}{2}$ kg/ha and superphosphate with P 9.8 kg/ha. The trial lasted for three years with widely different rainfall. They came to the conclusion that row-sowing combined with fertilizing always resulted in the highest yields, but that this combination was most effective in years of moderate rainfall. In wet years, neither row-sowing nor fertilizing were very effective. In dry years, row-sowing increased yield if combined with fertilizer; without fertilizer, broadcast crops had the highest yields.

According to Patil & Joshi (1978), the traditional sowing time in India is similar to that in Ethiopia. They claim that later sowing at the end of August induced flowering in a sunny October and that the yields increased by 86% in India. In view of the longer cycle of niger and the incidence of night frost in Ethiopia, it seems doubtful whether shifting the time of sowing to a later date be desirable in Ethiopia.

At Bako, the opposite was observed in 1970: 'Sowing date trials showed that early sowing in the middle of June is very important for yield'. In 1971, on the other hand, no such effect was reported with sowing on 15 June, and 4 and 24 July (Bako RSPR, 1970; 1971).

Seed rates in broadcasting are c. 10–15 kg/ha (Baldrati, 1950) while in row sowing at Bako no significant differences were found at seed rates of 2, 4 and 6 kg/ha (Bako RSPR, 1971). Patil & Joshi (1978), however, indicated that denser sowing increased seed yield considerably in India.

Seed dressings showed hardly any difference in yield between the treatments and control at Bako (Bako RSPR, 1970).

A plant with many branches produces well, hence thinning of seedlings is important to secure adequate stand and good yields. If necessary, thinning may be done in the young stage (Chavan, 1961). According to Patil & Joshi (1978), though, yield is best at high densities. As far as I know, thinning is not practiced in Ethiopia.

Weeding and soil cultivation are not done in Ethiopia. According to Patil & Joshi (1978), weeding once, 20 days after sowing, may more than double the yield.

Pests and diseases are not much problem. According to Stewart & Dagnatchew (1967), the following parasites were found on niger in Ethiopia: *Alternaria dauci* (Kuehn) Groves & Skolko, on seed (Shewa); *Anguina ?amsinckia*, nematode leaf-gall (Shewa, Welega); *Bremia lactucae* Regel, downy mildew (Shewa); *Oidium* sp., powdery mildew (Shewa, Harergie); *Phyllachora* sp., tar-spot (Shewa); *Puccinia guizotiae* Cumm., rust (Kefa, Harergie, Shewa, also reported by Gjaerum, 1977); *Rhizoctonia solani* Kuehn, post-emergence damping-off (Kefa); *Septoria* sp., shot-hole (Shewa); *Xanthomonas guizotiae* D. Yiergou, bacterial leaf-sport (Shewa).

Schmutterer (1971) found the following pests on niger: *Haplothrips articulosus* Bagn. and *Synapothrips* sp. (*Thysanoptera*), common in flower heads, apparently not very harmful (Bako); *Trichothyrea mulsanti* Guér. (*Coleoptera*), occasionally observed on flower heads, causing slight damage by feeding on them (Bako); *Curculionidae* (unidentified, *Coleoptera*), a grey-and-black species slightly harmful by feeding on leaves (Bako); *Dioxyna sororcula* Wied. (*Diptera*), most harmful pest of niger in the Bako area, maggots found in flower heads, destroying seeds, many pupae attacked by parasitic *Hymenoptera*. In Eritrea, *Phytometra orichalcea* F. (*Lepidoptera*) can be a damaging pest (de Lotto & Nastasi, 1955).

Niger is often attacked by parasitic plants in India. Particularly *Cuscuta chinensis* Lam. may be troublesome. This species is also reported from Ethiopia (Cufodontis, 1961, p. 727) and thus is a possible future pest in that country too. It can be controlled effectively with chlorpropham and propyzamide (Tosh et al., 1978; 1979).

A pest of other crop plants is *Orobanche cernua* Loefl. It is also found in Ethiopia (Cufodontis, 1963, p. 920; herbarium JdeW 6477) be it in a limited area of E Harergie. Niger is not sensitive to this *Orobanche* sp., but it acts as a trap crop: it induces *Orobanche* seeds to germinate and then they die (Krishnamurti, 1977).

At maturity, niger sheds most of its foliage, adding much organic material to the soil (Chavan, 1961). In Ethiopia, time of shedding depends on altitude, somewhere between October and February (Huffnagel, 1961).

Because of its growing and flowering habit, ripe heads and young flowers may be present on the same plant at harvest. Because niger is subject to heavy seed-shedding when ripe, the moment to start harvesting should be chosen carefully. The best moment is just before the majority of the heads is ripe.

The normal harvesting procedure in Ethiopia is to cut the whole plant near the base, transport it carefully to the winnowing place, and heap it there for final drying.

Threshing is easy with a stick or by treading with oxen. The mixture so obtained is very dirty up to 10% plant residues and soil: it should be carefully winnowed and sieved (Chavan, 1961). In Ethiopia, I saw threshing done on hides to minimize contamination with soil. When offered on the market, Niger seed has on average a purity of 96% (weight/weight). The main impurities are inert matter and weed seeds, notably *Guizotia scabra* (Williams, 1975).

Mechanical harvesting and threshing are also possible (Saville & Wright, 1958).

As niger is grown in diverse habitats, yields of seed are very different: most authors indicate between 300 and 700 kg/ha (e.g. Tozzi, 1943; Schäfer, 1964; Statistical Abstract, 1970); but also lower and higher yields have been reported from Ethiopia such as 1000 kg/ha (Corni, 1938; Melka Werer RSPR, 1971), 1300 kg/ha (Tissot, 1938), 180 kg/ha (Guidotti, 1937), 199 kg/ha (Asrat Felleke, 1965). Similar yields are obtained in the Himalayas (Bhardwaj & Gupta, 1977).

The seed is stored in all kinds of containers. In Ethiopia, it is transported in bags of cloth or hides, or simply wrapped in cloth.

According to Prinz (1976) stored Niger seed is hardly attacked by insects but shows considerable reduction in germination after three years. The latter observation is not confirmed by my experiences with seed from Ethiopia. It still germinated very well after a storage of c. 4 years in paper bags at room temperatures fluctuating from 20 to 35°C.

Uses

During transport, Niger seed dries easily and strongly, making oil extraction more difficult and resulting in inferior oil. Therefore it is mainly consumed where it is produced (Baldrati, 1949). In most of Ethiopia, it is the prime supplier of cooking oil, not only for Ethiopians but also for expatriates (my own experience; Lemordant, 1971).

Traditionally the oil is prepared from slightly roasted seed, which is pounded or ground. The soft mass is placed in hot water and squeezed. By this process, the oil is liberated and starts floating. It is then skimmed off the water and is ready for cooking (my own observations; Braun, 1848; Chiovenda, 1929; Lemordant, 1971). The addition of some mustard seed (*Brassica nigra* (L.) Koch) improves the taste of the oil (Baldrati, 1949).

Traditional processing results in a very low yield of oil. Suzzi (1904 & 1905) indicated that seeds, containing more than 310 g of oil per kilogram only yielded 180 g/kg, while extraction would have given close to 300 g.

At present, much seed in Ethiopia is processed in commercial oil-mills. The oil reaches local shops in large cans. It is retailed, measuring with small cans. At home, the oil is stored in bottles, tins, calabashes or pots.

If the oil is extracted at home, the remainders may be discarded outside the house, where it is eaten by passing animals. It is also possible to mix the mass with honey to make a sweet-bread (Wittmack, 1907; Kostlan, 1913).

The literature on the use of the presscake as cattle feed is confusing. Tissot (1938) reported that presscake is highly appreciated by cattle, and Chavan (1961) reported that it is a well known cattle feed in India. It is considered good for diary cows and the nutritive properties compare favourably with other oilcakes. Chavan continues that Niger cake is rarely used as manure, because of its value as cattle feed, although it has a good composition for it. According to Vegetable Oils and Oilseeds (1962), on the other hand, the residue after crushing is not suitable as cattle feed.

The oil may be used in cooking, for anointing the body, for adulterating more valuable oils, and medicinally (use as sesame oil). Refined oil is used for the preparation of soaps and paints, for lighting, and for cleaning machinery. There seems to be some scope for its use in cosmetics on account of its odourless nature and capacity for absorbing fragrance of flowers (Chavan, 1961).

In Ethiopia, crushed Niger seed is, just like most other oilseeds, mixed with pulses and used to prepare vegetarian wot (stew). Slightly roasted seeds my be ground with salt to prepare litlit. This is sometimes given to young boys with big appetites, to keep them from eating too much. Slightly roasted seeds may also be boiled in water, which becomes flavoured by it (chilka). People drink it particularly during the fasting season (Siegenthaler, 1963).

The oil is used in birth control and, cooked with spices, in the treatment of syphilis. Niger sprouts mixed with garlic and 'tej' (mead) are used to cure cough (Griaule, 1930).

In Europe, the seed is used in the preparation of animal feed and is especially known in the feed for cage birds. There is some evidence, though, that niger is not necessarily beneficial to birds. When 15% of Niger cake was included in the diet of pullets from a day old to 6 weeks of age, weight gain and efficiency of food conversion were significantly less than if no niger was included (Ramakrishnan et al., 1978).

The fresh plant is not eaten by cattle, only sheep eat it. It may, therefore, be planted as a protective border along a field of a crop more favoured by animals (Baldrati, 1950). After silage, cattle will eat it (Chavan, 1961).

Due to vigorous growth, even on poor soils, niger is a good plant for green manuring (Chavan, 1961).

It is possible to make protein concentrates of Niger seed. Studies with rats on the food value of such concentrates showed that the manner of preparation had a large influence on their value (Eklund, 1971; 1974).

From Niger seeds, a medium can be prepared that is useful in distinguishing *Cryptococcus neoformans* (Sanf.) Vuill., a fungus that induces serious brain ailments, from other similar fungi (Paliwal & Randhawa, 1978).

Chemical and physical properties

According to Chavan (1961), numerous seed samples from India showed considerable uniformity in colour, seed size and oil content. As can be seen from data of Ferrara (1943) and myself, Ethiopian niger is not so uniform. The 1000-seed weight is in the range 2.0–4.5 g (Chavan, 1961), one litre weighing 580–670 g (Guyot, 1949; Linder, 1976).

The seeds of niger contain 300–500 g of oil per kilogram (Mensier, 1957; Prinz, 1976). Authors reporting on Ethiopian niger usually indicate 450 g/kg as maximum (e.g. Chiovenda, 1929; Candussio, 1941). This latter observation accords well with the oil contents I found in 22 samples of my collection. On a dry basis, 1 kg of the sample with lowest oil content contained 303 g of oil, that with the highest oil content 444 g. Most samples had 410–425 g of oil per kilogram of seed. The average of all samples was 413 g/kg.

The composition of some Ethiopian Niger seed and presscakes is given in Tables 34 and 35.

Table 34. Composition of 7 batches of Niger seed from Ethiopia (source: Ferrara, 1943).

Provenance	Density (g/l)	Content (g/kg)				
		H_2O	Crude oil[1]	Crude protein	N-free + cellulose	Ash
Gonder	564	63.4	426.0	170.5	279.2	60.9
Injobara (Tana)	560	66.7	369.6	129.7	372.2	61.7
Ismala Georgis (Tana)	500	65.7	360.0	161.2	354.1	59.0
Gonder	492	70.9	333.3	189.7	368.4	37.6
Harer	610	56.5	334.4	185.6	351.0	72.5
Addis Abeba	565	68.6	360.6	166.7	352.9	51.2
Addis Abeba	594	68.6	365.8	170.8	346.7	48.1

1. Note that the highest and the lowest oil contents were found in samples from the same region.

Table 35. Composition of some samples of Niger seed flour, presscake and oil from Ethiopia (source: Ågren & Gibson, 1968).

	Whole seed flour	Whole seed presscake	Whole seed extracted	Oil
Number of samples investigated	19–26	4–6	1	2
Gross energy (MJ/kg)	(15.730)20.335(22.260)	(12.720)14.480(15.440)	12.930	34.730–35.020
Moisture (g/kg)	(26)59(100)	(59)76(98)	113	0–5
Nitrogen (g/kg)	(27)33(46)	(43)44(45)	49	0
Nitrogen × 5.49 (g/kg)	(146)183(253)	(228)239(249)	267	0
Fat (g/kg)	(139)334(415)	(23)58(101)	44	995–1000
Carbohydrate total, including fibre (g/kg)	(301)378(542)	(448)524(619)	442	0
Fibre (g/kg)	(135)183(309)	(201)240(290)	189	0
Ash (g/kg)	(40)59(107)	(70)80(90)	105	0
Calcium (g/kg)	(1.97)3.31(5.19)	(5.27)5.78(6.81)	6.15	
Phosphorus (g/kg)	(5.26)8.43(12.08)	(6.80)13.07(23.50)	15.81	
Iron (mg/kg)	(135)725(1960)	(751)2122(4130)	843	
β-carotene equivalent (μg/kg)	0	0	0	
Thiamin (mg/kg)	(5.1)8.8(14.0)			
Riboflavin (mg/kg)	(2.3)4.3(10.6)			
Niacin (mg/kg)		(39)41(43)		
Tryptophan (g/kg)	(1.57)2.22(2.97)	(3.01)3.03(3.04)		
Ascorbic acid (mg/kg)	0			
Rubbish in sample as purchased (g/kg)	(80)150(350)			

Table 36. Some characteristics of Niger seed oil (sources: Chavan, 1961; Mensier, 1957).

Relative density at 15°C	0.923–0.927
Solidification point	−9 to −15
Acetyl value	24
Reichert-Meissl number	0.1–0.9
Insoluble fatty acids	940 g/kg oil
Refractive index n_D(15°C)	1.4708–1.4768
n_D(40°C)	1.4662–1.4689
Free acidity	0.068–0.071 mol KOH/kg oil
Saponification value	189–198
Iodine value (Wijs)	126–139
Bromine absorption (Wijs)	80
Unsaponifiable matter	5–12 g/kg oil
Maumené test	81–82°C
Hehner value	94–95

Table 37. Mass fractions (%) of the fatty acids in Niger seed oil. C, data of Chavan (1961); GP, data on an Ethiopian sample of Grieco & Piepoli (1967); SL, data on 22 samples from my collection (method: hexane extraction, liquid gas chromatography).

	SL[1]	Average	GP	C[2]
Myristic (14:0)			trace	
Palmitic (16:0)	8.4–9.5(11.2)	9.1	9.4	5.0–8.4
Palmitoleic (16:1)			0.2	
Heptadecanoic (17:0)			trace	
Stearic (18:0)	6.0–8.7	6.8	6.7	2.0–10.6
Oleic (18:1)	(5.4)6.4–8.5(11.6)	7.7	5.9	6.0–38.9
Linoleic (18:2)	65.9–75.5	73.0	76.5	51.6–74.1
Linolenic (18:3)			0.2	
Arachidic (20:0)	0.3–0.7	0.5	0.5	
Eicosenic (20:1)			trace	
Behenic (22:0)	(0.0)0.3–0.7	0.4	0.6	
Lignoceric (24:0)	(0.0)1.0–2.8(4.9)	2.0		
Total saturated	(16.5)17.1–21.2(26.1)	c. 19	c.17	14.5
Total unsaturated	(73.9)78.0–83.6	c. 81	c. 83	85.5

1. Linolenic + eicosenic 0.1–0.4, average 0.2.
2. Lauric + myristic + capric + caprylic 0.35–1.7. Linolenic, arachidic, behenic, and lignoceric all less than 1%.

After crushing, about 100 g of oil remains per kilogram of presscake; solvent extraction leaves less (Chavan, 1961).

The slow drying (McCarty, 1980) oil is limpid, pale yellowish, and has a faint odour and sweetish taste (Chavan, 1961). Some of its characteristics are presented in Table 36.

If the oil is prepared in the traditional way (see p. 142), it is reddish yellow, less fluid, clear, with a pleasant, slightly sweetish nutty taste and a slightly resinous aftertaste (Chiovenda, 1929).

According to Prinz (1976), there is a striking difference between oils of niger from Ethiopia and from India. In Ethiopian oil, c. 70% of the fatty acids are linoleic (as in my collection), in Indian oil only 50%, the difference being made up of oleic. It is not clear whether these differences are caused primarily be genetic or by climatic factors. In Ethiopia a strong interaction between composition of the oil and tempera-

Table 38. A survey of the glycerides found in Indian Niger seed oil (source: Chavan, 1961). Values are mass fractions (%) in total glycerides.

Trilinolin	2	Palmito-dilinolin	6
Oleo-dilinolin	40	Palmito-oleo-linolin	11
Dioleo-linolin	30	Stearo-dilinolin	2
Myristo-dilinolin	2	Stearo-oleo-linolin	4
Myristo-oleo-linolin	3		

Table 39. Common composition of the presscake from Niger seed from India (source: Chavan, 1961). Data in g/kg.

Water	59–125	Fibre	98–165
Oil	56–95	Soluble carbohydrates	211–272
Total nitrogen	54–67	Ash	68–109
Crude protein	338–481		

ture during seed formation was found in a trial at different altitudes in sunflower, but not in niger. However the content of linoleic acid increased to 85% in a trial with very cool growing conditions at Bako (Prinz, 1976). Some data on the composing fatty acids are summarized in Table 37.

Comparison of the data of Chavan (1961) with my findings and those of Grieco & Piepoli (1967) suggests that Ethiopian Niger seed oil contains more saturated fatty acids, particularly lignoceric.

The main composing glycerides as given by Chavan (1961) are presented in Table 38. In view of the larger proportion of linoleic in Ethiopian niger oil, these values will not hold true for Ethiopian oil.

The raw oil becomes rancid by hydrolysis if it is kept for some time. It also thickens, indicating polymerization. This seems to depend on enzymic action, which is stopped in the absence of air. If the oil is heated to 110–120°C and kept out of contact with air, it remains unchanged for a long time. On hydrogenation, the oil forms a white solid fat (Chavan, 1961).

The average composition of presscake as given by Chavan (1961) is shown in Table 39. A comparison of the data of Chavan (1961) and of Ågren & Gibson (1968) (Table 35) shows that presscake from Ethiopia has a strikingly lower protein content than the Indian one, but a much higher content of carbohydrate (inclusive fibre).

2.10 Helianthus annuus L. (Compositae)

Sunflower is called jabar suf or ferenj suf ('white man's safflower') (Amharic), dubi or nugi adi (Gallinya), and serir-ghet (Eritrea) in Ethiopia. It was first reported from N Ethiopia by Quartin Dillon at the beginning of the 19th Century (Baldrati, 1950), and it was introduced much later into C Ethiopia. According to farmers, it came to the Debre Zeit area after World War II (Asrat Felleke, 1965).

Wherever it was introduced in traditional agriculture, it remained a plant of little importance, sown in some rows or small groups in the garden, only seldom mixed with cereals. In the last 15 years or so, large plantings, often with irrigation, were established at experimental stations and national development schemes.

Sunflower grows well in Ethiopia at altitudes below 2500 m (Baldrati, 1950), but it is more common below 2200 m. Yields of 1500 to 2500 kg of achenes ('seeds') per hectare are reported under unirrigated conditions (e.g. Brhane, 1971; Jimma Stn Progr. Rep., 1971) and close to 4000 kg/ha under irrigation (Melka Werer Progr. Rep., 1971).

Photograph 19. Sunflower and cucurbits near Alemaya.

In 1970 and 1971, the Bako Res. Stn Progr. Rep. indicated that sunflower had out-yielded all other oilseed crops in several successive years, and that it was the only oil crop well suited to the area.

At higher altitudes, such a sowing time should be chosen that the seed is ripe at the onset of night frosts. The latter can destroy the crop completely (Brhane, 1971). It is usually sown at the onset of the big rains (June-July) and harvested in November-December.

Sunflower is a good precursor for tef, while, except where following itself, precursors (maize, tef, Niger seed, bean, chick-pea, and fallow) did not have a significant effect on its yield (Bako Res. Stn Progr. Rep., 1971).

Some parasites are known to attack sunflower in Ethiopia (e.g. Kupzow, 1932a; Stewart & Dagnatchew, 1967; Schmutterer, 1971; Walker & Boxall, 1974) but they are not generally a problem. Birds and rodents, on the other hand, can cause such large losses that cultivation of sunflower for seed is not feasible (Frahm-Leliveld, 1963; Bako Res. Stn Progr. Rep., 1970; 1971).

Sunflower of traditional agriculture in Ethiopia always is a tall plant. This is because in Ethiopia a very important product of sunflower is the stalk, which is used as building material (my own information, Alemaya region; Asrat Felleke, 1965; Rydén, 1972; Linder, 1976). The seed is usually roasted and eaten as such; for this purpose, white seed is preferred.

In Arussi, Rydén (1972) found three types of achene: (1) 'white'; (2) 'black with a few faint grey stripes'; (3) 'black with grey stripes, broadened on edges'. No correlation between the phenotypes of achenes and plants could be established.

In my collection, 7 distinct achene colours are present. They are surveyed below. (1) 'White': Royal Horticultural Society colour chart 159C (orange-white group); (2) 'light grey': RHS-CC 202B-D (black group); (3) 'grey-black': RHS-CC 200A (brown group) to 197A (greyed-green group) with very fine lines in RHS-CC 202A (black group) rendering it blackish, especially basally; (4) 'light-grey, brownish to greenish tinged': RHS-CC 199A-D (grey-brown group), sometimes darker basally in RHS-CC 164B to 165A-B (greyed-orange group); (5) 'grey with white stripes': RHS-CC 197A (greyed-green group), stripes RHS-CC 159C (orange-white group); (6) 'grey with light stripes, chamois tinged': RHS-CC 199A but darker (grey-brown group), stripes RHS-CC 159A (orange-white group); (7) 'black with white edges and some white stripes': RHS-CC 200A (brown group) to 202A (black group), stripes RHS-CC 156C-D (greyed-white group).

Ferrara (1943) investigated three samples of seed from Ethiopia. Some of his observations are summarized below (g/kg).

Provenance	Moisture	Crude oil	Crude protein	Cellulose + N-free	Ash
Javello (Kefa)	741	284	132	479	31
Harer	684	251	151	501	29
Harer	754	332	113	449	30

From other regions, higher oil contents in seed were reported: Baldrati (1950, Keren, kernel 420 g/kg), Rydén (1972, Arusi, Type 1, 220 g; Type 2: c. 450 g; Type 3: 503 g/kg). In four samples of my collection, the whole dried achenes contained c. 170 to 350 g/kg.

Ågren & Gibson (1968) surveyed the average food value of whole Ethiopian sunflower seed as follows.

Food energy (MJ/kg)	(19.707)20.418(21.255)
Moisture (g/kg)	(43)55(63)
Nitrogen (g/kg)	(25)27(32)

Crude protein (N × 4.94; g/kg)	(124)135(158)
Crude fat (g/kg)	(274)296(328)
Total carbohydrate, inclusive fibre (g/kg)	(458)474(496)
Ash (g/kg)	(35)40(47)
Calcium (mg/kg)	(1650)1900(2040)
Phosphorus (mg/kg)	(4650)5530(6110)
Iron (mg/kg)	(340)500(660)
Thiamin (mg/kg)	c. 116
Riboflavin (mg/kg)	c. 14
Niacin (mg/kg)	c. 36
Tryptophan (mg/kg)	(6570)6710(6850)

2.11 Jatropha curcas L. (Euphorbiaceae)

(Somalinya: andelmeluc, antelmeluc, anthalmelou; Tigrinya: abelmeluk; English: physic nut, purging nut, pulghere; French: pourghère, pignon d'Inde).

This plant is a vigorous bush with soft wood, 1–8 m tall. It has a straight stem with grey or reddish bark, with wide white spots. The wood and marrow contain long lactiferous vessels, stretching into the roots. Latex appears at the least injury and dries to a brownish mass (Adam & Ferrand, 1958).

The large leaves are alternate, palminervate, 3–5-lobed, coarse, long petioled and usually dark-green; at the end of the dry season, they are partially dropped (Adam & Ferrand, 1958).

The yellowish monosexual flowers are in corymbiform, terminal cymes. They have well developed pentamerous flowers; sepals and petals basally fused, corolla campanulate. Male flowers in the perifery of the inflorescense; female flowers in the centre; gynoecium similar to that of non-spiny castor (Larochas, 1948).

The fruits are similar to those of castor but are indehiscent as long as they remain on the plant. They are dark and not spiny; they weigh c. 1.5–3 g, more than half seed weight (Larochas, 1948; Adam & Ferrand, 1958).

The elliptic seed is similar to that of castor but thicker. It is black with numerous yellowish dots and basally with a bilobate reddish caruncle. The caruncle is hardly visible on the dry seed (Larochas, 1948).

Pulghere is reported from the northern and southern lowlands of Ethiopia (Cufodontis, 1956). It originates from the hot regions of C and S America, whence it was introduced into Africa by the Portuguese (Adam & Ferrand, 1958). In Ethiopia, it was probably introduced during the last half of the Nineteenth Century (Baccarini, 1909). It can now be found subspontaneously practically all over the warmer countries of the world. It is often planted as a hedge (Adam & Ferrand, 1958). To my knowledge, it is not cultivated to any extent in Ethiopia.

The plant will grow practically everywhere in the hot tropics, both in dry and in humid climates, up to 1000 m (Larochas, 1948). Cultivation can be compared to that of castor, with the exception, that this plant can be propagated by cuttings. The plants starts to produce flowers c. 4–5 months after propagation. Seedlings are more productive than cuttings (Adam & Ferrand, 1958); they have a much stronger root system

Table 40. Average composition of the kernel of pulghere (g/kg; data from Calvino, 1925).

Moisture	74.5	Crude oil	453.0
Ash	45.5	Carbohydrate	14.0
Protein	377.0	Crude fibre	36.0

(Calvino, 1925).

Rather strong stalks 40–100 cm long are used as cuttings; they are put into the soil. If sown, three to four seeds are planted in each hole, 1-1½ m apart. This is equivalent to 5–8 kg/ha. Both planting and sowing are at the onset of rains. Crop care is as that of castor (Adam & Ferrand, 1958).

The shrub can live up to 50 years and stands pruning very well. The latter practice favours fructification and facilitates harvesting. Its perennial habit might make it a useful plant in fighting erosion (Larochas, 1948; Adam & Ferrand, 1958).

The fruit stays rather long on the plant so that harvesting time is not critical. After harvest, the fruits are heaped in piles, where spontaneous dehiscence takes place. The seeds can be collected and given their final drying (Adam & Ferrand, 1958).

Yields of 400–1200 kg of seed are obtained in the Cape Verde Islands, equivalent to about 3–3½ kg per plant, but experimental plantings in West Africa have produced as much as 8000 kg of seed per hectare (Larochas, 1948; Adam & Ferrand, 1958).

The seed weighs c. ½–¾ g (Adam & Ferrand, 1958), and is 16–20 mm long and 10–12 mm wide (Calvino, 1925). It contains 300–400 g of oil per kilogram and about 190

Table 41. Some characteristics of pulghere oil (data from Ubbelohde, 1920; Larochas, 1948; Adam & Ferrand, 1958).

Relative density at 15 °C	0.917–0.923
Viscosity (mm^2/s) at 28 °C	c. 60
at 100 °C	c. 8.5
Solidification temperatures	
expelled oil	−13 to −15 °C
laboratory-extracted oil	c. 0 °C.
Refractive index at 15 °C	1.4720–1.4733
Flashpoint	247 °C
Flame point	395 °C
Acidity (as oleic)	0.4–5.5
Saponification value	c. 175–200
Iodine value	c. 93–109
Acetyl value	4–9
Hehner value	c. 96
Reichert-Meissl value	0.55
Caloric value (kJ/g)	38.39–39.69

Table 42. Composing fatty acids of pulghere oil. (Source: Gunstone et al., 1964). (Substance fraction %.)

palmitic	16.4	oleic	39.8
hexadecenoic	1.3	linoleic	36.1
stearic	6.4		

g proteins (Adam & Ferrand, 1958; Barclay & Earle, 1974). The kernel, forming 60–70% of the seed weight, contains about 500–600 g of oil per kilogram (Adam & Ferrand, 1958).

Industrially, the seed yields 280–300 g of oil per kilogram, leaving a poisonous cake, which is comparable to that of castor. The oil has the same medicinal properties as castor oil, but is stronger: 10 drops of pulghere oil have the same effect as a spoonfull of castor oil (Larochas, 1948).

The leaves have haemostatic properties, which are used locally to cure wounds (Larochas, 1948).

Seeds and oil should be used carefully because of the presence of an alkaloid, which is at least as powerful as that of castor (Adam & Ferrand, 1958).

The oil is good for soap manufacture and has excellent burning properties. The Chinese use it for preparation of their varnishes, and locally it is used against skin diseases (Adam & Ferrand, 1958). Eritreans use the oil in combination with kosso (*Hagenia abyssinica* (Bruce) Gmelin) to combat tapeworm (Suzzi 1904 & 1905).

The oil is semidrying to non-drying, yellow, changing to reddish by heating or prolonged exposure to air; its odour is sweet and its taste is as that of castor oil (Larochas, 1948; Adam & Ferrand, 1958).

The average composition of the kernel, as given by Calvino (1925) is presented in Table 40.

Some characteristics of the oil and its fatty acid composition are given in Tables 41 and 42, respectively.

2.12 Linum usitatissimum L. (2*n* = 30) Fig. 7

'Linum': the old Latin name for this plant.
'usitatissimum': most useful.

Linnaeus, Sp. Pl. ed. 1: p. 277 (1753).
Type: a plant from Algeria; designated by Kulpa & Danert (1962, p. 342) (LINN, specimen 396.1, lecto., microfiche!).

Synonyms

Linum usitatissimum L. var. *vulgare* Boenn., Prodr. Fl. Monast. Westphalorum: p. 94 (1824).
Linum usitatissimum L. var. *indehiscens* Neilr., Fl. Nied.-Oesterr.: p. 864 (1827).
Linum indehiscens (Neilr.) Vav. et Ell. in Wulff, Fl. cultivated Pl., vol. 5: p. 117 (1940) (no latin description).

Linum usitatissimum L. var. *strepens* Auct. (p. 158, Note 2).
Linum africanum Hort. non L.

Literature

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1948: Desgrange, Le lin, plante oléagineuse, Oléagineux 3(2): p. 80–86. (agric.)
1949: Ciferri, La sistematica del lino, 203 p. (tax.)
1962: Kulpa & Danert, Zur Systematik von Linum usitatissimum L., Kulturpfl. Beiheft 3: p. 341–388. (tax.)

Vernacular names: telba, talba, talwa (Amarinya); kontar, konter, telba, talba, tarba (Gallinya); mutu (Kafinya); entatie, entade, endade, lina (Tigrinya).
Trade names: linseed, flax seed (English); graine de lin (French); semen lini, oleum lini (medical).

Geographic distribution

Cultivated flax most probably originated in the Near East. The earliest finds date from the 5th Millenium B.C.. It is certainly one of the first oil crops ever domesticated in that area. For millenia, *Linum* remained the only commonly cultivated oilseed (Helbaek, 1959). It is not certain, though, whether all linseed grown through the ages was *Linum usitatissimum* L. (B[accarini], 1909). The countries where the plant is now in demand as an oil plant are mainly situated around the Arabian Peninsula.

In practically all parts of Europe, Africa and the Near East, *Linum* has been cultivated at some time or another. Material found in Iraq may constitute the link between the *Linum* of dynastic Egypt and *Linum* from Stone Age Europe; they differed in several aspects. Iraq happens to be situated in the middle of the distribution area of the most probable progenitor: *Linum bienne* Miller (Helbaek, 1959).

For cultivation, the two groups usually distinguished are fibre flax and oilseed flax. They have a different habit and habitat. Fibre flax is only cultivated in cool moist climates, characteristic of the northern temperate zone. Linseed is successfully grown in subtropical regions and tropical highlands, between about 0 and 50° latitude. According to most authors (e.g Bunting, 1951; Desjobert, 1954) this is because linseed withstands periods of drought much better. But Zusevics (1966) thought that this pattern of distribution has been caused by economic rather than by ecological processes.

In the first half of this century, important areas of linseed production were centred around the Great Lakes of N America, in Argentina and Uruguay in S America, and in the S Soviet Union (Bunting, 1951). At that time, Ethiopia too was one of the main suppliers to world trade linseed (Ciferri, 1949). Since the decline of international trade in linseed, the main producers are the countries in which the crop forms part of traditional agriculture.

Linseed has been cultivated in Ethiopia from time immemorial (Tissot, 1938). According to Braun (1848) and Wittmack (1907), linseed was cultivated all over Ethiopia, especially in the highlands. If these observations were correct, the situation has changed: it is now grown exclusively in the highlands. It is found particularly in the higher parts, where such crops as Niger seed and safflower do not produce well. This is illustrated by the observations of Linder (1977), who found in Arussi that no flax was cultivated at altitudes below 2000 m. At altitudes between 2500 and 3000 m, however, linseed occupied 43% of the cultivated land. Also Werdecker (1955) and Rydén (1972) found linseed only over 2200 m in that area. In the area near Debarak, where linseed is an important crop, it is cultivated mainly at altitudes of 2400 to 2600 m (my own observation; Troll & Schottenloher, 1939). But in older literature, indeed, lower altitudes are mentioned: 1500 m (Corni, 1938) and 1000 m (Ciferri, 1944). Cool fields may be specially selected (Candussio & Scabardi, 1953).

The Provisional Military Government (1977) published the following survey of the estimated area and production of linseed in the different provinces of Ethiopia.

Place	Estimated area (in 1000 ha)	Estimated average yield (kg/ha)	Estimated total production (in 100 Mg)
Arussi	4.0	236	9.4
Bale	4.5	329	14.8
Beghemder	2.0	400	8.0
Gemu Gofa			
Gojam	13.3	158	21.0
Harergie			
Illubabor	0.4	176	0.7
Kefa	0.1	393	0.4
Shewa	10.1	719	72.6
Sidamo			
Welega	1.8	206	3.7
Welo	0.9	234	2.1
Ethiopia	37.1		132.7

With this 37100 ha, flax covered c. 0.8% of the agricultural area of Ethiopia. It was mainly produced on farms smaller than 5 ha. A similar figure for the linseed area of Ethiopia was given by Bridges (1960): 34800 ha. But in the Statistical Abstract of 1970, much higher figures are given. According to this source, the area increased from 113000 to 120000 ha in the years from 1966 to 1970. In that same period, the yield increased from 500 to 520 kg/ha, resulting in a production of 56.5 to 62.1 Gg.

From what I have seen, the most important linseed areas of Ethiopia are situated in Arussi with the adjoining areas in Bale and the Chercher Mountains, in E Welega and E Gojam, around Lake Tana, the Simien Mountains, Tigre, Eritrea, and SW Welo. The high figure, given for Shewa in the preceding survey, was a surprise to me. Probably the linseed-producing areas of this province are situated in the north, a region I did not survey closely.

Description

Habit: annual herb, glabrous in all its parts except inside fruit, (20)30–60(80) cm tall, (1)2–8(45)-stemmed by basal branching; each stem with (2)3–7(26) branches in the upper part, terminating in a flower; when growing under continuously humid conditions, branches may develop later on the lower parts as well; branching of second order takes place usually only in the axils of the last two leaves under each flower, branching of higher orders commonly only in the axil of the leaf under a flower.

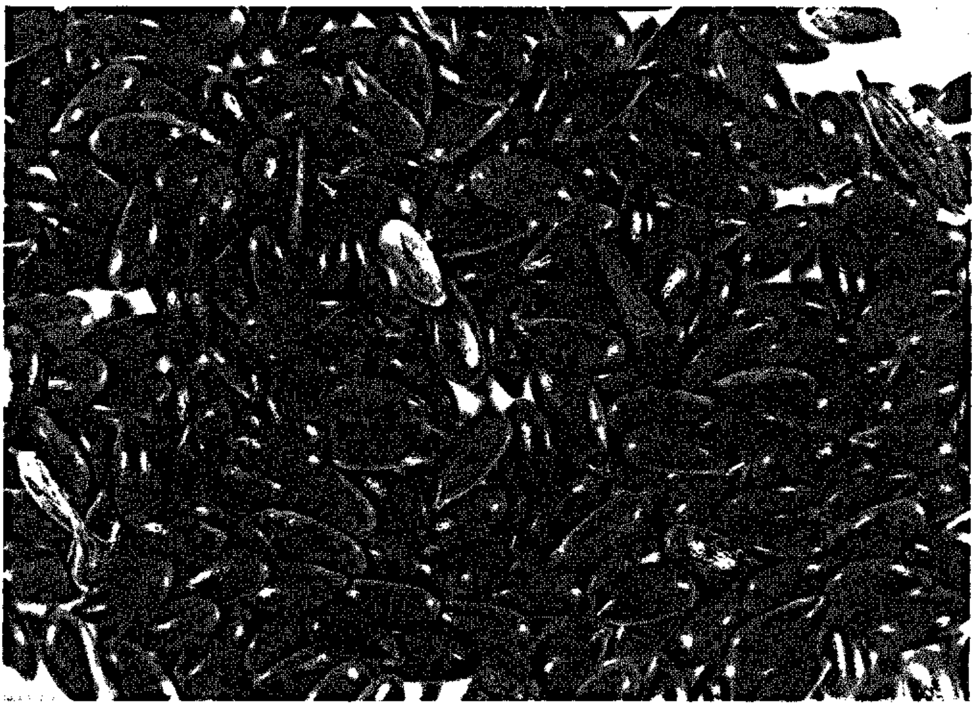
Stems erect or ascending, seldom prostrate, cylindrical, up to 6 mm diam., smooth, pale (yellowish to purplish or greyish) green, sometimes darker green or only so near apex or with darker green spots, base often purplish tinged or woody and with clearly visible lenticels, apically less leafy than basally, with the largest leaves ± in the middle.

Leaves alternate to subopposite, sessile, narrowly elliptic to linear or lanceolate, up to 48 mm long and 8 mm wide, dull (greyish or bluish) medium green, sometimes light green, trinervate from base almost to the acute top.

Pedicel at anthesis 3–22 mm long.

Full-grown flower bud ovoid, acuminate to acute at apex; the contorted petals becoming apparent the day before anthesis.

Sepals 5, quincuncial, broadly elliptie to ovate, the innermost sometimes nearly circular, (5)6–8(9) mm × (2)3–4($5\frac{1}{2}$) mm, green, with a transparent, whitish, (apically)



Photograph 20. Brown *Linum usitatissimum* seed from Haik (SL 1109; × 5).

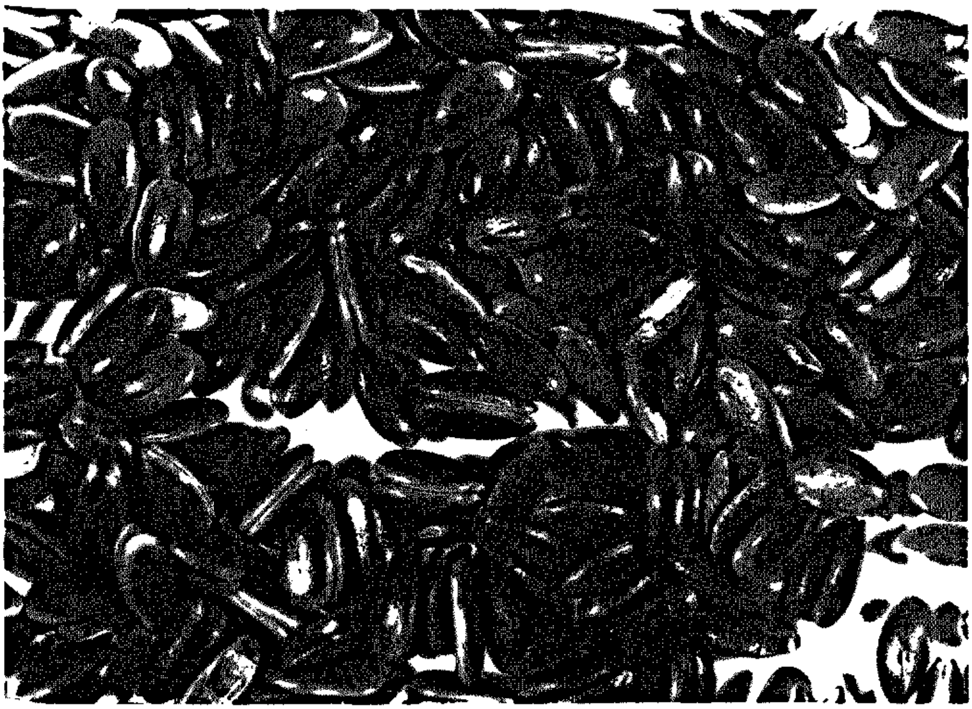
fimbriate margin and a mucronate (or acute) top, the outer two more slender than the others, their whitish marginal zone being much narrower (sometimes absent), with 3 main veins and 2 smaller ones.

Corolla funnel-shaped to cup-shaped, soon caducous; petals 5, implanted above the receptacle on the united base of the stamens, (purplish) blue, usually with darker veins, seldom white, thin, obovate to obtriangular or obtrulliform (8)9–13(15) mm × (4)6–10(11) mm, with bluntly undulate upper margin and with cuneate to attenuate, shortly clawed, 1-veined base, the vein branching once palmately into 3 and then dichotomously.

Stamens 5, alternating with the petals, with a basal gland outside on the shortly united base, which forms a shallow ring, and with 0–2 lobe(s) between; free parts of filaments up to 6½ mm long, semiterete to flat, tapering, flat to very shallowly furrowed inside, white, often blue near apex, sometimes entirely pale blue; anthers oblong, c. 1–2 mm long, basifixed, the cells protruding basally, free for about a third of their length, opening laterally by two slits lengthwise, blue, seldom yellow.

Ovary superior, ovoid to ellipsoid, usually broadly so, 2–3½ mm diam., green, with 5 epipetalous locules; each locule nearly always with a basal septum, which turns into a shallow, glabrous, seldom ciliate ridge on the ovary wall near the apex, and with 2 axillary, pendulous, anatropic ovules with a ventral raphe and an obturator.

Styles 5, often shortly connate at base, filiform, c. 2–2½ mm long, white, (pale) blue



Photograph 21. 'Double' seed of *Linum usitatissimum* cv. Lakeside from Haik (SL 1111; × 5).

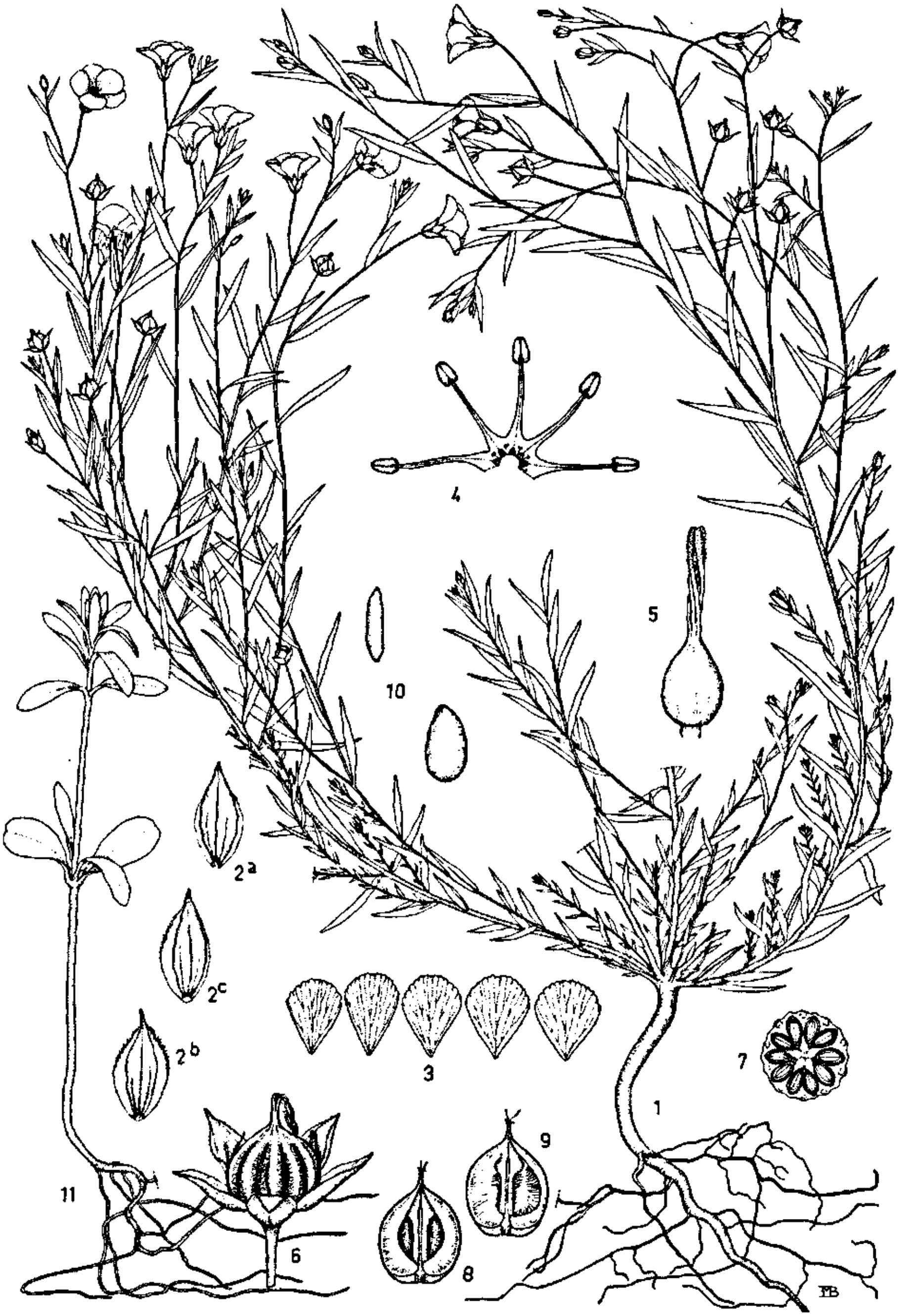


Fig. 7. *Linum usitatissimum* L. 1. Habit ($\times\frac{1}{2}$). 2a. Outer sepal. 2b. Inner sepal. 2c. Middle sepal ($\times 2$). 3. Petals ($\times 1$). 4. Anther tube laid open ($\times 2$). 5. Pistil ($\times 5$). 6. Young fruit ($\times 2$). 7. Section across of young fruit ($\times 2$). 8. Longitudinal section of young fruit with 'regular' false septa, seed removed ($\times 2$). 9. Longitudinal section of young fruit with narrow, ciliate false septa, seed removed ($\times 2$). 10. Seed ($\times 2$). 11. Seedling ($\times 1$). 1, SL 3508; 2–5, SL 1640; 6–8 and 10, SL 1733; 9, SL 3605; SL 1607.

or greenish.

Stigmas filiform, $1\frac{1}{2}$-2 mm long, inside with short papillae all over, outside often so in the apical part (up to a third of the length), white, whitish blue, pale blue or greenish.

Fruit an indehiscent glabrous capsule, sometimes opening apically with up to 10 very short splits, subglobose to broadly ovoid, up to 12 mm high (including beak), up to 11 mm diam., light brown, truncate at base, with beak up to 2 mm long, smooth, each carpel with 3 very shallow furrows lengthwise, partially covered by the persistent calyx, with 5 complete, true septa and 5 sickle-shaped false septa, the latter sometimes reduced to a ridge or absent; septa glabrous, less commonly with ciliate margin.

Seeds up to 10 per fruit, laterally shallowly biconvex, obovate to almost elliptic in outline, basally with a small beak, c. $3\frac{1}{4}$–$5\frac{1}{2}$ mm × $1\frac{1}{2}$–$2\frac{1}{2}$ mm × $\frac{3}{4}$–$1\frac{1}{4}$ mm, usually ,brown, less often yellowish, glossy, smooth. Embryo large, erect, covered with endosperm; embryo and endosperm rich in oil.

Seedling epigeal, with a filiform root system with many laterals. Hypocotyl cylindrical, glabrous, pale green, brownish tinged at base, up to 50 mm long. Cotyledons opposite, elliptic to obovate or broadly so, up to 17 mm long, up to $9\frac{1}{2}$ mm wide, with obtuse, often shallowly retuse top and cuneate base, medium green, beneath paler than above, trinervate, central vein longer than the others. Epicotyl up to 4 mm long, usually c. 1 mm, pale medium green. Leaves spirally arranged, often subopposite above the cotyledons, narrowly elliptic to narrowly obovate, further as leaf of full-grown plant, up to 16 mm long, up to 5 mm wide. When the epicotylar shoot is c. 5 mm long, tillering may start in the axils of the cotyledons.

Notes

(1) The family *Linaceae* consists of 22 genera, 8 of which are indigenous to Africa (Winkler, 1931). It is known mainly for the genus *Linum* L., which contains about 200 species (McGregor, 1960). This genus finds its main distribution in the subtropical and temperate zones of the N hemisphere (Tobler, 1928; Ray, 1944). Because many species are highly polymorphic, there is a considerable synonymy and confusion on both interspecific and infraspecific relationships (Plessers, 1966).

Linum maritimum L. and L. *perenne* L. were formerly cultivated as a fieldcrop in S Europa but presently the only species cultivated as such is *L. usitatissimum*. Some other species are cultivated as ornamentals (Tobler, 1928).

The closest relative of *L. usitatissimum* is *L. bienne* Miller. The two species are the only ones in the genus that are homostylous and several of their other floral characters are very similar as well (Ciferrri, 1949). The chromosome numbers are the same: $n = 15$, $2n = 30$–32 (Simonet, 1929) and the two species can be crossed easily. The hybrid is fertile, intermediate between the two species, and segregates normally in following generations (Tammes, 1923). Several authors (e.g. Körniche, 1888; Schilling, 1935; Bunting, 1951) take it for granted that *L. bienne* is the wild progenitor of *L. usitatissimum*. In the terms of Mansfeld (1953), *Linum usitatissimum* is a specioid within *L. bienne*.

Occasional reports of successful crosses with other *Linum* species are, in my opinion, often the result of mistaken identity of the plant involved. Particularly the name *Linum africanum* is often applied to forms of *L. usitatissimum*. This appears to be so in literature when the flowers are reported to the blue or white (for more information see Ray, 1944; Plessers, 1966). True *Linum africanum* L. is a yellow-flowered species with opposite leaves from Africa (L., Sp. pl., ed. 1, p. 280, 1753). The yellow-flowering *Linum* species are always treated as a separate section of the genus, which never has white or blue flowers.

Unfortunately, the identity of plants indicated as *L. africanum* by Bari & Godward (1970), for instance, cannot be verified because no herbarium vouchers were conserved. No conclusions are warranted from the research of Bari & Godward.

Linum bienne has two geographic races: and Atlantic-Mediterranean coastland race, usually described as perennial and formerly known as *L. angustifolium* Huds., and a continental biennial race, distributed in the semi-arid foothills of Iraq, Kurdistan and Iran (Helbaek, 1959). It can be distinguished from *L. usitatissimum* by lower stature, narrower leaves, thinner branches and smaller reproductive parts. It makes two types of tillers: fertile and sterile, whereas *L. usitatissimum* makes only fertile tillers.

Within *L. usitatissimum* s.l., the following groups can be distinguished by agronomic characters (Schilling, 1935).

Linum usitatissimum L. s.l.

Perennial or biennial wild (*L. bienne* Miller) ←	→ Annual or winter annual cultivated (*L. usitatissimum* L. s.s.)
Shattering ←	→ Non-shattering
Winter annual ←	→ Annual, spring crop
Large-seeded oilseed flax ←	→ Small-seeded
Oilseed flax ←	→ Fibre flax

The Ethiopian flax belongs to the small-seeded oilseed flaxes.

(2) Cufodontis (1974, p. 356) indicated the presence of *L. usitatissimum* L. var. *crepitans* Bönn. in Ethiopia. In my material, I did not encounter this variety, nor did I find it in the literature on Ethiopian flaxes (Ciferri, 1941; 1944; 1949). Ethiopia is not in the area for this variety (Tammes, 1908; Ciferri, 1949).

Among Cufodontis's synonyms of this variety is *L. usitatissimum* L. var. *strepens* Schübler. Cufodontis interpreted *strepens* as a misspelling of *crepitans*. Indeed Schübler & Martens (1834, p. 211) published only var. *vulgare* and var. *crepitans* within *L. usitatissimum*.

I have not traced the origin of '*strepens*'; Schübler did not use it and Cufodontis's reference therefore is incorrect. However, before Vavilov's expedition to Ethiopia (and even much later: Fiori, 1939), all linseed of mountainous Italian E Africa was generally referred to as *L. usitatissimum* L. var. *strepens* Schübl. (Ciferri, 1941; 1944).

Schübler & Martens' (1834) var. *vulgare* contains the type of *L. usitatissimum* L., and so ought now to be called *L. usitatissimum* L. var. *usitatissimum*. Their var. *crepitans* is not found in Ethiopia. Schübler & Martens referred it 'auf der Alp und im Schwarzwald'. The German folknames 'Klanglein' and 'Springlein' obviously account for *'crepitans'*. Var. *crepitans* is lower, more branched, with larger flowers and capsules (capsules dehiscing) and earlier ripening, and more pallid seeds than var. *'vulgare'*.

Ethiopian *Linum usitatissimum* has indehiscent capsules.

In *L. usitatissimum*, Bönninghausen (1824) described a var. *crepitans* ten years before Schübler & Martens. Cufodontis therefore is correct in citing *L. usitiatissimum* var. *crepitans* Bönn. Since var. *crepitans* Bönn. is most probably the same as var. *crepitans* Schübl. (both authors referring to 'Klanglein', but Schübler did not mention Bönninghausen) and since it has dehiscent capsules, the variety is not Ethiopian and Cufodontis ought not to have entered var. *crepitans* Bönn. in his Enumeratio.

Ciferri (1941, 1944), while discussing 'var. *strepens* Schübler', stated that in commerce several distinct qualities of 'var. *strepens* Schübl.' were distinguished. However in 1949 in the general revision of *Linum usitatissimum*, no reference to 'var. *strepens* Schübler' is found, and no explanation is given for its absence. Ciferri perhaps abandoned 'var. *strepens* Schübler' because it was clear to her that the name was an error.

Ciferri (1949) proposed a taxonomy for *Linum usitatissimum* based on Wulff & Elladi's revision (in Russian). I have not followed the species concept of these authors and adopted Kułpa & Danert (1962) instead.

Because *Linum usitatissimum* in Ethiopia bears indehiscent capsules, 'shattering' in the sentence: 'Yield of flax was low mainly due to shattering', in Mulugeta Assefa (1972) must be interpreted as a loss by cracking of too dry fruits. This may happen if the plants are left too long on the field (p. 185). The fact that American cultivars were included in the remark supports this opinion. Also Dillman (1953) indicated that some Ethiopian cvs. tend to this habit ('The seeds shatter to some extent when harvest is delayed').

(3) The genetical survey on flax given by Płonka (1951, 1957) shows that the number of genes governing the main colour of floral parts and seed in flax is not large. Although there are modifier genes, the differences in colour are so clear-cut that many authors recognize taxa based on them (e.g. Howard & Rahman Khan, 1924; Ciferri, 1949; Kułpa & Danert, 1962).

Another character often used is that of the ciliation of the false septa (e.g Ciferri, 1949). This character is monofactorial with some modifier genes (Tammes, 1930). In my collection, the differences between non-ciliate and ciliate were so large that it was not a problem to decide which category a specimen belonged to. Apparently this is not so on a world-scale, as Kułpa & Danert (1962) do not use this formerly applied character at all.

(4) Ethiopian linseed is rather similar to that from India, and several authors dis-

tinguish an Indo-Abyssinian group (e.g. Ciferri, 1949; Płonka, 1957). Compared to other groups, those plants are distinguishable by the combination of small stature, thin stems, small leaves, flowers that do not fully open, violet colour on seedling, stems, and particularly on almost ripe fruits, their calyces and peduncles (Ciferri, 1949, p. 66, 80).

There is a different pattern of variation in India and Ethiopia, though. It is illustrated by the fact that of the 28 taxa, distinguished in the Indo-Abyssinian group by Ciferri (1949), only two are found in both countries.

In the Ethiopian material grown at Wageningen, there was some violet at the base of the stems of most plants, but not generally violet on the fruits, and certainly not as strong as suggested by Ciferri (1949). The colour of the nearly mature fruits was green with lighter longitudinal stripes. Also the labels of Bos 7752, F. G. Meyer 8624, PJ 5516, PJ 5669, and WdeW 6734, collected in Ethiopia, did not mention a violet colour.

According to Ciferri (1944), the leaves of Ethiopian linseed are light green and those of Indian linseed greyish green. In my collection, there were only a few plants with light green leaves, the majority being medium green and there were also plants with greyish green leaves.

(5) Observations on the SL seed-collection (WAG).

(a) Colour

With the unaided eye, 4 colour groups could be distinguished in my Ethiopian linseed collection and there were only a few samples that were difficult to place in one of the groups. The groups are 1. 'brown', sometimes with a greenish shade, 2. 'light brown', 3. 'beige' and 4. 'yellow'. Quite often mixtures were present. Surprisingly enough, mixtures containing a minor proportion of beige or of yellow seeds were found only in the 'brown' group. The proportion of the lighter-coloured seeds varies from less than 1% to nearly 50%. The mixed-coloured seed-samples represent the cultivar population: one single plant produces seeds of one single colour.

A comparison with the colour chart of the Royal Horticultural Society (London) showed all the groups to have basically colours of the greyed orange group. The following survey gives the colour of the main component; the samples with a minor component of beige and yellow are indicated by (+).

1. 'Brown' = colour 165 A. With 65 samples, this is the largest group. To it belong the following SL numbers: 14, 20, 24(+), 28, 33, 35, 39, 49, 58, 100, 114, 120, 167(+), 197, 211, 229(+), 252, 260, 295, 302(+), 303, 304, 348, 380, 381, 421(+), 425, 489, 499, 500, 560, 601, 742, 763, 803, 821(+), 827, 873, 975, 1023, 1056, 1089, 1090, 1108(+), 1109, 1110, 1111, 1197, 1208, 1209, 1238, 1248, 1274, 1293, 1294, 1298(+), 1337, 1344, 1382, 1383(+), 1434, 1461, 1480(+), 1536, 1565.

In it, the following tendencies are present:

- towards 200 D (brown group), giving a darker impression
- towards 166 A, giving a more reddish brown impression
- towards 165 B, giving a lighter impression.

2.'Light Brown' = a colour between 164 A and 165 B. To this belong SL numbers, 34, 38, 59, 66, 68, 173, 187, 206, 218, 256, 559, 638, 680, 681, 822, 898, 929C, 943, 962, 1057, 1162, 1408, 1409, 1426, 1462, 1481, 1512, 1564.

In it tendencies are present towards colours 164 A and 165 A. In both cases the impression is slightly darker. Also a tendency towards 166 B was found, this induces a more reddish brown tinge.

3. 'Beige' = colour 164 B: SL 63, 65, 81, 121, 132, 1479, 1511.

4. 'Yellow' = colour 164 C: SL 41, 249, 269, 422, 490, 639, 1107, 1384.

The samples classified 'beige', were all from Kefa and Illubabor, while the 'yellow' samples were from Welo, Harergie, and Sidamo. In the mainly brown samples to which those colours were a minor component, those from Illubabor, Sidamo and Shewa belonged to 'beige', and the one from Welo to 'yellow'. Those from Harergie showed both colours separately, while the sample from Gojam had a mixture of both.

The distribution of the different groups suggests that 'brown', 'light brown' and 'beige' can be found in all linseed producing areas of Ethiopia, while 'yellow' is less frequent or absent in the Kefa-Illubabor region.

There was no correlation between colour and average weight of the seed, but the heaviest seeds were found in 'brown'. They are most probably from a non-Ethiopian cultivar (p. 167, Note 6).

(b) Weight (p. 190)

A plot of frequency against thousand-seed weight suggests the existence of 3 main groups of seed weights: one below 3 g, one between 3 and 4.1 g, one between 4.1 and 5 g. Two minor groups were present between 5.1 and 6 g and between 6.1 g and 7 g. The prevalence of the groups is regionally bound. If we divide Ethiopia in the following 4 regions: SE (roughly the region between lines Addis Abeba–Awasa–border, and Addis Abeba–Djibouti), SW (a similar region between Addis Abeba–Awasa–border, and Addis Abeba–Asosa–border), NE (region between line Addis Abeba–Djibouti and Addis Abeba–Massawa), and NW (the rest of Ethiopia), we see differences appearing as represented in Table 43. The smallest seeds are found in areas with high rainfall.

Although these observations were based on small and unequal numbers of samples, the differences are so large that no further considerations seem to be necessary.

But for one (SL 1294), the seed weight of samples from which plants grew with ciliate or reduced false septa in their fruits was higher than average. The number is too small, though, to be conclusive. Ciliate septa were only found in offspring of the brown group, particularly in the south (Bale, Sidamo and adjoining areas), in the Chercher Highlands, and near Haik (Welo). Reduced or absent false septa were found in the brown and light brown groups from the Haik region and from Aksum.

(6) I have tested two keys, that of Ciferri (1949) (essentially the same as that of Elladi) and that of Kulpa & Danert (1962) with my materials, observations and specimens. The key of Ciferri proved to be generally satisfactory. Only a few plants could not be classified into a var. within ssp. *indoabyssinicum,* but is was still possible to determine their variety.

The key of Kulpa & Danert caused me some difficulties. Because I was not aware

Table 43. Regional distribution of thousand-seed weight of linseed from different regions of Ethiopia within the SL collection.

SE[1] (51 samples)			SW[1] (24 samples)		
weight (g)	number of samples	proportion of samples (%)	weight (g)	number of samples	proportion of samples (%)
<3	3	5.9	<3	15	62.5
3–4.1	38	74.5	3–4.5	8	33.3
4.2–4.9	7	13.7	4.2–4.9	1	4.2
>4.9	3	5.9	>4.9	0	0
NE[1] (21 samples)			**NW[1] (10 samples)**		
weight (g)	number of samples	proportion of samples (%)	weight (g)	number of samples	proportion of samples (%)
<3	0	0	<3	2	20.0
3–4.1	3	14.3	3–4.1	4	40.0
4.2–4.9	17	81.0	4.2–4.9	4	40.0
>4.9	1	4.8	>4.9	0	0

1. See text, p. 161.

of their criteria while collecting the material, I did not note the angle of opening of the flower and the length-width ratio of the petals. It is difficult or impossible to determine these characters from herbarium material. As the petals become generally caducous in ethanol, preserved flowers do not give any clue about the angle of opening either.

The synonyms referred to the vars. by Kulpa & Danert, when compared to the vars in the key be Ciferri, prove that Kulpa & Danert segregate linseed in Ethiopia as follows in 4 vars.

Var. *albocoeruleum* How. & Rahm.; in synonymy Linum indehiscens (Neilr.) Vav. & Ell. with vars. copticum Vav. & Ell. and neoscioanum Cif.

Var. *axumicum* Cif. with synonym Linum indehiscens (Neilr.) Vav. & Ell. var. abyssinicum Vav. & Ell.

Var. *caesium* How. & Rahm.; in synonymy Linum indehiscens (Neilr.) Vav. & Ell. with vars. himalaicum Vav. & Ell., erytreum Vav. & Ell., aethiopicum Vav. & Ell., harraricum Vav. & Ell., gondaricum Vav. & Ell., scioanum Cif., amharicum Cif., neoamharicum Cif. and bisamharicum Cif.

Var. *candidum* Vav. & Ell.; in synonymy Linum indehiscens (Neilr.) Vav. & Ell. var. addis-abebae Vav. & Ell.

The diagnostic characters of vars *albocoeruleum, axumicum, caesium* and *candidum* suggest that Kulpa & Danert (1962) thought that in Ethiopian linseed the flowers never opened more than 60°, and that the 'narrow' petals (length more than $1\frac{1}{2}$ times the width) only occur in combination with yellow seed.

Neither observation is fully correct, particularly that about the length/width ratio of the petals. This is not surprising if we consider that Kulpa & Danert had only five Ethiopian entries in their collection. Their observation certainly represents the more usual situation, though. For the correlation of yellow seeded with 'narrow' petals, they are right, but I found also 'narrow' petals in combination with brown seed (var. *pratense* How. & Rahm.). I had to make the observations from cooked material and the values found differed generally not much from $1\frac{1}{2}$ in their length/width ratio.

To decide on the angle of opening of the flower from herbarium material is, of course, risky. However I found that all those herbarium specimens I identified that did not fit in ssp. *indoabyssinicum* in the key of Ciferri, fell into var. *usitatissimum* with the key of Kulpa & Danert. The vars they represent in Ciferri's taxonomy are all in the synonymy of var. *usitatissimum* sensu Kulpa & Danert. This proves in my opinion that this character, when applied to dry material, is of more practical value than one would tend to think.

Like other crops with a long history and a wide distribution, linseed has a confusing taxonomy. It is made more complicated by inaccurate rendering or citations of names, sometimes leading to wrong conclusions (Note 2). Often taxa are distinguished that are subject to the Code but the rules of the Code are partly or completely ignored. For instance, Elladi (1940) does not give Latin descriptions, Ciferri (1949, p. 120) makes illegitimate changes of name, and Kulpa & Danert (1962) do not designate types, except for the type variety. A variety has to be typified and Kulpa & Danert did not do so, which means that their varietal names are illegitimate. Therefore the names designated by Howard & Rahman Khan (1924; concerning this publication: vars *albidum, albocoeruleum, album, caesium, indicum, lutescens, luteum, pratense, purpureum*) and Ciferri (1944; vars *amharicum, axumicum, bisamharicum, neoamharicum, neoscioanum, scioanum*) are the only subspecific taxa in the keys of Ciferri (1949) and Kulpa & Danert (1962) that are validly published.

Because the varieties should be interpreted as cv. groups (Kulpa & Danert, 1962, p. 384: 'Sortengruppe') rather than as botanical varieties, I adopted the terms convar (conv.) and provar (prov.) instead of subspecies and variety, respectively. I thus avoided nomenclatural complications because the use of the taxa conv. and prov. is not regulated by any printed code.

The following is an abbreviated version of Ciferri's keys in which the status of the taxa has been changed as described above.

Analytical key for determination of the convars of *Linum usitatissimum*.

1. Seeds small, 3.6–4.9 mm long, 1.8–2.4 mm wide, 1000-seed wt 2.1–6.2 g. Fruits small, 6.1–8.3 mm long, 5.7–6.8 mm diam. Flowers small, diam. 15–21 mm, seldom 22–24 mm, in plants with wrapped petals smaller.

1.1. Flowers do not fully open. Hypocotyl of the seedling and the immature fruit normally intensely coloured with anthocyanin. 1000-seed wt 2.7–5.7 g. convar *indoabyssinicum*

1.2. Flowers wide open. Hypocotyl of the seedling weakly or not coloured with anthocyanin; immature fruit without anthocyanin, seldom weakly coloured. convar *eurasiaticum.*

2. Seeds large, 5.6–6.2 mm long, 2.8–3.1 mm wide, 1000-seed wt 10–13 g. Fruit 8.5–11.1 mm long, 7.6–8.5 mm diam. Flower wide open, 26–31 mm diam. convar *mediterraneum*

3. Seeds large or medium sized, 1000-seed wt 9.4–10.8 g for the large seeds, 6.3–9.3 g for the medium-sized seeds. Fruit 9.4–10.5 mm long, 7.8–8.0 mm diam. for the large-seeded group, 8.4–9.4 mm long and 6.8–7.5 mm diam. for the medium-sized group, intensely coloured with anthocyanin before ripeness. Flower small, often not fully open, the petals adhere for a long time. convar *hindustanicum*

4. Seeds medium-sized, 1000-seed wt 6.3–9.3 g. Fruits 7.3–9.4 mm long, 6.9–7.5 mm diam., anthocyanin on young fruit very weak or absent. Flower medium-sized or large, 22–24 mm diam., fully open, petals soon caducous. convar *transitorium*

Key for the Ethiopian provars within convar *indoabyssinicum.*

1 Seeds brown
1.1 Corolla sky-blue
1.1.1 Anthers blue
1.1.1.1 Septa ciliate (rare, cycle of medium duration). . . . . provar *himalaicum*
1.1.1.2 Septa glabrous
1.1.1.2.1 Septa narrow, reduced (extremely rare). . . . . provar *erytraeum*
1.1.1.2.2 Septa of regular dimensions (the most common provar, cycle short or medium). . . . . provar *aethiopicum*
1.1.2 Anthers yellow
1.1.2.1 Septa glabrous (rare, short cycle). . . . . provar *harraricum*
1.1.2.2 Septa ciliate (very rare to rare, cycle rather short to medium). . . . . provar *scioanum*
1.2 Corolla light sky-blue
1.2.1 Yellow anthers
1.2.1.1 Septa glabrous (rare, cycle short). . . . . provar *gondaricum*
1.2.1.2 Septa ciliate (rare, cycle rather short to medium). . . provar *amharicum*
1.2.2 Anthers blue
1.2.2.1 Septa glabrous (rare, cycle rather short to medium). provar *neoamharicum*
1.2.2.2 Septa ciliate (rare, cycle very short). . . . . provar *bisamharicum*
1.3 Corolla so light blue, that it is almost white. Anthers yellow. Septa glabrous
1.3.1 Septa regular (extremely rare). . . . . provar *copticum*
1.3.2 Septa reduced (very rare, cycle rather short). . . . . . . .provar *neoscioanum*
2 Seeds yellow or beige
2.1 Corrolla violet blue. Anthers blue
2.1.1 Septa glabrous (second most frequent provar, cycle short to medium). . . . . provar *abyssinicum*
2.1.2 Septa ciliate (very rare, cycle rather short). . . . . provar *axumicum*

2.2 Corolla so light blue, that it is almost white. Anthers blue. Septa glabrous (very rare, cycle medium). . . . . provar *addis-abebae*

The keys of Kulpa & Danert (1962) (in which the status of variety has been changed (p. 163)) read as follows. As all my material belonged to convar *usitatissimum*, only the key to the provars of that taxon are given here.

Key to *L. usitatissimum* L. convars

1 Ripe fruit opens both loculicidally and septicidally; seeds fall out. . . . . convar *crepitans*

2 Ripe fruit closed or only split septicidally; seeds remain in the fruit

2.1 Plants usually over 70 cm tall distance between cotyledonary affixing site and the lowest implanted reproductive branches (= technical stem length) equal to or more than $\frac{3}{4}$ of the plant height (the height of the plant should be measured after flowering); plants under 70 cm with a technical stem length of $\frac{4}{5}$ or more . . . . convar *elongatum*

2.2 Plants usually less than 70 cm tall, technical stem length less than $\frac{4}{5}$ of plant height

2.2.1 1000-seed wt equal to or over 9 g; plants mostly one-stemmed. . . . . convar *mediterraneum*

2.2.2 1000-seed wt less than 9 g; plants sometimes with basal tillers. . . . . convar *usitatissimum*

Key to convar *usitatissimum* provars

1 Calyx cup-shaped; corolla tube shaped or funnel shaped, with an angle of opening less than 60°

1.1 Petals with their length more than $1\frac{1}{2}$ times the width, basally overlapping for less than a third of their length

1.1.1 Petals blue or blue-violet

1.1.1.1 Seed brown or brownish grey. . . . . provar *pratense*

1.1.1.2 Seed yellowish or yellowish olive-green. . . . . provar *axumicum*

1.1.2 Petals whitish

1.1.2.1 Seed brown or brownish grey. . . . . provar *albidum*

1.1.2.2 Seed yellowish or yellowish olive-green. . . . . . . provar *angustipetalum*

1.1.3 Flower pink or reddish violet, seeds brownish grey. . . provar *purpureum*

1.2 Petals with their length equal to or less than $1\frac{1}{2}$ times the width, overlapping basally for more than a third of their length

1.2.1 Flower whitish

1.2.1.1 Seed brown or brownish grey. . . . . provar *albocoeruleum*

1.2.1.2 Seed yellowish or yellowish olive-green. . . . . provar *candidum*

1.2.2 Petals blue or blue violet; seeds brown or brownish grey. . provar *caesium*

1.2.3 Petals pink or reddish violet; seed yellowish or yellowish olive-green. . . . . provar *elegans*

2 Calyx saucer-shaped; corolla broadly funnel-shaped or saucer-shaped; angle of opening over 60°

2.1 Flower ± star-shaped; petals more than $1\frac{1}{2}$ times as long as wide, basally overlapping for less than a third of their length

2.1.1 Petals whitish

2.1.1.1 Seed brown or brownish grey. . . . . provar *album*

2.1.1.2 Seed yellow or yellowish olive-green. . . . . provar *pekinense*

2.1.2 Petals blue or bluish violet; seed brown or brownish grey. . provar *indicum*

2.2 Circumference of flower circular; petals with a length equal to or less than $1\frac{1}{2}$ times the width, overlapping basally for more than a third of their length

2.2.1 Petals blue or bluish violet

2.2.1.1 Seed brown or brownish grey. . . . . provar *usitatissimum*

2.2.1.2 Seed yellow or yellowish olive green. . . . . provar *elladii*

2.2.2 Petals pink or reddish violet

2.2.2.1 Seed brown or brownish grey. . . . . provar *purpurascens*

2.2.2.2 Seed yellow or yellowish olive-green. . . . . provar *choresmicum*

2.2.3 Petals whitish

2.2.3.1 Seed brown or brownish grey. . . . . provar *lutescens*

2.2.3.2 Seed yellow or yellowish olive-green. . . . . provar *luteum*

The following is a survey of the relations between the provars recognized by Ciferri and those recognized by Kułpa & Danert within my collection. Given are the number of the seed collection from which the plants were grown that were used for the determinations.

Provar according to Ciferri's key		Provar according to Kułpa & Danert's key
abyssinicum		*axumicum*

Bos 8372, SL 63, SL 81, SL 269, SL 490, SL 1107, WP 85, WP 2711.

aethiopicum		*caesium*

Bos 8362, Bos 8628, SL 14, SL 33, SL 59, SL 120, SL 218, SL 348, SL 421, SL 425, SL 489, SL 499, SL 560, SL 680, SL 821, SL 827, SL 898, SL 1023, SL 1108, SL 1110, SL 1409, SL 1434, SL 1461, SL 1481, WP 119, WP 401, WP 2181, WP 2714, WP 4992.

aethiopicum		*indicum*

SL 68, SL 211, SL 295, SL 500, SL 1090, SL 1248.

aethiopicum		*pratense*

Bos 8043, Bos 8068, Bos 8075, Friis, Hounde & Jacobsen 196, SL 20, SL 100, SL 187, SL 197, SL 206, SL 256, SL 380, SL 638, SL 763, SL 822, SL 962, SL 1162, SL 1197, SL 1274, SL 1461, SL 1536, WP 395, WP 2711-A, WP 2864.

aethiopicum		*usitatissimum*

SL 381, SL 559.

aethiopicum	conv.	*usitatissimum*

Bos 7752, WdeW 6734.

asiaticum		*usitatissimum*

SL 1382.

bisamharicum		*caesium*

WP 74.

erytraeum *caesium*
SL 943, SL 1111.
erytraeum *pratense*
SL 39.
harraricum conv. *usitatissimum*
WP 1683.
himalaicum *caesium*
SL 229, SL 1110, WP 74, WP 4905, WP 4908, WP 4932.
himalaicum *pratense*
WP 4908.
himalaicum *indicum*
SL 500.
neoamharicum *caesium*
SL 114, WP 119, WP 2711-A, WP 2714.
neoamharicum *pratense*
SL 58, SL 742, SL 975, WP 3285.
neoamharicum conv. *usitatissimum*
WP 10.
tauricum *usitatissimum*
SL 1208, SL 1209, SL 1238.

Provars *asiaticum* and *tauricum* do not belong to the Indo-Abyssinian convar but to convars *eurasiaticum* and *transitorium*, respectively. The plants grown from the indicated seed numbers showed a habit, strongly differing from the rest of the field. The 1000-seed weight was too high for convar *indoabyssinicum*. For SL 1382, it fitted into convar *eurasiaticum* but was too low for the other taxa recognized by Ciferri (1949). Ciferri also indicated that this latter convar had been imported into E Africa. The numbers that I classified as provar *tauricum*, have a 1000-seed weight fitting into conv. *hindustanicum* and also into conv. *transitorium*. However the large and early caducous flower and the size of fruit require, according to Ciferri's key, that they be placed in convar *transitorium* provar *tauricum*. It is noteworthy that Italy belongs to the natural area of convar *transitorium* and that all three numbers are from a limited area in the Goba (Bale) region. It is thus very likely that they are an introduction dating from World War II.

By both keys, the progeny of one seed sample sometimes fell into more than one provar. So WP 74 produced plants that had clearly lighter blue flowers than others, resulting in two provars within the taxa distinguished by Ciferri. SL 1461 produced plants that had a petal length/width ratio of both more and less than $1\frac{1}{2}$, resulting in two provars within the taxonomic treatment of Kulpa & Danert.

I am convinced that, if more plants had been studied, the number of such mixed progenies would have been larger, because also the habits of the plants of one progeny were often heterogeneous.

Considering the distribution of provars *caesium* and *pratense* (both sensu Kulpa & Danert) within my collection, the relative frequency of provar *pratense* seems to be higher in the Shewa–W Gojam area than in the rest of Ethiopia.

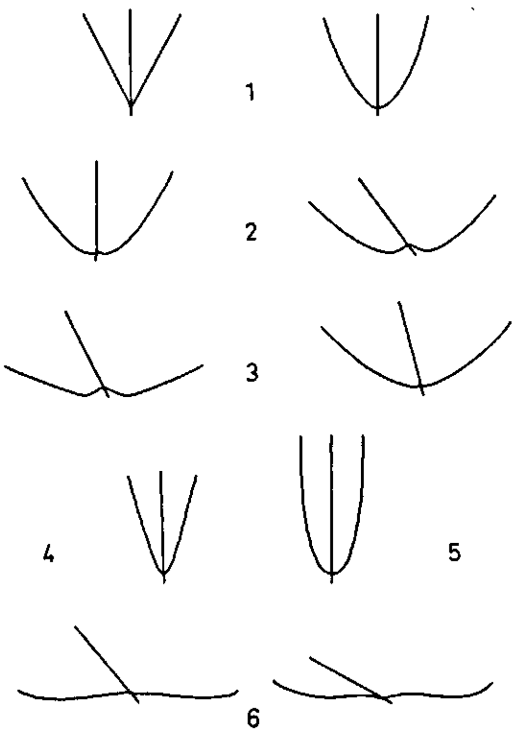


Fig. 8. Six growth habits distinghuished in a field of Ethiopian linseed at Wageningen.

(7) To collect herbarium material, the plants were grown outdoors at Wageningen at a row distance of 60 cm and with 20 cm in the row. In the field, 6 habits were distinguished (Fig. 8).

1. Most common was a habit with loosely virgate tillers and an open appearance.
2. Somewhat less common was a habit with a very open appearance, the tillers often basally ascending or humifuse, and the primary stem often oblique, quite often with more tillers than with the first habit.
3. Third in order of frequency were plants with a structure as in 2, but more compact.
4. Fourth in order of frequency were plants with an erect open appearance.
5. Equally frequent to 4 were erect plants, distinguishable from those of the fourth group by their greater height, their darker green colour and their larger leaves, flowers and fruits. The latter showed a striking resemblance to a few cvs from the United States which were sown as well (cvs New River, Dakota, Marine).
6. The least frequent was a very characteristic habit: the whole plant is loose and prostrate, the primary stem sometimes being ascending or oblique. The leaves point downwards. This habit was found only in plants grown from two seed samples from Haik (about 30 km N of Dessie, Welo) collected in different years.

Unfortunately the characters virgate, ascending, and humifuse tend to become unrecognizable in herbarium material. The compactness of the plants shows reasonably well on herbarium sheets. Habits 5 and 6 are so characteristic, that they are easy to preserve on herbarium sheets. For 5 and 6, it was easy to correlate field habit and herbarium sheets, but I could not find a dependable relation between the field habit and the 'herbarium habit' for the sheets belonging to 1–4.

Nearly three quarters of the plant populations of my collection were rather uniform in growth habit and cycle. About a fifth showed two different habits, while only $\frac{1}{20}$ showed several habits. Though it was not the rule, the ± prostrate plants tended to flower later than plants with a more erect habit, even within one collection number.

Over large areas, the plant populations may be similar forming a land-race, for instance the populations grown from SL 742, SL 803, SL 821; these represent the linseed grown around Debre Markos. Uniformity was also reported from Arussi by Rydén (1972), but Linder (1972) reported from the same area that the cultivars were not uniform.

A phenomenon I did not find in the literature was that of 'twin' seeds. Such seeds originate by the seeds of one locule sticking together ventrally. I found such twin seeds to be sparsely present in samples from Wotter and Feddis in the E Chercher, from Jimma, Agaro, Nekempt and Axum. In a few samples from Haik (Welo), however, such pairs formed the major portion of the samples, giving the latter a characteristic appearance. I found the phenomenon only in conjunction with brown or light brown seed.

Such twin seeds were sown experimentally. The twin seeds from samples of which they formed only a very minor portion mostly failed to germinate and the one that did, did not produce a progeny with such twins. Probably those seeds were occasional malformations. Twin seeds from the samples from Haik, on the other hand invariably produced plants with their seeds twinned. This phenomenon was found in plants with glabrous and ciliate normally developed false septa (progeny of SL 1108 and SL 1110) and with reduced false septa (progeny of SL 39 and SL 1111). The average weight of the individual seeds of such twins (1000-seed wt 4.6 g) was above the average of the whole collection (1000-seed wt 3.8 g).

Determinations to provars lead to provar *caesium* in the key of Kulpa & Danert, except for SL 39. Because of differences in the characters of the false septa (in the key of Ciferri), the twin-seeded samples fell into provars *aethiopicum*, *erytraeum* and *himalaicum*.

The plants growing from SL 39 (SL 3486, SL 3570, SL 3646) and from SL 1111 (SL 3447, SL 3501, SL 3615, SL 3656) were so uniform and characteristic that I designate the rank of cultivar to them. I call this cultivar 'Lakeside' (Haik meaning lake in Amharic). Some of the characters of the cv. were indicated earlier (reduced septa, twin-seededness, habit, seed colour, flower colour).

The habit makes the plants look like 'proles prostrata' of Vavilov & Elladi, as depicted in Ciferri (1949, p. 153). When the plants of cv. Lakeside start to flower, though, the prostrate branches do not bend upwards as they do in the 'proles prostrata'.

'Lakeside' had the shortest cycle of all accessions at Wageningen, flowering a week before the majority of the accessions. By this short cycle too, it does not fit into 'proles prostrata'.

(8) Some of the characters of the Indo-Abyssinian group suggest a short growing cycle. Kupzow (1932a) indeed reported that, on average, the flaxes of Ethiopia have the shortest vegetative period, although earlier ripening forms from elsewhere were present in his collection. Dillman (1953) too reported that the Ethiopian introductions he investigated were 'early to midseason'. Mulugeta Assefa (1972), on the other hand, reported that, on the average, the cycle of 13 Ethiopian linseed accessions was longer than that of 9 American cvs at Alemaya (c. 2000 m).

(9) Yellow anthers in combination with blue or white corolla are never found in fibre flax. Only in linseed were the combinations found (Ciferri, 1949, p. 63). Yellow anthers were uncommon in my Ethiopian collection too, although Ciferri indicated that such combinations were found particularly in Ethiopia.

(10) Within the genus, Xavier & Rogers (1963) found a multitude of pollen forms, which were highly characteristic to the species. They described the pollen of *Linum usitatissimum* in the following way: more or less oblate triangular, diam. 52.2–59.2 μm, colpi 3, short-pointed, 7–10.5 μm wide; exine 3.5–4.25 μm thick; excrescences dimorphic, diam. 0.5–0.75 μm, absent on furrow membrane.

An investigation of the variability in pollen characters in the infraspecific taxa of L. usitatissimum is desirable.

(11) Because the types are still available, the suggestion of Kulpa & Danert (1962, p. 343/44) to declare the names *Linum humile* and *Linum bienne*, both of Miller (Dict. ed. 8, 1768), nomina dubia rejicienda is a denial of the type method and against Article 62 of the Code.

(12) In their valuable publication on cultivated flax, Kulpa & Danert (1962) designated LINN 396.1 the type of *Linum usitatissimum* and, thus, of var. *usitatissimum*. According to their key, var. *usitatissimum* shows the following combination of characters:

1. Fruits indehiscent
2. Plant under 70 cm
3. At fruiting length of unbranched tiller divided by total height less than $\frac{4}{5}$
4. 1000-seed weight < 9 g
5. Calyx saucer-shaped
6. Corolla widely funnel-shaped or saucer-shaped with an angle of opening over 60°
7. Flower with circular outline
8. Petals less than $1\frac{1}{2}$ times as long as wide
9. Petals covering each other at least for the basal $\frac{1}{3}$ of their length
10. Flower blue(-violet)
11. Seed (grey-)brown.

I was unable to study the type specimen in LINN. The microfiche nevertheless warrants the following notes.

To 1: In accordance to the definition given by Kulpa & Danert, the fruits remain closed; confirmed by microfiche.

To 2, 3: LINN 396.1 consists of 2 cut tillers. Thus neither the height of the plant nor the unbranched stemlength can be measured with certainty. The Linnaean speci-

men is from Algeria and, according to Martinez (1957), N African flaxes are now up to 70 cm high. With the length of the branching part of the tillers of the Linnaean specimen (c. 17 cm) in these, not yet fully developed, tillers, they remain under the $\frac{4}{5}$, even of 70 cm. The habit of LINN 396.1 thus most probably conforms to the key.
To 4: The 1000-seed weight could not be determined, but according to Martinez (1957), the seeds of N African flax are 3–4 mm long. In my collection, seeds of even greater length weighed less, so that this assumption seems correct.
To 5–9: As there is no flower available, none of these characters can be determined. In view of the origin of the type specimen, one would expect Algerian material in the tables of Kułpa & Danert but there is no evidence that they examined any Algerian specimens except the type.
To 10–11: I could not verify flower and seed colour but N African cultivated flaxes have a blue flower and brown seed (Martinez, 1957).

Although there is no evidence of any discrepancy between *L. usitatissimum* var. *usitatissimum* as typified by LINN 396.1 and Kułpa & Danert's key, there is in their work no confirmation of the characters based on specimens originating from the type locality.

(13) Description was based on the following specimens.

Bale	Goba market: SL 1208, SL 1209; Goro market: SL 1248; Robi market: SL 1238.
Beghemder	Addis Zemen market: SL 59; Gonder market: SL 58, SL 873, SL 929 C, WP 4992; Infranz market: SL 827.
Eritrea	Adi Caieh market: SL 898.
Gojam	in field, 26 km NW of Debre Markos: F. G. Meyer 8624; Dejen market: SL 763; Elias market: SL 803; Lumane market: SL 742; Telili market: SL 821, SL 822.
Harergie	Alemaya market: Bos 8068, SL 20, SL 24, SL 218, SL 229, WP 10; in field near Alemaya: Bos 7752, WP 395, WP 401, WP 466; grown in Alemaya: PJ 1494–PJ 1496, PJ 2769–PJ 2774, PJ 3111–PJ 3116, WP 217, WP 281, WP 295, WP 350, WP 728, WP 748, WP 1780, WP 2181; Asbe Teferi market: SL 14, SL 489, SL 490; Bati market: Bos 8075; Bedeisa market: SL 680, SL 681; Chelenko market: SL 249, SL 252, SL 256, SL 260, SL 269; Deder market: SL 380, SL 381; Dire Dawa market: Bos 8362, Bos 8372, WP 119; Feddis market: SL 167, SL 173, SL 187; Ghelemso market: SL 638, SL 639; Harer market: Bos 8043, WP 74, WP 85; Jijiga market: SL 348; Kara market: SL 601; in field 20 km W of Kobbo: WP 1236; Kuni market: SL 559, SL 560; Langhe market: SL 197, SL 295, SL 302, SL 303, SL 304; Mulu market: SL 421, SL 422, SL 425; Waichu market: SL 499, SL 500; in field near Waichu: SL 2947; Wotter market: SL 206, SL 211.
Illubabor	Bure market: SL 1511, SL 1512; Jemero market: SL 1434, SL 1461, SL 1462; Metu market: SL 1479, SL 1480, SL 1481.
Kefa	Agaro market: SL 81, SL 100; Bonga market: SL 1408, SL 1409; Bonga waterfall, secundary rainforest, ± 1850 m: PJ 5516; Bonga–Jimma road, c. 30 km from Bonga, 1400 m: PJ 5669; Chena market: SL 1426; Jimma market: Bos 8628, SL 114, SL 120, SL 121, SL 132; WP 3284, WP 3285; in field 20 km S of Jimma: I. Friis, A. Hounde & K. Jacobsen 196; Yebu market: SL 63, SL 65, SL 66, SL 68.
Shewa	from the collection of Debre Zeit Experimental Station of the College of Agriculture: WP 4905–WP 4940; Kofale market: SL 1274; Kolito market: WP 2864; Kuyera market of Shashemane: SL 1197; in field 170 km S of Mojo: WP 1683; in field between Nazret and Asella: WP 1535; Robi market: SL 1162; Shashemane market: SL 1293, SL 1294, SL 1298.

Sidamo	Agere Selam market: WP 2711; Awasa market: SL 1337, WP 2714; Kebre Mengist market: SL 1344; Neghele (Borana) market: SL 1382, SL 1383, SL 1384.
Tigre	Adishow market: SL 1023; Axum market: SL 943.
Welega	Dembidolo market: SL 1536; Nekempt market: SL 1564, SL 1565; in field 10 km W of Nekempt: WdeW 6734.
Welo	Bati market: SL 1056, SL 1057, SL 1090; Dessie market: SL 1089; Gude Beret market: SL 49; Haik market: SL 39, SL 41, SL 1107–SL 1111;Kembolcha market: SL 962, SL 975; Robit market: SL 28, SL 33–SL 35, SL 38.
Grown at Wageningen	SL 1608–SL 1612, SL 1636–SL 1647, SL 1673, SL 1716–SL 1725, SL 1730–SL 1735, SL 1737–SL 1739, SL 1745, SL 1761–SL 1762, SL 1811, SL 1842–SL 1845, SL 1848–SL 1849, SL 1861–Sl 1862, SL 1865–SL 1872, SL 1874, SL 1928–SL 1933, SL 3418–SL 3469, SL 3485–SL 3491, SL 3495, SL 3498–SL 3503, SL3508–SL 3512, SL 3526–SL 3533, SL 3538–SL 3541, SL 3565–SL 3573, SL 3598–SL 3622, SL 3626–SL 3630, SL 3644–SL 3646, SL 3670–SL 3705, SL 3707–SL 3714, SL 3754–SL 3761, SL 3785–SL 3800, SL 3807–SL 3809, SL 3873–SL 3874, SL 3954–SL 3957, WP 5610–WP 5613, WP 5854–WP 5858, WP 5894–WP 5898, WP 6045–WP 6049, WP 6214–WP 6216, WP 6539–WP 6541, WP 6546, WP 6551–WP 6552, WP 6752–WP 6757, WP 7418–WP 7429, WP 7431–WP 7437.

Ecology

1. Temperature

Linseed may be grown successfully in many climates, but mainly in temperate regions. The temperature (°C)-time product for linseed is 1600–1850°C. days (Zusevics, 1966). Optimum temperatures for seed production have a relation with the growing habit. Long-stemmed flax, usually grown for fibre with the seed as by-product only, prefers 16–19°C. Short-fibre flax and tall seed-flax prefer $19\frac{1}{2}$–24°C, while short-stemmed seed-flax can be grown under very different conditions. It will grow well in dry and hot subtropical climates as well as in tropical regions with high precipitation and it is less demanding about the soil (Ciferri, 1949). With little rain and particularly with high temperatures seed yield and contents of oil, tocopherol and crude fibre decrease, while the saturation of the oil and the contents of protein, linamarin and mucilage increase (Toxopeus, 1938; Desgrange, 1948; Zusevics, 1966; Schuster & Marquard, 1974). In experiments in a phytotron, Iran Nejad (1976) and Schuster et al. (1978b) found the influence of temperature on composition to be larger than that of daylength and of relative humidity of the air. (Ranges: daylength 19 and 12 h; temperatures 'in light' 24.5 and 18°C, 'in dark' 16.5 and 10.0°C, relative humidity 85 and 50%.)

In the tropics, oil with good drying properties can be produced only at altitudes over 1000 m (Toxopeus, 1938). The normal altitude range around the equator is 1600–2700 m (Westphal, 1976/77). The range I found for Ethiopia is from 1200 m (Ciferri, 1949) to 3500 m (Rydén, 1972). Linseed is always more important at higher sites in a given region and there is a relation between the general topography of the area and the altitude of main production fields therein. So Chiuderi (1942) reported that the main production areas of SW Ethiopia lie at altitudes of 1600–2000 m. In the neighbourhood of Bacá (Harergie), occasional stands can be found at 1500–1600 m, but it is more common over 1800 m (Tozzi, 1943). In Arussi, the normal altitudes are 2200–2600 m (Werdecker, 1955; Rydén, 1972). The fields at the lower altitudes are usually cultivated as 'small-rain crops'. The plants remain smaller and have a lower productivity (Tozzi, 1943; Provisional Mil. Gov., 1977).

Flax seed will germinate at temperatures between 1 and 40°C (Mándy et al., 1969) but, at temperatures over 35°C, germination is bad (Dillman & Toole, 1937). It is vernalized by a temperature of 2°C for 5–20 days. The time required for complete vernalization is related to the growth habit of the cultivar and Ethiopian linseed usually has only a small to moderate reaction. It flowers up to two weeks earlier if vernalized (Ciferri, 1949). Apparently the optimum temperature for germination is related to the cultivar, since the observed ranges vary between the authors. Mándy et al. (1969) indicated 20–25°C, Dubetz et al. (1962) 13–18°C, both in the range of temperatures found in most of the Ethiopian highlands around sowing time.

Although the average daily temperatures may be excellent for flax growing, nightly frosts may injure the crop in certain regions during part of the year. The seedling can withstand temperatures of -7 to $-3\frac{1}{2}$°C (Ciferri, 1949). Such temperatures do not occur in the traditional growing season of flax in Ethiopia, but with an increase in the irrigated area, this may become relevant.

Flax is susceptible to frost damage when the plant bears flowers and young fruits. As boll formation occurs over an extended period, the chances of frost injury are greater than during other stages. Advanced plants, when injured by frost, compensate the damage by developing stem branching. Often injured plants eventually yield very well. Mowing of injured plants does not appear to stimulate regrowth much beyond this natural stem branching (Queensland, 1962). The incidence of frost in November and December is known from some Ethiopian regions where flax is grown. Brhane (1971) reported that two cultivars, sown on 30 June and 15 July in 1970, were heavily damaged by frost before ripeness. Their yield was small and of a bad quality. The seeds must have been in full development. Once the seed is nearly ripe, temperatures down to -8°C do not influence the oil contents or the saturation of the oil, but the latter gets a darker colour and the 1000-seed weight decreases (Zusevics, 1966).

For balanced development of the seed, an average temperature of c. 20°C is desirable (Iran Nejad, 1976). The influence of higher temperatures is particularly clear during the first three weeks after flowering and at temperatures above 32°C (Ford & Zimmerman, 1964; Iran Nejad, 1976). When the seed is dry, it can resist temperatures from -29 to +47°C without much damage (Dillman & Toole, 1937).

2. *Water*

Linseed prefers dry and sunny weather with well distributed moderate rains (Kempe, 1935), but crops can be grown to maturity on little seasonal rain if the soil contains stored water or if water is available in the subsoil (Toxopeus, 1938; Queensland, 1962). A regular supply of water in linseed is particulary desirable as long as the crop has not yet closed. Once closed, regular rain is no longer needed and soil water combined with dew is often sufficient for further development of the crop (Kempe, 1935). The total precipitation should preferably be between 500 and 1000 mm (Westphal, 1976/77). Considering the distribution and amounts of rain (Mesfin, 1970: maps 24–27), and the time of sowing, we see that the amounts of rain falling on the linseed crops in most of Ethiopia are in this range.

Although insufficient precipitation causes a decrease in yield, seed size, oil contents and iodine number (McGregor, 1960; Iran Nejad, 1976), too much rain is also harmful. The plant is highly sensitive to standing water and even shallow depressions in a level field were often sufficient to induce bad growth on such spots in the rainy season (Toxopeus, 1938). So flax should not be sown at the onset of the rains if the region has a long rainy season (Queensland, 1962). In Ethiopia, it is customary in most regions to sow in July–August after the first heavy showers are over. According to Ciferri (1941) later sowing is not feasible, because the crop will be destroyed by flax rust.

Much rain during flowering results in poor seed-setting. Wet conditions after the fruit has been set induce fungal attacks and lower the quality of the seed and its oil (Friederich, 1956; McGregor, 1960). In the maturing period, an occasional shower will do no harm to the crop and may even destroy harmful insects in some areas (Toxopeus, 1938). Higher precipitation, however, may make the seed germinate in the fruit and induce new vegetative growth (Tobler, 1928; Toxopeus, 1938; Queensland, 1962).

Irrigation of linseed has given markedly higher seed yields (Desgrange, 1948; Queensland, 1962). It is particularly effective in the seedling and flowering stages (Yusuf et al., 1978). The seeds contain more oil and less protein than seeds produced without irrigation in the same region and year (Ermakov, 1969). Irrigation on soils rich in nitrogen often reduces amount of available nitrogen and thus makes the oil contents of the seeds higher (p. 175). Irrigation commonly extends the growth cycle of linseed and this too mostly increases oil contents (Meyer, 1935).

In irrigating linseed, care should be exercised to cease irrigation in time to avoid new growth in the maturing crop (Queensland, 1962).

In a phytotron, the relative humidity of the air exercised some influence on the amount and composition of the oil, but this influence was much smaller than that of the temperature (Iran Nejad, 1976; Schuster et al., 1978b). For ranges see p. 172.

3. Soil

The soil influences linseed far less than climate and weather conditions. Linseed will grow on almost any soil as long as sufficient humidity and some fertility are available, but it will grow best on humous medium-heavy soils of a sandy or loamy character. The only soils unfit for linseed cultivation are dry sands, wet and compact clays, and marshy or very acid grounds (Meyer, 1935; Zusevics, 1966). The structure of the soil is more important than its fertility: it should be loose enough to absorb showers and allow them to percolate quickly, because of the high sensitivity of linseed for standing water (Kempe, 1935; Toxopeus, 1938). Because of the slow initial development of the flax seedling, soils that show heavy swelling and shrinking, or that form crusts, can create problems in some climates (Tobler, 1928).

On the ability of the flax root to penetrate hard layers, opinions differ. Tobler (1928) reported that the root is capable of penetrating such layers. Desjobert (1954) indicated that a reasonable production was possible on a shallow calcareous soil over limestone, because the roots penetrate it. Desgrange (1948) and Butler et al. (1950), however, reported that flax roots need a deep loose soil. Contradictory to the experiences of Desjobert, Tobler (1928) and Kempe (1935) indicated that calcareous soils are unfit for flax. It is possible that they base their observations on the demands of fibre flax.

Linseed prefers a pH of 6 to 7 on most soils, particularly on the lighter ones (Wanjura, 1935; Jasper, 1939; Zusevics, 1966), but slightly higher values on heavier soils (Butler et al., 1950). Although excellent results were achieved on soil with a pH of only 5 in California, linseed usually produces best on neutral to slightly alkaline soils (Zusevics, 1966). Only above pH 9 will growth be strongly reduced (Wanjura, 1935).

Linseed is moderately tolerant to salinity. Mesfin Abebe (1971) compared in Ethiopia the emergence of 5 oilseed crops at 11 levels of salinity (NaCl). If the number of seedlings was taken as a measure of tolerance, the tolerance decreased in the following order: cotton > flax > Niger seed > sesame > safflower, but if the tolerance was related to the number of days to emergence, Niger seed was the most tolerant (the least delayed): Niger seed > safflower, cotton > flax > sesame.

In a pot trial, Ram Deo & Ruhal (1971) found that increasing salinities decreased seed yield through the range 0.1–2.3 S/m (at 25°C). Seed weight and oil contents decreased up to 1.75 S/m. At 2.3 S/m, where the number of seeds dropped very abruptly, they increased again.

The saturation of the oil increased in the step from 0.115 to 0.61 S/m, but decreased in all later steps.

Flax often gives only a small response, or no response at all, to fertilizer during growth (Friederich, 1956; McGregor, 1960; Lino, 1971). In general, the results with organic fertilizers are not satisfactory (for instance Meyer, 1935). The calibration of the fertilizer is very important in linseed, but no general formula can be given: a local assessment will be needed (Desjobert, 1954). Nitrogen and potassium should be easily available in the vegetative stage of the plant, phosphorus is important in the stage of seed formation (Jasper, 1939).

The role of nitrogen is not clear; the results are often conflicting. Wanjura (1935), for instance, reported that some nitrogen fertilizers had a strong effect on the development of the stem, whereas calcium ammonium nitrate had little or no effect. Mathur & Kavitkar (1963), however, found no difference in the reaction to ammonium sulphate, ammonium sulphate nitrate, urea and calcium ammonium nitrate.

Nitrogen, particularly in combination with phosphorus, usually induces extended flowering and increased seed production. The seeds contain more protein but less oil, and this oil is more saturated than with seeds produced at lower levels of nitrogen (e.g. Yayock & Quinn, 1977; Iran Nejad, 1976; Singh & Singh, 1978). Thus, if the crop is grown for oil production, exact trials will be needed to decide which nitrogen treatments make the seed yield increase and the oil contents decrease to such extent that the net result is profitable (Meyer, 1935).

The changed composition is not the result of differences in constituents of the later formed seeds, which have other maturing conditions than the earlier formed seeds. In a phytotron, the effects of nitrogen on composition were similar or even stronger with constant environmental conditions for all seeds (Dybing, 1964).

On research stations in Ethiopia, it is common to give 50–100 kg of nitrogen per hectare in the form of urea or nitrophos (for instance Bako Res. Stn Progr. Rep., 1971).

Phosphorus may induce a higher oil content, affecting seed yield, protein content of the seed and saturation of the oil in the same way as nitrogen fertilizer (Singh & Singh, 1978). At research stations in Ethiopia, the common rate of phosphorus is 40–50 kg/ha (for instance Bako Res. Stn Progr. Rep., 1971).

Potassium, together with nitrogen, often increases yields by strengthening straw (Meyer, 1935; Zusevics, 1966). According to Kayser (1925), proper dressing increases the saponification value and the iodine number of the oil. This was particularly true for a combined nitrogen and potassium fertilizer. It thus seems that to a certain extent potassium counteracts the effects of nitrogen and phosphorus on the properties of the oil. The ratio of nitrogen to potassium is decisive for the point where saturation of the oil becomes unacceptably low with increasing seed yields, caused by nitrogen fertilizers (Zusevics, 1966).

A balanced fertilizer for linseed commonly contains nitrogen, phosphorus and potassium in mass ratios 1:1:4 to 3:4:11 (Wanjura, 1935; Desgrange, 1948; Desjobert, 1954).

It seems that some chlorine is favourable for flax. Calcium is particulary necessary for good soil structure, not as nutrient. Iron deficiency is seldom seen in linseed (Wanjura, 1935; Scholz, 1937). Magnesium has a similar effect to potassium and a synergistic action with chlorine (Meyer, 1935). Boron sometimes has an increasing effect on yield, particularly under dry and warm growing conditions (Zusevics, 1966).

Linseed was often believed to be an exhausting crop (Desgrange, 1948; McGregor, 1960), but it was established in the United States that, in any crop year, flax will remove less nitrogen, phosphorus, potassium and sulphur than wheat, oats and barley (McGregor, 1960). For optimum production, flax makes rather high demands on the fertility of the soil because its roots have a relatively small ability to extract nutrients with a low solubility from the soil and it has a short growing cycle (Wanjura, 1935;

Crop	Yield (kg/ha)			Nutrients (kg/ha)		
	Seed	Straw	Leaves	N	P	K
Flax	600	4500	500	45	13	66
Barley	2500	3000	500	59	11	40
Maize	4500	6500	1500	106	22	105
Rape	2400	5000	1700	113	25	79

Zusevics, 1966). Wanjura gave a comparison of the yields and element rates of some crops. It is shown on the preceding page.

4. Light

Cultivars of linseed differ in their reaction to daylength. Some cultivars flower with short and long days indiscriminately; others flower earlier with longer days; still others bloom under long day only (Ciferri, 1949; Sinha et al., 1973; Sirohi & Wasnik, 1978). There is a strong relation between the reaction to daylength and environment, notably temperature (Ciferri, 1949; Honsell, 1951). The influence of daylength is most effective at a temperature of 12°C during light and with humid soil (Zusevics, 1966). In general, linseed will grow well under short-day conditions (Ciferri, 1949; Sirohi & Wasnik, 1978), but seed yields will be lower (Ciferri, 1941; Sirohi & Wasnik, 1978).

The influence of daylength on the time of flowering is so large in some cultivars, that authors from regions with wide differences in daylength indicate that the time of sowing has little effect on the time of flowering (de Fina, 1939 as cited by Honsell, 1951; Queensland, 1962). Late sowing, then, results in less tillered smaller plants, which flower over a shorter period.

The effects of longer daylengths on oil contents of the seed and fatty acid composition of the oil are very similar to those of lower temperatures, but less pronounced. Such periods induce higher oil contents and less saturated oil (Susulski & Gore, 1964; Iran Nejad, 1976), but there are also cultivars producing seeds that are richer in oil with shorter days (Carder, 1964 as cited by Iran Nejad, 1976; Pavlov & Krumona, 1977).

Development of the plant

In the early stages of development, the linseed plant grows slowly with its aerial parts. The plant then forms a long root. It remains larger than the aerial parts during the whole life-span of the plant. The roots can reach a length of more than a metre (Arny & Johnson, 1928; Tobler, 1928; Meyer, 1935; Ciferri, 1949).

According to Tobler (1928), the root is capable of penetrating hard soil. The form and the dimensions of the final root system do not only depend on the growing conditions, notably soil environment and water supply, but also on the cultivar. The largest root systems are formed in easily penetrable soil with limited water supply. At first, a thin thread-like vertical taproot is formed with many laterals in the upper 30–40 cm. Under wet conditions and in a compact soil, this is the final stage. Under conditions with less water near the surface some of the lateral roots bend downwards about 15 cm from the stem and may reach the same depth as the taproot. These differences may have a genetic background: some cultivars always tend to the one or to the other root system (Arny & Johnson, 1928).

Cultivars with a horizontal growing habit (Ciferri, 1949) or from higher altitudes (Meyer, 1935) tend to form stronger root systems than cultivars with a more erect habit or from lower situated areas. In African linseed, the number of primary side-roots is not as large as in cultivars from other parts of the world, but they are extremely long (Meyer, 1935).

Ethiopian linseed develops side-shoots in the axils of the cotyledons in a young stage. At Wageningen, this happened already in plantlets, 6–7 cm tall. Out of these, accessory stems are formed, which reach a height similar to that of the main stem. Their number depends on genotype and on available space. Linseed reacts to wider spacing with the formation of more accessory stems. The height is little influenced by plant density (Khan & Bradshaw, 1976). In regions with long summer days, late sowing results in fewer branches (Tobler, 1928).

After 2–3 weeks of slow growth, all stems start to develop rapidly. If temperature and humidity are optimum, the stems may become 2–5 cm longer in 24 hours (Zusevics, 1966). They form side-branches, which bear the flowers. Usually the development of the main stem remains some days ahead of that of the tillers. The height at which these branches are formed and their length differ between cultivars. According to Elladi (Ciferri, 1949), there is a clear relation between the ultimate height of a cultivar and the duration of its vegetative cycle, apparently independent of the number of accessory stems. Indeed the many-branched Ethiopian flax has a low stature and a short cycle.

The foliage is comparatively sparse. The leaf position with respect to the stem of the plant is a good guide to the general health of the plant. In healthy plants, the leaves tend to adopt a horizontal growth habit; in plants suffering from nutritional disorders or inadequate soil moisture, the leaves incline upwards and tend to hug the stem (Queensland, 1962).

The flowers are generally self-pollinated and open early in the morning. The petals usually fall to the ground on the same day the flower opens. In Wageningen, the petals of Ethiopian flax were usually shed around noon. On rainy days, the flowers remained shut. In the literature, variable amounts of natural crossing can be encountered. The most extreme values I encountered in Ciferri (1949), who stated: selfing is the rule, with natural crossing of less than 1%, but up to 40% crossing has been observed. In their experiment with two cultivars having a synchronous flowering period, Henry & Chih Tu (1928) found the crossing to decrease from 1.26 to 0.33% when they increased the distance between rows from 30 to 150 cm. Thus precautions will often be necessary to maintain the purity of a flax cultivar.

Flowering continues for 7 to 10 days; with some cultivars and in cool wet weather, flowering may continue for a much longer period (Dillman, 1928). At Wageningen in 1974 and 1975, the individual Ethiopian accessions of my collection flowered for about 1 month. Iran Nejad (1976) found non-Ethiopian flax cultivars to flower for 10 to 11 days in Holetta.

According to Hovland & Dybing (1973) and Dybing & Carsrud (1975), flowering in linseed occurs in distinct cycles. In field trials and under controlled conditions at the University of Dakota, they found four cycles. They ascribe the phenomenon to hormone production of the young fruit. The same authors found that only about half the flower buds on the plant formed flowers. The other half remained shut and did not form fruits.

At the time of peak flowering, the surface of the linseed crop consists mainly of flower buds, flowers and fruits. The major portion of the leaves is confined to the more shaded part of the canopy. The sepals are extremely important for the seed formation in the fruit. They remain green almost until the fruits mature and are well positioned in intercept light.

Deshmukh et al. (1976) found that removal of the sepals directly after the petals were shed reduced the seed yield by almost nine-tenths. If three sepals were removed 25 days after flowering, the seed yield per fruit still decreased significantly. They also found a positive correlation between the sepal area and the seed weight per fruit in 9 cultivars, but some cultivars produced more seed per fruit with the same or smaller sepal area than others.

The fruit can contain ten seeds, but this number is seldom reached. The number of seeds per fruit is a character of the cultivar; it tends to be inversely correlated with seedsize.

In view of the growing habit and the importance of the sepals in linseed, it is not surprising that Khan & Bradshaw (1976) found that spacing of the crop has little effect on the number of seeds per fruit, nor on individual seed weight. The effect of spacing on seed yield per plant was very clear.

The growth in volume of the fruit and of the seed is rapid and uniform for the first two weeks. After that short period, the final size is attained. The weight of the undried fruit shows the same pattern and it remains almost constant until maturity, when it decreases. The weight of dried fruits and seeds increases slowly for the first few days. From then on, there is a more rapid and fairly uniform daily increase in the dry weight to a maximum after a month or so. The dry weight remains constant during ripening when the fresh weight declines rapidly (Dillman, 1928). The seed develops first mainly in length and width, and fills slower. So thickness of dried seeds is a better measure of the state of maturity than are the other dimensions (Tobler, 1928).

The oil is formed in the first month after flowering (for instance Ford & Zimmerman, 1964; Dorrell & Hodgins, 1975). About three quarters of it is stored in the cotyledons (Dorrell, 1975). Dillman (1928) found the content of oil in dry matter to increase from 2 to 40% in 15 to 18 days, the increase beginning at the 7th to 9th day after flowering. Once the maximum was reached, there was only very slight change up to full maturity. There is, thus, an increase in the total oil content of the seeds so long as there is an increase in dry weight. Developments, similar to those described by Dillman (1928), were found by Johnson (1932a), but in some cultivars Jain & Dubey (1969) found an absolute decrease in content of oil of nearly 5% within a week of total ripeness.

It is often indicated in literature that the saturation of the oil is a character of the cultivar, but that environmental influence is large. Most authors described a relation of less saturated oil with lower temperature (for instance McGregor, 1960; Ford & Zimmerman, 1964); others relate higher saturation with lower latitude (Zusevics, 1966). Only one author, Price (1968), reported the oil of 8 cultivars, grown at a warm

Table 44. Survey of publications on some correlations between characters found in linseed.

Character 1	Character 2	Correlation	Author
Time from full bloom to maturity	Oil contents	+	Johnson 1932b; Meyer 1935
Time from full bloom to maturity	Content of water-soluble protein in total protein	–	Iran Nejad 1976
Time from sowing to full bloom	Oil content	+	Meyer 1935; Iran Nejad 1976
White flower	Time from sowing to flowering	+	Ciferri 1949
High seed yields	Brown seed	+	Culbertson & Kommendahl 1956; Culbertson et al. 1960
High seed yields	Seed size	+	Saxena & Asthana 1962
High seed yields	Strong branching	+	Saxena & Asthana 1962
High seed yields	Plant height	+	Saxena & Asthana 1962
High seed yields	Length of unbranched part of stem	+	Pathak & Bajpaye 1964
Yellow seed	Seed weight	+	Culbertson & Kommendahl 1956; Cubertson et al. 1960
Yellow seed	Liability to damage and bad germination	+	Culbertson & Kommendahl 1956; Zusevics 1966
Yellow seed	Unsaturation of oil	+	Culbertson & Kommendahl 1956
Yellow seed	Oil contents	+	Zusevics 1966
Oil content	Saturation of oil	+	Johnson 1932b; Meyer 1935.

place in Australia, to be less saturated than the oils from the same cultivars grown at a cool place. According to Zimmerman & Klosterman (1959), special care should be taken with sampling in trials comparing differences in saturation of the oil of different cultivars or from different sites. They found the linolenic acid contents, the leading factor in the amount of saturation of linseed oil, to vary as much as 17.5% between individual plants of one cultivar, grown on the same field in the same year. By natural crossing, the composition of the oil of different seeds on one plant may even be different (Yermanos & Knowles, 1962).

The oil steadily becomes less satured between the 5th and the 17th day after flowering. Desaturation starts at the same time as the oil contents start to rise, and reaches maximum about a week before the maximum oil content is reached (Johnson, 1932).

Dillman (1928) found that 38% of the seeds, collected 15 days after flowering, already germinated. Seeds collected 18 and 24 days after flowering showed 80 and 90% germination, respectively. The maximum germination, reached in his tests, was 95%.

So growing conditions from 1 week to about 3 weeks after flowering determine the amount and quality of the seed. High temperatures and drought during this period cause too quick ripening of the seed and therefore a low seed weight and low oil contents (Friederich, 1956; Jain & Dubey, 1969). As is common in oilseeds, the protein contents are usually negatively correlated to oil contents (Zusevics, 1966; Oliva et al., 1978).

Seed yield (kg/ha) is mainly dependent on number of fruits per square metre, number of seeds per fruit and seed weight (Blackman & Bunting, 1954; Friederich, 1956; Pathak & Bajpaye, 1964). Many correlations have been found in linseed between plant characters relatively easy to observe, and yield of seed and oil. Properties of the oil and protein were found to be correlated with plant characters too. A survey of some of the publications on such correlations is given in Table 44. Several of these correlations can also be found in the results reported by Schuster et al. (1978a). They compared 9 cultivars (from Germany, Morocco, the United States, Canada and New Zealand) at 9 localities spread over the world (3 in Federal Germany, 1 in Canada, Yugoslavia, Morocco, Turkey, Japan, New Zealand, and in Holetta, Ethiopia) during 1972 and 1973.

If we compare the averages of all cultivars from all sites with the averages from Holetta, we can see that the times to flowering and to full maturity were (among) the longest in Holetta, and that the fat contents, were among the highest, while contents of linolenic acid were low and of oleic acid high there.

The productivity of linseed is related to seed-size and number of fruits (Ciferri, 1949). According to Badwal et al. (1971) and Chowdhuri (1972), capsule number per plant and 1000-seed weight are even the most important criteria for high-yielding lines. As there is a tendency in large-seeded cultivars to form less fruits (Ciferri, 1949) or seeds per fruit (Toxopeus, 1938), a 1000-seed weight of c. 7 g should be considered optimum for yield (Toxopeus, 1938).

Husbandry

Theoretically, fibre and seed could be produced from the same flax crop, but in practice the quality and yield of the two products suffer whenever this is done (Toxopeus 1938; Bunting 1951). In Ethiopia, this was never a problem as the only reason for cultivation of flax is seed production (p. 187).

Flax is a poor competitor with weeds. Weeding is difficult as long as the plants are still small. For high yields, fields should be selected that are as free from weeds as possible and the main aim of cultural practices should be destruction of weeds, particularly in the young crop (e.g. Queensland, 1962). If weeding is insufficient, yield losses of 30% or more are quite normal (Friederich, 1956; Moore, 1969). In later stages, the leafiness and the height of the cultivar are important agronomic characters in its competitiveness (Friederich, 1956).

As soon as the seedlings have a height of c. 10 cm, weeding should begin (Kempe, 1935). Usually it will be necessary to weed 1–3 times (Toxopeus, 1938). Row-sown crops can be weeded mechanically if the rows are far enough apart. Because the seedling is so small at first, the first shovelling can often be done only when the weeds have already grown too big. Chemical control is then necessary. The best stage for application of herbicides to linseed is 10 cm (Butler et al., 1950; Lino, 1971) to 20 cm (Queensland, 1962).

Several chemicals are available for the control of weeds in linseed. Particularly MCPA is often recommended (for instance Friederich, 1956; Queensland, 1962; Cultivar, 1978). The maximum safe rate of MCPA is 375 g/ha. High-volume sprays should be used, preferably up to 225 l/ha (Queensland, 1962).

In Queensland, some measure of control of weeds has been obtained in linseed by letting sheep graze on the standing crop. Sheep delicately avoid the linseed and at least, check the edible weeds (Queensland, 1962).

The nature of the preceding crop is related to the goal of obtaining a clean seed-bed. All crops that are regularly weeded or that suppress weeds are good predecessors to linseed, particularly root crops and legumes (Meyer 1935; Zusevics 1966). According to some authors (e.g. Kempe, 1935; Desjobert, 1954), it is more important that the field is free from weeds than that a particular crop precedes linseed. But according to Butler et al. (1950), annual oilseeds are not good preceding crops.

On the other hand, linseed is a good precusor to most other crops, particularly legumes. It is an excellent crop on newly fallowed soil (Zusevics, 1966).

For optimum production, linseed requires good tilth and fertility status of the soil. It is therefore not recommendable to cultivate linseed as last crop in a rotation (Butler et al., 1950).

In Ethiopia, these circumstances are not met in traditional farming. Although a field relatively free from weeds may be selected, field maintenance is minimal, if not absent (Ciferri, 1941; Rydén, 1972; my own observation). Rydén (1972) described the practice in Arussi as follows. 'Most farmers do not weed at all and those who do make one, or seldom two, handweedings during the whole growing season. This makes that flax fields are often very weedy and sometimes it may be hard to decide if it is a flax field or a fallow'. It is also common to cultivate flax as the last crop in the rotation (Ciferri, 1941; Kuls, 1963; Kline et al., 1969; Rydén, 1972). According to Ciferri (1941), linseed is sown thinly after the cereals without trying to get the maximum yield. Everything the exhausted soil produces with the least work is accepted as pure profit.

In August, the number of weed plants on Arussi fields is commonly 3–3½ times as high as the number of flax plants. Fields at greater altitudes contain more weeds than lower-situated fields. The seed used for sowing is an important source of weed infestation. Cleaning the seed before sowing, combined with one weeding, resulted in a 15% higher seed yield than that of uncleaned seed with one weeding. A second weeding was necessary to obtain similar yields with cleaned and uncleaned seed (Linder, 1976).

In Ethiopia, it is common practice to sow linseed once every 4–7 years on the same field. Most authors suggest that 5 to 7 years should elapse between two linseed crops on the same field, a second successive crop being considerably worse than the first (e.g. Kempe, 1935; Toxopeus, 1938; Butler et al., 1950). Desgrange (1948), though, believed that this subject was highly controversial. He indicated that trials in different regions had given conflicting results and that the time lapse should be assessed locally.

Desgrange even stated that it seems likely that linseed could be grown successively on the same field for several years, if soil management and fertilizer were sufficient.

In Ethiopia, the preparation of the seed-bed is similar to that for cereals and small-seeded crops. The land is superficially ploughed once or twice (Ciferri, 1941; Rydén, 1972). In mechanized cultivation, one deep ploughing is usually recommeded, followed by superficial treatments. The deep ploughing should bring the soil into good condition to absorb and retain water (Kempe, 1935; Desjobert, 1954; Lino, 1971). Because linseed roots are rather fibrous, the soil should stay sufficiently firm (Desgrange, 1948, Lino, 1971). The superficial treatments before sowing must pulverize the soil to a fine seed-bed. The seed-bed should not be made too deep because a deep one restricts moisture supply and causes the seed to fall too deep at sowing (Desgrange, 1948; Butler et al., 1950).

If fertilizer treatment is envisaged, this should be done with care; dung and manure usually give an irregular and impredictable result. If the crop preceding linseed was fertilized that way, the results are generally excellent (Butler et al., 1950). Sometimes good results are achieved with a combination of organic and synthetic fertilizers (Desgrange, 1948). Due to its growth rhythm (p. 177), the crop after emergence sometimes seems to lack nitrogen. The decision to supply extra nitrogen should be postponed until the plants have come to the stage of rapid growth, because linseed will easily lodge with excessive nitrogen (Butler et al., 1950; Desjobert, 1954).

According to the Provisional Military Government (1977), 9.7% of the Ethiopian flax area is fertilized with dung and 0.2% with chemicals. In view of the observations of myself and others (p. 182), the first figure seems very high.

The seed can be broadcast or sown in rows. The first method is the common one in Ethiopia. Sowing in rows saves seed and results in better and more uniform emergence (Desjobert, 1954; Friederich, 1966), mainly because the depth of sowing is better controlled (Butler et al., 1950). Sowing should be shallow, 1–2 cm sufficing in moist conditions, 2–3 cm when the weather is dry (Desgrange, 1948; Butler et al., 1950; Desjobert, 1954). Deeper sowing affects emergence: if sown 4 cm deep, the number of seedlings is 35–50% lower than if sown at 2–3 cm (Zusevics, 1966). In Ethiopia it is common practice either to leave the broadcast seed without any further treatment on the field, or to plough the seed under (Kostlan, 1913; Rydén, 1972). With the latter procedure, part of the seed will be too deep for germination; with the former procedure part will not be deep enough.

Because of the ability of linseed to form more branches if more space is available, the density of sowing and the distance between the rows can vary within wide limits without much influence on seed yield. In the Netherlands, seed yields are not significantly different for fields sown with 20 or with 120 kg of seed per hectare (Friederich, 1956). Similar results were reported from Uruguay (Lino, 1971) and from Kenya (Nicholson, 1971). Sowing the same amount of seed (40 kg/ha) at distances of 10 to 35 cm between the rows did not siginificantly influence yield of seed and oil, nor did it influence the number of fruits per plant or the seed weight. The saturation of the oil decreased slightly with increasing distance (Elsahookie, 1978).

According to Friederich (1956), there is a small difference in the reaction to density of plants sown mechanically and broadcast. Mechanically sown crops react to higher densities with a small reduction in the number of seeds per fruit, broadcast plants with a reduction in number of fruits per area, but the fruits contain more seeds. As the reductions due to either effect are similar, yields of crops sown either way are comparable.

Weed competition and the type of mechanization are, therefore, the most important factors in determining the amount of seed needed for sowing (Nicholson, 1971; Elsahookie, 1978). Usually 40 to 70 kg of seed per hectare is recommended for temperate regions, 40 kg/ha applying to more humid conditions (Desgrange, 1948). For tropical conditions, under which flax germinates better, seed rates of 25 to 40 kg/ha are sufficient (Toxopeus, 1938). The nature of the cultivar may also play a role, because there are indications that yellow-seeded cultivars germinate less well than brown-seeded ones (Culbertson & Kommendahl, 1956). The germination rate of 10 samples from Arussi was found on average to be 87.5% by Linder (1976).

Kline et al. (1969) reported that the seed rate in Arussi, with local farmers was 75 kg/ha. In view of the similar cultural practices, it can be expected that seed rates in other regions of Ethiopia are not very different. This high rate is necessary because the seed emerges poorly (p. 183). On experimental farms where the crop is sown and weeded, and seed cleaned by machine, the seed rates used are 25 (Kulumsa, Arussi: Linder, 1976) to 30 kg/ha (Bako, Shewa: Bako Stn Progr. Rep., 1971). Corni (1938) reported good results from Eritrea with a sowing density of only 15 kg/ha.

Seed dressing with fungicide results in more plants per area and are often recommended (Culbertson & Kommendahl, 1956; Butler, 1950), but Friederich (1956) believed that seed treatment hardly increased the yield because of the branching habit of linseed. Apparently the quality of the seed-coat is the major factor in the effect of seed treatments. It can be cracked by careless threshing (Erwin et al., 1964) and by genetic disposition (Culbertson & Kommendahl, 1956). To my knowledge, seed dressings are not applied to linseed in Ethiopia.

Sowing should be done as quickly as possible after the last soil preparation (Toxopeus, 1938), and the time of sowing should be selected in such a way that the danger of drought during early development is avoided (Bunting, 1951). Late sowing decreases seed yield and seed weight (El-Nekhlawi et al., 1978) but influences the composition of the seed only slightly (Johnson, 1932a; El-Nekhlawi et al., 1978).

In most of Ethiopia, sowing is done at the onset of the big rains. Bako Research Station (1971) reported that a delay of sowing of three weeks decreased the yield considerably. In some regions, sowing is later to avoid undesirable effects of too heavy rains and clouds (Ciferri, 1941). Only a minor portion of the crop is sown as 'belg' crop, that is a crop cultivated in the small rains and sown in March (Tozzi, 1943; Prov. Mil. Gov., 1977). North of Asmara, there is a region where sowing is done in December because of another wet season (Corni, 1938).

Due to its open habit and low competitive power, linseed is a good crop for mixed cultivation with non-agressive crops (Butler et al., 1950). For Ethiopian conditions, the combination with low-growing leguminous crops seems attractive. Indeed I saw combinations with fenugreek and lentil in the Chercher Mountains, but also mixtures with a number of larger crops (tomato, wheat, barley, rapeseed). In the latter mixtures, linseed was always the major crop. It is common practice in Ethiopia to leave other crop plants while weeding. As flax mostly precedes fallow in the local rotation, it is likely that such fields were pre-fallow.

Literature on the effects of diseases and insect attacks on linseed in Ethiopia is rather scarce. The disease most mentioned is rust (Ciferri, 1941; Baldrati, 1949; Linder, 1976). Linder (1976) also indicated that at Kulumsa Farm in 1968–1969 up to 85% of the plants of local cultivars of flax was infested with *Septoria* wilt. Stewart & Dagnatchew (1967) listed 5 fungi found on linseed in Ethiopia. Schmutterer (1971) reported several pests of flax for some areas of Ethiopia, but these authors gave no measure of damage. Yohannes Woldemichael (1976), on the other hand, was not specific about the species involved. He reported that seed yields in the 1974 National Yield Trial varied from 60 to 1706 kg/ha and that these large differences were due to bad weather at some places and to attacks from insects and powdery mildew. Corni (1938) only reported that the crop does not require much care but that it is subject to a number of diseases.

After a growing period of c. 100 days, ripening is indicated by yellowing of the leaf and browning of the fruits. It is common practice to harvest at full maturity, when the plants are completely brown and the seeds can be heard rattling in the dry fruit. This is also often recommended (e.g. Butler et al., 1950; Queensland, 1962). In Ethiopia, this stage is reached after 3 to 4 months, mainly depending on altitude and the season the crop is grown. With dry weather, it is possible to leave the ripe crop on the field for one or two weeks without losses (Dillman, 1928; Friederich, 1956).

In the literature, opposite views can be found on the best time for harvesting. Apparently there is a great influence of the differences in cultivars and growing conditions. Desjobert (1954) and Jain & Dubey (1969) warn against too early harvest because the oil content is known to increase up to 12% in some cultivars in the last two weeks before total ripeness. The latter authors, on the other hand, also warn against late harvest. They found the oil content to decrease before seed weight had reached its maximum. In some cultivars, this decrease was such that the total oil yield declined. Desgrange (1948) and Zusevics (1966) recommended harvesting before complete ripeness because totally ripe linseed would show considerable losses by fruit-cracking and would yield oil of a lower quality. Hodgins (1975) cites a number of authors who found that oil content reached its peak well before total ripeness. They found that swathing, even in a rather young stage of development of the fruit, did not significantly affect the yield.

Jain & Dubey (1969) and Dorrell & Hodgins (1975) recorded an increase in seed weight after the oil content had started to decline. It thus seems that the crop should be harvested before total ripeness where it is grown for the production of oil. Where it is cultivated for seed, as in Ethiopia (p. 187), the stage of complete ripeness should be chosen.

In regions where rains fall when the crop is maturing, troublesome secondary growth and flowering may occur. This regrowth can be dealt with by spraying with 2,4-D-ester at rates of 600 to 1100 g/ha (Queensland, 1962).

In traditional cultivation in Ethiopia, linseed is harvested with a sickle or sometimes by pulling the whole plant. The plants are then transferred to the winnowing floor, where they are heaped and, if necessary, dried. Threshing is done by beating with a stick or by having oxen tread the plants. The straw is separated from the seeds and chaff with a fork. The remaining mass is heaped up on the winnowing floor by means of a brush made of leafy branches.

Ferrara (1928) gave the following account of the cleaning procedure in Eritrea. It accords well with my own observations in other parts of Ethiopia, and is also applicable to other small-seeded crops like rape and Niger seed.

The seeds and chaff are transferred to a basket made of straw or palm veins with a capacity of c. 10 litre. It is winnowed by keeping the basket slightly inclined at man's height and make the contents fall out slowly in the wind. In the new heap, partial separation has taken place of the seed and chaff. Further separation is with a special brush, made of stiff stalks of *Pennisetum*. These stalks are bound in such a way that they are kept in a fine but stiff, open fan. Winnowing is repeated 2–3 times.

Further purification is done in a wide and shallow container, made of straw or palm veins. In it, the seed is subjected to a particular shaking and rotating movement which makes the heavier particles go downwards and the lighter ones go upwards. By patting the bottom upwards, the contents are thrown up a bit and the litter falls out. Successively, the seed passes through a wide sieve, taking out larger impurities, and a fine sieve to take out the particles smaller than the seed.

Mechanical harvesting and threshing are possible, combining only if the moisture content of they crop is less than 100–110 g/kg (Zusevics, 1966). When the crop is less dry, it should be harvested with mowers or mower-binders. The crop can then be dried in cocks or swaths (Desgrange, 1948; Bunting, 1951; Zusevics, 1966).

Threshers should be adjusted precisely to the cultivar to avoid mechanical injury. Large-seeded cultivars with high oil content appear to be more susceptible to such injury than the smaller-seeded ones (Friederich, 1956; Erwin et al., 1964). Combine-threshed linseed in California contains about a third of cracked seeds. This damage could be avoided by proper adjustment of the peripheral speed of the cylinder, or by choosing a thresher of the 'Vogel' type (Erwin et al., 1964).

Seed yields in Ethiopia usually vary from 300 to 500 kg/ha. Under good growing conditions, yields are from 800 to more than 1000 kg/ha (for instance Ferrara, 1928; Corni, 1938; Statistical Abstract, 1970; Rydén, 1972; Linder, 1976). Lower and higher values are found too. Figures of 150 to 300 kg/ha were, for instance, reported from Bako (Bako Res. Stn Progr. Rep., 1971), Adi Ugri (Guidotti, 1937) and certain fields in Arussi (Rydén, 1972). High yields, both of Ethiopian and of non-Ethiopian cultivars were reported from research stations only, for instance 1415 kg/ha from Ethiopian cultivars in Debre Zeit (Asrat Felleke, 1965), 1100 kg/ha from imported cultivars in Kulumsa (Linder, 1976) and 1650 kg/ha from imported cultivars in Holetta (Iran Nejad, 1976). The Provisional Military Government of Ethiopia (1977) estimated the average yield over all of Ethiopia for crops sown in the big rains to be 360 kg/ha and for crops grown in the small rains 340 kg/ha. It added that linseed had been shown to give the highest yields at farms, smaller than ½ ha (in traditional cultivation). On such small farms 800 kg/ha was a common figure. This yield was also the highest encountered by Rydén (1972). The average yield on state farms was 1280 kg/ha (Prov. Mil. Gov., 1977).

From other parts of the world and under mechanized farming, the yields usually range 1250–2000 kg/ha, for instance for Queensland (Queensland, 1962), for California (Dybing & Carsrud, 1975), Europe (Zusevics, 1966) and Africa (Desgrange, 1948). Desgrange (1948) also mentioned that the average yield of linseed in traditional cultivation in Africa was 300–500 kg/ha, thus comparable to that under similar Ethiopian conditions. Experimental plots, on the other hand, had produced 3500 kg of seed per hectare. The highest recorded yield I encountered was reported by Dybing & Carsrud (1975), who indicated that in the Imperial Valley in California, under irrigation and with optimum conditions, close to 4000 kg/ha was harvested.

According to Ciferri (1941), the main reason for lower yields in Ethiopia is the shorter day of the tropical environment as compared to the days in the above indicated areas. But Toxopeus (1938) indicated yields up to 2000 kg for the Island of Java, which has an even shorter day than most of Ethiopia.

Zusevics (1966) reported that with the harvest of 1 ha of an average linseed crop, 60–80 cm tall, 5000–5600 kg of organic matter is removed from the field. It is composed of 1800–2400 kg straw, 1600–2000 kg of seed and 1600–2000 kg of husks.

Linseed keeps its viability very well under storage. Preferably warehoused, linseed should not contain more than 100 g of moisture per kg, although the seed resists high temperatures and fungal attacks up to a moisture content of 120 g/kg (Zusevics, 1966). As long as the temperatures are not continuously over 40°C, undamaged seeds can be stored for more than a year without any effect on emergence and even damaged seed keeps its vigour for about 8 months (Erwin et al., 1964).

Depending on field conditions before harvest and during drying and storage, flax seed remains viable for 7 years or more (Mándy et al., 1969; Andersen & Andersen, 1972). In 1949, Ciferri even reported that well stored healthy ripe seeds lose only 2% of their viability in 9 years.

In Ethiopia, the seed is stored inside the house in tins or leather bags or, particularly with larger amounts, a special store is built near the house. It often consists of a cylindrical framework of wood and an obconical plastered floor and with a thatched roof. In view of the climate in the areas where linseed is cultivated in Ethiopia, the decreased vigour of the seed, as reported by Linder (1976) (p. 184) should be attributed to the presence of damaged and unripe seeds.

Uses

Flax is cultivated worldwide for its seed and for fibre. In Ethiopia, it is only cultivated for the seed; use as a fibre plant is generally unknown. This seeming neglect may be explained by the general lack of water for retting when preparing fibre. Cotton has no such requirement.

The seed may be used in wot after roasting and pounding. When used for this purpose, it is mixed with pulses (Siegenthaler, 1963; Knutson & Selinus, 1968). Roasted and crushed seeds may be mixed with cold water or cooked to prepare a porridge. This is consumed with salt and red pepper. According to Braun (1848), it was a miserable fasting food for the rich but daily food for the poor. In Eritrea, a similar porridge, sabhi, is prepared for which the roasted seeds are finely ground between stones (Ferrara, 1928). Linseed meal, either pure or with berberre, was an important travel food for the Amaras (Kostlan, 1913).

In the highlands of Beghemder, flax is a staple food. During the entire year, the wot is made of split field-peas and roasted and crushed flax seeds (Knutson & Selinus, 1968; Selinus et al., 1971). Near Mekelle, flax seeds are added to hot porridge made from emmer wheat or barley. This porridge is particularly served on fasting days and to pregnant women (Selinus et al., 1971).

In view of the important role of linseed in the diet of the people N of Gonder, it is interesting to note that in that same area the incidence of goitre is very high (Miller et al., 1976). There may be a relation between the eating of food containing very small amounts of linamarin, a component of linseed, for a long time, and goitre (e.g. Delange et al., 1973; Hill, 1973).

According to Wittmack (1907) and Ciferri (1941), oil was prepared from the seed in Ethiopia, but I never heard of this use. Ciferri added that this was only done when the other oilseeds had been used and ample linseed was still available in the house. It is more common to prepare a beverage from it: chilka. To prepare this, roasted and crushed seed is boiled in water, sometimes with butter, salt or honey added. Siegenthaler (1963) remarks that chilka is particularly imbibed during the fasting season, when alcoholic drinks are taboo. My impression was that it is popular throughout the year in many regions of Ethiopia.

A drink similar to chilka, but thicker by longer boiling, is used to strengthen the skin. Its consumption cures itches and thickens the soles of feet (Siegenthaler, 1963).

Linseed may be mixed with medicinal plants to ease their use as medicaments (Griaule, 1930; Lemordant, 1971). The slippery seed may be put under an eye-lid to remove dirt or other objects (Siegenthaler, 1963). Concoctions of linseed and water are used to cure dysentery (Lemordant, 1971) or as a diuretic (Cufodontis, 1958).

Flax seed is also used to tan skins. The roasted and crushed seeds are boiled until the oil has escaped the seed; then the hides are soaked in the solution (Siegenthaler, 1963; Lemordant, 1971).

In international trade, linseed was long in demand for its oil and the presscake was valued as a feed for all classes of farmstock (Bunting, 1951; Desjobert, 1954). The oil is used to prepare paints, varnishes, printer's ink, oil-cloth, core oils for the foundry industry, for floor coatings, soft soap, and pharmaceutical uses (Tobler, 1928; Bunting, 1951; McGregor, 1960). In 1951, Bunting could even state that linseed oil was the most important drying oil of commerce. It is now less appreciated.

The high linolenic acid content of linseed oil has excluded it from the edible oil market because this acid is partly responsible for the appearance of undesirable off-flavours in refined oils after processing (Yermanos & Hemstreet, 1965).

Ethiopian flax seed usually contains rather large proportions of other seeds, notably *Cruciferae* and *Guizotia* spp. (Ferrara, 1928; Baldrati, 1949). In trade, these impurities are important, especially for oil seeds, because they influence the drying properties of the expressed oil. Ferrara (1928) found c. 6% impurities in Eritrean linseed samples, and up to 10% in samples from other parts of Ethiopia. The nature of the impurities was also different: Eritrean samples contained more soil, dust, capsule fragments and rubbish, while samples from other Ethiopian provinces contained considerable proportions of other seeds. He stated that oil prepared from Eritrean linseed had an excellent drying quality. The amounts of impurities mentioned by Ferrara (1928) and Baldrati (1949) were also present in my seed collection.

The presscake and linseed meal form a good animal feed, but they contain cyanogenic matter. Hydrocyanic acid can be removed with hot water (Tobler, 1928; Queensland, 1962; Hill, 1973).

The slime, which is part of the testa, is used in medicine (semen lini), externally for softening covers, internally to strengthen the intestine. The latter use is known also to veterinarians. Technically it was used as a mild textile dressing, to prevent incrustation of boilers, and in the production of colloidal gold (Tobler, 1928). Schormüler & Winter (1958) found the mucilage to have a large buffer capacity. According to them, its use in the production of mixed beverages, particularly if based upon fruit juices, would be justified.

Linseed straw produces a coarse fibre unsuitable for linen manufacture. Since it does not readily rot, it is usually burned as a waste product. It can be used for the manufacture of high-quality paper or as a coarse fibre, for instance in packing, insulation and burlap (Bunting, 1951; Friederich, 1956). More recent is its use in ornamental tapestry. Some uses and their processes were described by Simor (1967). In Ethiopia, the straw is commonly discarded near the threshing place where it is eaten by the ever-present cows, goats and sheep. It has a rather high nutritive value, as has the chaff, which is excellent feed for fattening animals because of its stimulating action on the intestine (Zusevics, 1966).

Some people develop a skin allergy if they have to handle a lot of linseed. The oil does not induce allergic symptoms (Rajka, 1950).

Chemical and physical properties

Flax seeds are normally brown, but yellowish, green, and intermediate colours can be found too (Tobler, 1928). In my Ethiopian colllection, only brown, light brown and yellowish seeds are present (Note 5). The surface is glossy, a dull surface often indicating the presence of diseases (Tobler, 1928).

Normally content of oil in linseed is c. 400 g/kg (Bunting, 1951), but values as low as 220 g/kg (Desgrange, 1948) to c. 300 g/kg (Ferrara, 1928; Toxopeus, 1938; Queens-

Table 45. Provenance, 1000-seed weight (g) (TSW, ± 50 mg/g), colour (Note 5), and oil contents (g/kg) of 33 samples of my Ethiopian linseed collection.

Provenance	TSW	Colour	Oil
Average of all	3.7	–	399
Langhe (H'gie)	3.4	Brown	383
Alemaya (H'gie)	4.6	Brown	414
Chelenko (H'gie)	3.7	Brown	424
Chelenko (H'gie)	3.8	Yellow	411
Jijiga (H'gie)	3.6	Brown	390
Asbe Teferi (H'gie)	4.0	Yellow	415
Waichu (H'gie)	3.6	Brown	403
Waichu (H'gie)	4.9	Brown	411
Ghelemso (H'gie)	3.6	Light brown	417
Bedessa (H'gie)	4.5	Light brown	411
Elias (Gojam)	2.7	Brown	376
Infranz (Beghemder)	4.2	Brown	382
Gonder (Beghemder)	3.5	Brown	397
Adi Caieh (Eritrea)	4.6	Light brown	424
Adi Show (Tigre)	4.7	Brown	408
Haik (Welo)	3.7	Yellow	408
Haik (Welo)	4.3	Brown	418
Goba (Bale)	6.7	Brown	443
Goro (Bale)	3.3	Brown	362
Shashemane (Shewa)	4.4	Brown	398
Neghele (Sidamo)	5.6	Brown	425
Neghele (Sidamo)	3.7	Brown	411
Neghele (Sidamo)	3.1	Yellow	372
Bonga (Kefa)	2.8	Light brown	378
Bonga (Kefa)	2.7	Light brown	364
Chena (Kefa)	2.7	Light brown	393
Jemero (Kefa)	4.4	Brown	406
Metu (Illubabor)	3.0	Beige	397
Metu (Illubabor)	2.6	Light brown	384
Buro (Illubabor)	3.3	Beige	401
Dembidolo (Welega)	2.6	Brown	378
Nekempt (Welega)	2.2	Light brown	385
Nekempt (Welega)	2.5	Brown	393

land, 1962) and as high as 500 g/kg (Iran Nejad, 1976) are reported. Suzzi (1904) found the seeds of Eritrean linseed to contain more than 340 g of oil per kg. By expression, only 300 g/kg was obtained. Similar oil contents were reported by Asrat Felleke (1965) for Ethiopia. According to Ciferri (1949, p. 85), the usual oil contents of Ethiopian linseed are 380–395 g/kg. Ciferri's data are in close accordance with the oil contents reported by Rydén (1972). I found slighty higher figures (on dry basis). In 33 samples of my Ethiopian collection, oil contents ranged (362)372–418(443) g/kg.

Several authors report a positive correlation between high oil content and yellow seed colour (for instance McGregor, 1960; Gursham & Khem, 1961), but Ferrara

Table 46. The provincial distribution of 1000-seed weights (g) (with number of samples from the province, *n*) in my Ethiopian linseed collection. (Moisture contents 60–65 g/kg).

Province	*n*	Mean	Maximum	Minimum
			1000-seed weights	
Bale	(3)	5.6	6.73	3.30
Beghemder	(4)	4.1	4.53	3.47
Eritrea	(1)	4.6	·	·
Gojam	(5)	3.0	3.33	2.70
Harergie	(37)	3.8	4.93	2.67
Illubabor	(8)	3.2	4.40	2.63
Kefa	(13)	3.0	4.07	2.33
Shewa	(6)	3.8	4.37	3.17
Sidamo	(5)	4.2	5.63	3.07
Tigre	(2)	4.6	4.70	4.40
Welega	(3)	2.4	2.60	2.23
Welo	(18)	4.5	5.40	2.60

(1928) reported that he could not find differences between brown, white and mixed seed samples from Eritrea, big enough to justify a preference for light-coloured seed. Most light-coloured samples of my collection contained more oil than the average of all samples, but the highest contents were found in brown-seeded samples. My findings, thus, are comparable to those of Ferrara. Table 45 represents the data discussed above.

The 1000-seed weight varies from 3 to 12 g, depending on the cultivar, the growing conditions and the latitude (McGregor, 1960; Queensland, 1962). Ferrara (1928) indicated that linseed from Eritrea was small with 1000-seed weight of 4.65 to 5.00 g, and bulk density 700 to 720 g/l. In my Ethiopian collection, the 1000-seed weight varies from 2.2 to 6.2 g (± 50 mg/g). The provincial distribution is given in Table 46.

The 1000-seed weight of my sample from Eritrea is close to the range indicated by Ferrara (1928), as are the values for the provinces bordering Eritrea. A review of the 1000-seed weights of my collection shows the following general distribution within Ethiopia: the heaviest seeds were found in Welo, Tigre and Eritrea in the north, and in Bale and Sidamo in the south. The smallest values were found in W Ethiopia S of Lake Tana, and in the Harergie Province. C Ethiopia and Beghemder were intermediate.

It is often reported (e.g. Howard & Rahman, 1924; McGregor, 1960; Ford & Zimmerman, 1964) that heavy seeds yield more oil than lighter ones. On the other hand, Sekhon et al. (1973) found this correlation not to be significant among 23 strains in which the heaviest were about twice as heavy as the lightest, nor could Despande & Malik (cited by Saxena & Asthana, 1962) find this correlation. Within the 33 samples

Table 47. Composition of linseed. (Data from Kayser, 1925; Ferrara, 1928; Tobler, 1928; Wanjura, 1935; Zimmerman & Klosterman, 1959; Queensland, 1962; Iran Nejad, 1976; and Schuster et al., 1978a. For the amounts of chemical elements, the content of ash given by Ferrara for Eritrean seeds was combined with data on composition given by the other authors).

	Usual range	Eritrean average
Oil (g/kg)	300–458	348
Moisture (g/kg)	36–83	70
Crude protein (g/kg)	190–290	240[1]
Carbohydrates (g/kg)	c. 229	–
Crude fibre (g/kg)	c. 55	–
Carbohydrates incl. crude fibre (g/kg)	275–308	308
Ash (g/kg)	25–80	34
Phosphorus (g/kg)		6.53
Potash (g/kg)		8.02
Magnesium (g/kg)		2.67
Calcium (g/kg)		2.09
Sodium (g/kg)		0.32
Silicon (g/kg)		0.10
Chlorine (g/kg)		0.03
Sulphur (g/kg)		0.02
Manganese (g/kg)		0.02
Vitamin A (mg/kg)	4.7	
B_1 (mg/kg)	4.1	
B_2 (mg/kg)	9.6	
C (mg/kg)	90.6	
D (mg/kg)	trace	
E (mg/kg)	19.4	

1. Iran Nejad (1976) found at Holetta that the protein contents of 9 introduced cvs varied from 190 to 250 g per kilogram of seed.

Table 48. Bulk density, 1000-seed weight (TSW) and composition of 8 samples of local small-seeded linseed cultivars from Ethiopia (Ferrara, 1943).

Provenance	Dens. (g/l)	TSW (g)	Ash (g/kg)	H_2O (g/kg	Crude oil (g/kg)	Crude protein (g/kg)	N-free extr. + fibre (g/kg)
Addis Abeba	686	3.48	32.3	78.1	385.4	159.8	344.4
Holetta	689	3.82	38.0	76.8	372.2	138.1	377.5
Gonder	650	4.47	32.3	69.7	401.2	133.7	363.1
Amare (Tana)	711	3.71	39.0	76.2	386.0	162.0	336.8
Amare (Tana)	690	3.53	41.0	75.0	380.2	166.1	337.7
Libo (Tana)	660	4.37	38.4	73.1	324.0	144.3	420.2
Jimma	715	2.93	37.8	84.8	356.0	171.2	350.2
Harer	700	3.95	38.0	79.7	364.0	183.1	335.2

Table 49. Composition of some samples of linseed from Ethiopia (amounts per kilogram of edible portion, Ågren & Gibson 1968).

	Whole seed	Whole seed presscake[1]
Food energy (MJ)	(17.320)20.500(23.010)	(14.310)14.810(15.270)
Moisture (g)	(39)58(79)	(78)99(119)
Nitrogen (g)	(17)32(43)	(31)37(42)
Protein (N × 5.28) (g)	(91)170(226)	(161)193(224)
Fat (g)	(111)297(399)	(33)39(48)
Carbohydrate total, including fibre (g)	(339)439(683)	(551)621(691)
Fibre (g)	(54)103(159)	(90)95(98)
Ash (g)	(28)36(43)	(37)48(58)
Calcium (mg)	(1370)2270(3090)	(2000)3090(4180)
Phosphorus (mg)	(2550)4540(6100)	(4800)5280(5750)
Iron (mg)	(1380)2940(5660)	(3630)5880(8120)
Thiamin (mg)	(1.2)3.5(7.0)	–
Riboflavin (mg)	(0.4)1.1(1.7)	2.1 (one sample)
Niacin (mg)	(12)20(27)	(19)20(21)
Tryptophan (mg)	3810 (one sample)	7190 (one sample)
Ascorbic acid (mg)	less than 1	–
Rubbish in sample as purchased (g)	*(20)50(90)*	–

1. More components and sometimes very different values can be found in Chichaibelu et al. (1977).

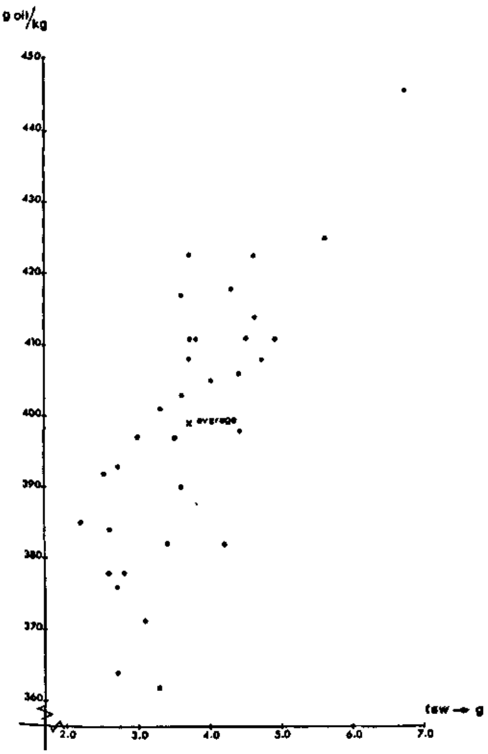


Fig. 9. Relation between 1000-seed weight (g) and oil contents (g of oil per kg seed) of 33 lots of linseed purchased on Ethiopian markets.

I investigated, there seems to be a clear tendency for heavier seed to contain more oil. (Fig. 9).

Data on the composition of linseed are given in Table 47. Composition of linseed from Ethiopia, as reported by Ferrara (1943) and Ågren & Gibson (1968), is presented in Tables 48 and 49.

Cold-pressed linseed oil is viscous, golden yellow, and has a characteristic bland taste and odour. Warm-pressed, the oil is amber yellow to brown, after removal of the mucilage greenish yellow; it has a sharp aftertaste (Tobler, 1928; Mensier, 1957). Generaly the oil of light-coloured seeds has a lighter colour, which is preferred by trade (Gursham & Khem, 1961).

Some characteristics of linseed oil and the relative fractions of the fatty acids constituting to the oil are given in Tables 50 and 51, respectively.

Von Mikusch (1952) indicated that there is strong evidence that, of all possible stereo-isomers of the unsaturated fatty acids, only those with cis configuration at each double bond are found in linseed oil. According to van Boekenogen (1946), the most important triglyceride in linseed oil is linolyl dilinolenyl glyceride, but Dutton & Cannon (1956) found in an oil with iodine value 183.5 the following triglycerides containing linolenic acid: 18.2% trilinolenyl glyceride, 12.3% linolyl dilinolenyl glyceride, and 4.1% dilinolyl linolenyl glyceride.

If kept far from oxygen, the oil can be stored for years without changing much. However, when it comes into contact with oxygen (air), the unsaturated fatty acids oxidize to form 'linoxin', a tough protective compound, very resistant to heat and

Table 50. Some characteristics of linseed oil. (Sources: Ferrara, 1928; Tobler, 1928; Mensier, 1957; Zimmerman & Klosterman, 1959. Ferrara's figures (F) are noted separately because his date are derived from Eritrean seeds.)

		(F)
Relative density at 15°C	0.927–0.936	0.930–0.934
Relative density at 24°C	0.9272–0.9304	–
Solidification trajectory(°C)	$^{-}15$–$^{-}27.5$	$^{-}15$–$^{-}18$
Saponification value	180–196	185–190
Iodine value	166–198 (Wijs)	186–192 (Uiibl.)[1]
Reichert-Meissl number	0	–
Hehner number	94–96	–
Acetyl value	4–10	–
Hexabromide value	23–38	–
Sulphocyanogen index	114–125	–
Refractive index	n_D(15°C) = 1.4808–1.4859	–
Zeiss butyrorefractometer	85–92 (at 15°C)	81–84 (at 25°C)
Acid number (as oleic)	<2	0.15–0.17
Titre (°C)	19–21	–
Unsaponifiable matter (g/kg)	5–15	–
Colour (Gardner scale)	(8)9–10(11)	–

1. Ciferri (1949, p. 87) indicated that the normal range for Ethiopian linseed oil was 182–185 (Wijs).

Table 51. Fatty acid composition of linseed oil as substance fraction (mmol/mol). (Sources Mensier, 1957; Zimmerman & Klosterman, 1959; Iran Nejad, 1976. 33 samples from Ethiopia (S)).

		(S)
Palmitic acid	30–70	43–123[1]
Stearic acid	20–50	19–63[1]
Arachidic + lignoceric acid	<10	–
Saturated fatty acids	80–120	62–186[1]
Oleic acid	100–380[2]	113–294
Linoleic acid	70–240	100–174
Linolenic acid	250–700[2]	405–683

1. One sample had the highest fraction of palmitic and stearic acids, and the lowest of linolenic acid. Of palmitolinic + hexadecadienic acids, it also contained nearly 50 mmol/mol.
2. According to Zimmerman & Klosterman (1959), the total of the linolenic and oleic acid contents in a world collection of 1175 cvs was consistently from 700 to 750 mmol/mol.

moisture (Bunting, 1951). In the drying process, weight increases by c. 18% (Tobler, 1928).

The proportion of linolenic acid among the total fatty acids is of prime importance in determining the drying quality of the oil. Oils with high contents of this acid form harder coatings and dry faster than low-linolenic oils. On the other hand, their colour retention is poorer (Zimmerman & Klosterman, 1959; Sekhon et al., 1973).

As there is a high positive correlation between the iodine value of linseed oil and the proportion of linolenic acid (Zimmerman & Klosterman, 1959; McGregor, 1960; Sekhon et al., 1973), this value is in general used to compare the drying quality of linseed oils. Positive correlations between yellowness of seed or smallness of seed and high iodine values have been reported (McGregor, 1960; Johnson as cited by Saxena & Asthana, 1962), but other authors describe these correlations as doubtful (Ford & Zimmerman, 1928; Gursham & Khem, 1961).

Pure protein in crude protein of linseed is more than 900 g/kg and is largely a globulin, lipoproteins being absent. Because of the high contents of nitrogen, the traditional factor of 6.25 to calculate the crude protein from the nitrogen contents of a sample results in too high an estimate; 6.16 would be a better factor than 6.25 (Schormüller & Winter, 1958). The protein has a high biological value for man and a good digestibility. The proportions of the essential amino acids lysine, methionine and tryptophan are high for a plant protein. On average, they form 3.8, 2.3 and 1.9% of the weight of crude protein, respectively (Iran Nejad, 1976; Schuster et al., 1978). Particularly consumption of milk protein in combination with linseed protein seems to be attractive for a balance of amino acids for man (Schormüller & Winter, 1958a). Iran Nejad (1976), who gives more details on linseed protein, describes the average composition of 9 cultivars of flax, grown in West Germany. His figures are presented in Table 52. Comparable values are found in Schormüller & Winter (1958).

It seems that a high mass ratio of the crude proteins soluble in water and salt solution

Table 52. Average contents (g/kg) of amino acids in crude protein of 9 linseed cultivars, grown in West Germany (Iran Nejad, 1976).

arginine	106	valine	50
histidine	21	alanine	39
isoleucine	43	aspartic acid	100
leucine	61	glutamic acid	220
lysine	40	glycine	52
methionine	16	proline	32
phenylalanine	58	serine	47
threonine	35	tyrosine	28

to those soluble in ethanol and in sodium hydroxide is indicative of a high biological value. This ratio is high for linseed and, compared to several other places in the world, this ratio was on average higher in Holetta than anywhere else (Iran Nejad, 1976).

About 5–6% of the weight of the dry testa is a mucilage. This makes the seed gain almost twice its weight in only one hour of soaking. The mucilage consists of pentosans, hexosans and galactans, cellulose and minerals, notably calcium, potassium, phosphorus, chlorine, sulphur, iron, aluminium, and silicon (Tobler, 1928; Erskine & Jones, 1957). Other data on the physical and chemical nature of the mucilage were described by Mangin (1893) and by Schormüller & Winter (1958).

In his worldwide experiment with 9 non-Ethiopian cultivars, Iran Nejad (1976) found the seeds grown at Holetta to be richer in mucilage than those from all other places but one.

The mucilage is also present in the freshly expressed oil and in the cake. It separates from the oil only after several months of standing, but it can be removed quickly by heating up to 270°C or by chemical treatment (Tobler, 1928).

A minor, but sometimes important, constituent of linseed is linamarin, a cyanogenic glycoside. According to Dunstan et al. (1906), this substance should be called phaseolunatin. Per kilogram, linseed contains enough linamarin to liberate 0.11–0.31 g of hydrocyanic acid (Tobler, 1928). This only happens in the pH range 2–7 (Iran Nejad, 1976). As the pH in the stomach is 1.5, poisoning does not occur. Seeds of 9 cultivars grown in Holetta contained over 2 years less linamarin than seeds from the same cvs

Table 53. Average composition of expressed and extracted linseed meal. (Data in g/kg, from Tobler, 1928).

	Expressed	Extracted
Moisture	111	110
Crude protein	275	332
Crude fat	99	36
N-free extract	345	368
Crude fibre	98	92
Ash	72	62

Table 54. Composition (g/kg) of flax chaff (Tobler, 1928) and of flax straw (Zusevics, 1966).

	Chaff	Straw		Chaff
Moisture	152	72	Clay minerals	8.1
Crude protein	68[1]	72[2]	Magnesium	5.2
Crude fat	41	32	Phosphorus	2.7
N-free extract	330	329	Sulphur	2.5
Crude fibre	310	435	Chlorine	1.9
Ash	99	70	Iron	1.1
Potash	17.2	–	Manganese	0.3
Calcium	14.8	–	Sodium	0.3
Silicon	14.4	–		

1. According to Zusevics, 10 g is digestible protein.
2. According to Zusevics, 58 g is digestible protein.

grown in other countries (Iran Nejad, 1976).

The plant also contains linamarin in amounts varying with the age of the plant. In young plants, contents 20 times as high as that of the seeds have been found (Dunstan et al., 1906).

Oil content of presscake is about 50–90 g/kg. It is greenish grey or light to dark brown. Extracted linseed meal contains about 10–35 g/kg (Tobler, 1928; Zusevics, 1966), and 300–400 g of protein (Bunting, 1951). The average composition, as given by Tobler (1928), is presented in Table 53.

Minor but important constituents are the slime of the seed-coats and the linamarin. By the presence of the latter, one kg of linseed meal can liberate 0.3–0.4 g of hydrocyanic acid (Tobler, 1928).

The chaff forms c. 10–15% (w/w) of the harvest (Tobler, 1928). Its composition is given in Table 54. The fat and protein contents vary with the presence of crushed or small seeds.

According to Wanjura (1935), 1 kg of flax straw contains about 12 g of potash, 0.65 g of phosphorus, 3.6 g of calcium and relatively large amounts of chlorine, sulphur, sodium and magnesium. Zusevics's data on straw composition are included in Table 54.

2.13 Maesa lanceolata Forsk. var. lanceolata (2*n* = 20) Fig. 10

'Maesa': Latinization of the Arabic name maas.
'lanceolata': lanceolate, because of the leaf form.

Forskål, Flora aegypt. arab.: p. CVI and 66 (1775).
Type: Forsk. Herb. No. 360, from Yemen (Oddein) (C, lecto, microfiche!).

Synonyms

Baeobotrys lanceolata (Forsk.) Vahl, Symb. Bot. I: p. 19 (1790).

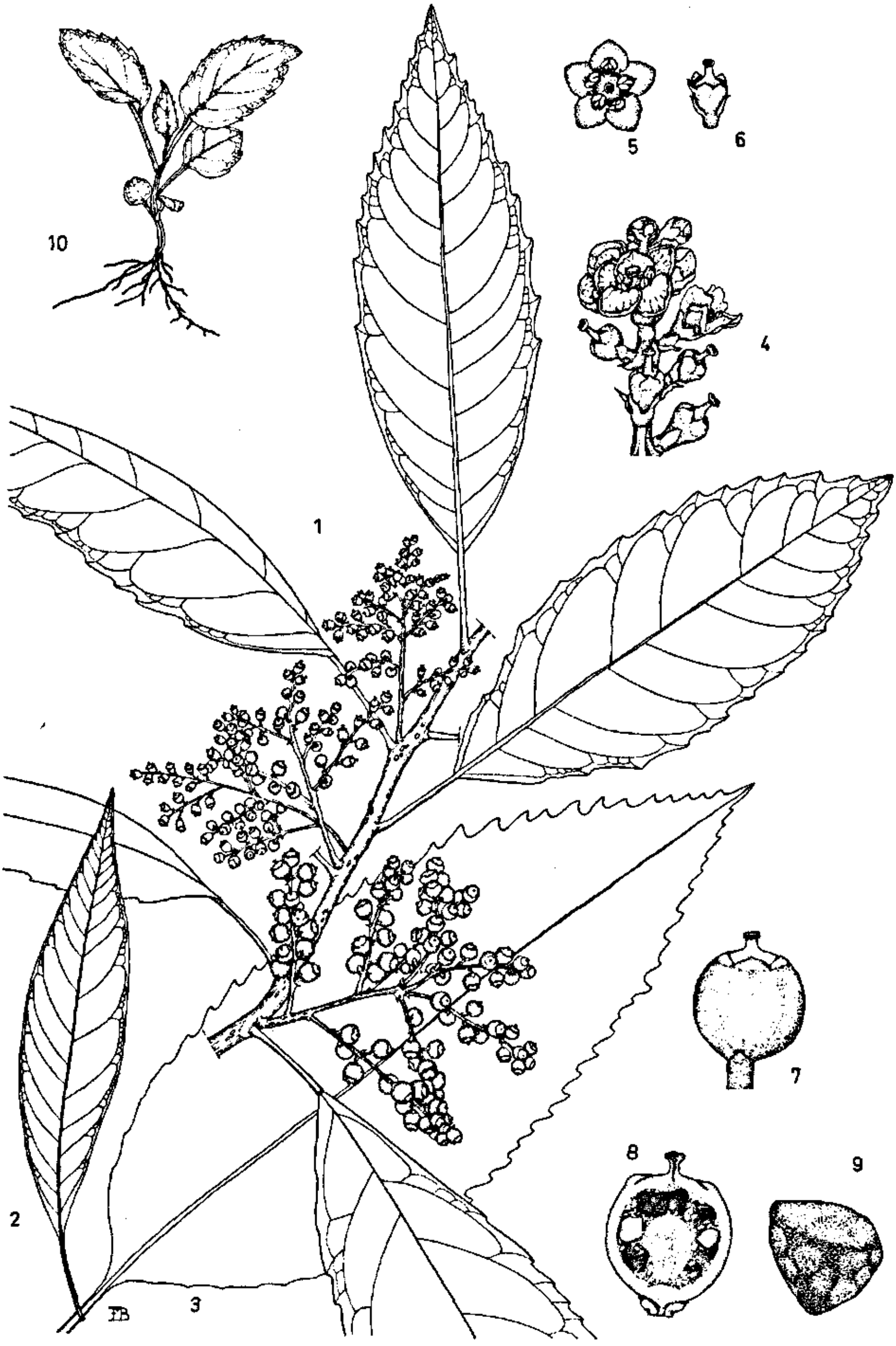


Fig. 10. *Maesa lanceolata* Forsk. 1. Branch in fruit (×½). 2 & 3. Some leaf forms (×½). 4. Branchlet of inflorescence (×4). 5. Flower from above (×2½). 6. Ovary (×2½). 7. Fruit (×4½). 8. Section lengthwise of fruit (×4½). 9. Seed (×15). 10. Seedling (×½). 1, PJ 3872; 2, F. G. Meyer 8618 WAG; 3, WP 5531; 4, PJ 3872; 5 & 6, JdeW 5094; 7–9, WP 3360; 10, SL 2050.

Maesa arabica Gmel., Syst. II: p. 403 (1791).
Maasa lanceolata (Forsk.) Roem & Schult., Syst. V: p. 226 (1819).
Maesa picta Hochst., Flora 24(1), Intelligenzblatt, p. 25 (1841).

Literature

1902: Mez, in Engler's Pflz. reich 9: p. 15–54. (tax).
1960: Cufodontis, Senck. biol. 41(5/6): p. 389. (agric.)
1963: Siegenthaler, IECAMA Jima Expt. Sta. Bull. 14: p. 12. (agric.)
1968: Faure, Mém. Mus. Hist. nat., nouv. sér. 2, botanique 18: p. 42. (tax.)
1980: Taton, Bull, nat. Plt.tuin België 50(1/2): p. 208–218. (tax.)

Vernacular names: erenja-kolo, geča, hamarara, kalalu, kelawa, kaleha, kalhaho, khalabo, kilaba, algalua (Amarinya); abaye, abaji, abiye, kalawa, galaba, geshi (Gallinya); imbis (Guraginya); saoria, sauarja, soarea (Tigrinya); gergečo, kelaua (Welaminya); maas, arar (Arabic); chesh (Ghimira).
Trade names: ?

Geographic distribution

Maesa lanceolata has been found all over tropical Africa including the islands, and in the hotter parts of subtropical Africa as well. Outside Africa, it is known from the Arabian Peninsula (Jacques-Félix, 1970; Taton, 1980). The other African species of *Maesa* have a more limited distribution and are not known from Ethiopia (Jacques-Félix, 1970; Cufodontis, 1974; Taton, 1980). Therefore, the determination of gelaba as *Maesa laevigata* Scheff. by Troll & Schottenloher (1939) must be a misidentification.

M. lanceolata can be found in the highlands of all Ethiopia (Cufodontis, 1974).

Description

Shrub or tree up to 10 m tall, crown up to 14 m diam.

Stem and branches subcylindric, diam. at breast height up to 60 cm, with greyish or reddish brown to brown bark.

Branchlets greenish brown, with pale brown (narrowly) elliptic longitudinal lenticels 1–2 mm long, glabrous or with short white to greyish brown hairs.

Leaves somewhat irregularly arranged, exstipulate; petiole half-cylindric, flat to grooved above, 1–5 cm long, glabrous or at the most puberulous above, green or brownish; blade elliptic or narrowly so, sometimes slightly ovate, c. 10–25 cm × 2–11 cm, slightly coriaceous, glossy, glabrous, beneath lighter green than above and often brownish on the midrib and the (5)14–16(18) main veins on each side, at top and base acute to acuminate, margin mostly serrate, often entire in lower half.

Inflorescence a dense, singly or rarely doubly compound raceme, axillary on the leafy shoot, up to 25 cm long and 10 cm diam.; branches puberulous, glabrescent in fruit, brownish green; bracts and bracteoles ovate to triangular, up to 1 mm long, bracts on the main axis up to 3 mm long, sometimes larger and leafy, mostly glabrous with ciliate margins, sometimes the midrib puberulous beneath.

Pedicel c. 1 mm long or less, sparsely puberulous or glabrous, with 2 opposite bracteoles.

Calyx 5-lobed; (pale) green to greenish brown; lobes deltoid to broadly ovate with ciliate margins.

Corolla 5-lobed; greenish, (greenish) white or creamy, sometimes lobes with lighter border and darker centre; tube c. 0.5 mm long, lobes ovate to deltoid, c. 1.5 mm long.

Stamens 5, inserted on the corolla tube opposite the lobes, c. 1–1.5 mm long; filaments up to 1 mm, light green; anthers and pollen yellow.

Ovary half-inferior, globose to ellipsoid, c. 1 mm diam., 1-celled, multi-ovulate.

Style club-shaped, c. 0.5 mm long, light green.

Fruit a globose berry with many seeds, up to 5 mm diam., base with two persistent appressed bracteoles; brown when ripe. The persistent calyx lobes form a dentate ring on the upper half.

Seed irregularly shaped, more or less oblong, triangular in transverse section, c. 1.5 mm long and 1 mm diam.; testa dark brown, finely bullate.

Seedling with epigeal germination. Root system well developed, laterals develop early and strongly. Hypocotyl light green to slightly brownish, easily forming adventitious roots. Cotyledons foliaceous, light green, suborbicular, base truncate, notched at the apex, c. 6 mm × 6 mm (when young c. 2 mm × 2 mm). First leaf ovate, c. 17 mm × 16 mm, relatively coarsely dentate. Successive leaves gradually becoming larger and more elongate.

Notes

(1) *Maesa* Forsk. is a genus of the *Myrsinaceae*. This family comprises about 1000 species in c. 33 genera. Some subfamilies are distinguished, one of which is the *Maesoideae*, consisting of the genus *Maesa* only. Within the genus, c. 100 species are recognized (Mez, 1902; Hegnauer, 1969). *Maesa* is distinguished from other *Myrsinaceae* by a calyx tube that is adnate to the ovary, by petals united basally into a short tube (Hepper, 1963), by the presence of bracteoles, and by fruit with more than one seed (Mez, 1902).

(2) According to Faure (1968), *Maesa lanceolata* has 20 somatic chromosomes. Four groups, differing in length and form could be segregated.

(3) I never encountered monosexual flowers, as described from Ethiopia by Richard (1851), nor did I find any mention of it in other literature.

(4) In his recent revision, Taton (1980) distinguished 3 varieties within *M. lanceolata*; only the type variety was ascribed by him to Ethiopia. My material confirms this observation.

(5) Because of the similarity of the bracteoles and the calyx-lobes, Forskål (1775) named the bracteoles 'outer calyx'.

(6) Description was based on the following specimens.

Arussi 7 km S of Asella: WP 1649.

Gemu Gofa	25 km S of Soddo (Shashemane Road): PJ 3689; 50 km S of Soddo (Shashemane Road): PJ 3872, PJ 3874.
Harergie	50 km from Alemaya (Kulubi Road): WP 855; 64 km E of Asbe Teferi (Deder Road): WP 1324; 80 km E of Asbe Teferi (Deder road): PJ 3527; Gara Mulatta: PJ 6140; S face of Gara Mulatta (9° 12′ N, 41° 46′ E): JdeW 5094; between Gara Mulatta and Bedeno (9° 08′ N, 41° 39′ E): JdeW 4377; 2 km S of Chelenko: SL 2901.
Illubabor	15 km SW of Gera (7° 45′ N, 36° 18′ E): F. G. Meyer 8863.
Kefa	Bonga, Catholic Mission: SL 3233, WP 5531; Bonga, near Catholic Mission: PJ 2099, PJ 2189, PJ 5388; 3 km N of Bonga: Tadesse Ebba 536; 5 km E of Bonga, Wushwush Road: PJ 2259A; road Bonga–Jimma: PJ 5296; 62 km N of Jimma: WP 3360; 60 km SW of Jimma, Bonga Road: WdeW 7859, JdeW 5401 (7° 30′ N, 36° 30′ E); near Yebu (7° 45′ N, 36° 52′ E): I. Friis, A. Hounde & K. Jacobsen 67.
Sidamo	Soddu-Wollamo village (6° 52′ N, 37° 46′ E): F. G. Meyer 8768.
Shewa	5 km NE of Addis Abeba: WdeW 11005; 5 km NW of Addis Abeba: WdeW 5955; 20 km NW of Addis Abeba: WdeW 6102; 14 km E of Shashemane: SL 3071; Entoto Mountain near Addis Abeba (9° 02′ N, 38° 48′ E): F. G. Meyer 8618; Mount Zuquala, c. 60 km S of Addis Abeba: WdeW 8611.
Welega	10 km NE of Lekemt [Nekempt]: WdeW 7250; 45 km E of Lekemt: PJ 6243.
Grown at Wageningen	SL 2050, SL 3880.

Ecology

Maesa lanceolata is mostly found in the highlands on slopes with forest and bushes. If it is found on sunny places, this mostly means that the shading cover has been removed rather recently (degraded forest). The literature usually indicates that *Maesa* is restricted to altitudes over 2000 m throughout its area of distribution (for instance Hutchinson & Bruce, 1941; Logan, 1946; Giordano, 1948).

In my Ethiopian material, however, the average altitude of the collecting sites of all specimens was just over 2100 m, but localities at 1500 m and 2870 m were noted. There was a striking difference between the average altitude of the plants from Harergie, Arussi and Shewa (2486 m) on the one hand, and that from those of W Ethiopia (1765 m) on the other hand. The range in the former region was 2200–2870 m, in the latter region 1500–2400 m. Similar values concerning these Ethiopian areas are recorded by Schottenloher (1939), Cufodontis (1960) and Burger (1974).

Troll & Schottenloher (1939) reported the east-west relation to be reversed in the Eritrea-Tigre region. They found the species on the E escarpments in Eritrea growing at altitudes of 1250 to 2450 m, but up to nearly 3000 m between Axum and the Takazze Valley. Most probably, these differences are caused by differences in moisture in the regions concerned.

According to Mesfin (1970, Maps 17–20) the average daily temperature in the regions from where *Maesa* was reported range from 16 to 20°C, and absolute maxima and minima fluctuate around 25–35°C and 2–10°C, respectively (Mesfin, 1970, Map 28). These values are close to those given by Burger (1974) for Deder (2350 m), which he considered representative for the Chercher Highlands: average daily maxima 22°C, average daily minima 7°C.

Moisture seems to be the most important factor in the habitat of *Maesa*. The labels of my material indicate that *M. lanceolata* prefers wetter places. Perhaps *Maesa* can also acquire water from dew: Schottenloher (1939) and Troll & Schottenloher (1939) indicate that *Maesa* is a species of the mist forest.

Flowers may be seen in most of the year, more abundantly during the rainy season. Reports from other parts of Africa (Pardy, 1956) indicate the same preference of *M. lanceolata* for wet conditions. Logan (1946) reported that the rain in some forests in Ethiopia in which *M. lanceolata* is a frequent species ranged from 1000 to 1400 mm annually. The localities of my specimens and collecting places mentioned in literature (Richard, 1851; Hutchinson & Bruce, 1941; Cufodontis, 1960) when entered on Map 26 of Mesfin (1970) suggest an average annual rainfall requirement of at least 800 mm.

The specimens I saw showed a strong influence of moisture conditions at the growing site on the size and shape of the leaf. Plants from wet regions have longer and particularly wider leaves; those leaves are less 'lanceolate'. Even more apparent is the influence on dentation: the wider the leaf, the more dentate.

According to Westphal's soil regions map (1975, Map 6) and the collecting sites of my material, most plants were found on the lava plateau and on the high parts of the Somali Plateau; in my collection, there are alsow a few plants from the W crystalline highlands. In the literature (Richard, 1851; Troll & Schottenloher, 1939; Cufodontis, 1974), the species has also been reported from the N crystalline highlands.

Comparison of the soil map of Westphal (1975, Map 7) with those collecting sites, indicates that most soils may be classified as Tropepts and Udalfs.

Husbandry

The label of WP 3360 indicates that the plant was cultivated in the Jimma region. I never encountered it cultivated and think that *Maesa* is always collected from the wild. Of course, *Maesa* bushes may be left where a forest was cleared for agricultural purposes. Afterwards, some trimming may be done whenever they interfere with the crop grown, I have never heard of it.

Uses

According to Siegenthaler (1963) one can find the 'dry seeds' on most Ethiopian markets most of the year round. This is not my experience: I encountered it only once on a market and the product offered was fresh, not dry. Possibly Siegenthaler confused the dry fruits of 'kachamo' (*Myrsine africana* L.) with those of *Maesa*. Kachamo fruits have a superficial similarity, and indeed can be found at the majority of Ethiopian markets for most of the year (Jansen, 1981).

Siegenthaler (1963) indicated that the fruits are sometimes used as a fish poison. He added that they are mainly used, mixed with cottonseed, to prepare an oil from it. The labels of several specimens from the Kefa region, confirmed by what I was told, indicate that only *Maesa* is used to prepare oil without additions, This oil is used to grease the frying plate for the 'injera' (unleavened bread) (Herbarium Tadesse Ebba 536, WP 3360; Siegenthaler, 1963). Cufodontis (1960) mentioned that the label of Straube II/4 indicated that near Chako (Kefa) the fruits were roasted and ground. The thick porridge so prepared was spread as such on the injera pan (meshisha). It is removed before spreading the batter.

The use as an oil plant is not indicated on labels of specimens from regions outside Kefa nor did I ever hear of such use elsewhere. In view of the use as meshisha, the observations of Kuls in Sidamo seem ambiguous (reported by Cufodontis, 1960): 'fruits seem to be used as millet' and 'millet-fruit-tree'. The mashed seed Kuls saw being spread may not have originated from *Maesa* and this added to the implied use, porridge that was actually eaten, Kuls' report needs confirmation.

The other use in Ethiopia, often mentioned in the literature (Richard, 1851; Cufodontis, 1960; Watt & Breijer-Brandwijk, 1962), is a vermifuge, a use also reported from other parts of Africa (Bally, 1937; Pardy, 1956). The fruits are crushed, mixed with mashed beans and taken in a large dose (Schweinfurth, 1891).

In Europe, its use as a taenifuge was investigated already more than a century ago. In the Journal de Pharmacie et Chimie of 1854 it was reported anonymously that Strohl had concluded that *Maesa* was a safe taenifuge, that it had a mild action, seldom accompanied by side-effects, that it was also safe for children and persons with a weak constitution ('such as women'), and that it was preferable to kosso (*Hagenia abyssinica* (Bruce) J. F. Gmelin) because of its safe and possibly taenicidal action. At the same time, it was reported that the urine of people to which *Maesa* was administered turned violet. Normally about 30–45 g of dry powdered fruits, given on an empty stomach, induced a liquil stool containing the dead tapeworm, 2–3 hours after administration.

The wood is used as firewood and an extract of it is used to tan leather red. The plant is also used in some rituals (Cufodontis, 1960).

With his description of the species, Forskål (1775) mentioned use as an adulterant to chat (*Catha edulis* Forsk.) in Yemen. In Ethiopia, I never heard of *Maesa* being used in that way.

Chemical properties

In 1857, Wittstein & Apoiger found boron in the fruits of *Maesa*. This chemical had not been known to occur in plants.

According to Hegnauer (1969), the fruits contain c. 20 g/kg of quinones, a chemical group which is highly characteristic for the family. The seeds have no starch; besides protein there is a highly variable amount of fatty oil, and most *Myrsinaceae* are rich in amyloid. Kooiman (1959) found that *Maesa* species are generally poor in amyloid.

Three small samples drawn from SL 1411 (collected at the market of Bonga, Kefa) were analysed. The method used was the same as for sesame (p. 279). The results are summarized in Table 55. The oil content fluctuated around 260–270 g/kg (oven-dry basis).

Table 55. Ranges in three analyses of substance fractions of fatty acids in total fatty acids in fruit sample SL 1411 of *Maesa lanceolata* Forsk. from Bonga market

	Subst. fr. (mmol/mol)
Palmitic	95–118
Stearic	41–62
Oleic	117–158
Linoleic	627–735
Linolenic + eicosenic	1–4
Ricinoleic or hexacosanic	10–36[1]

1. The highest value included lignoceric acid 30 mmol/mol.

2.14 Ricinus communis L. ($2n = 20^1$) Figs 11 and 12

'*Ricinus*': the Latin name for a dog tick, which the seeds of many cultivars resemble in general appearance. Ricinus is the old Roman name of the species.
'*communis*': common, normal.

Linnaeus, Sp. Pl. ed. 1: p. 1007 (1753).
Type: Hort. cliff. 450 (BM, lecto., photo!).

Synonyms

Synonyms as cited by Cufodontis, including all varieties and forms (Cufodontis, G., Enum. Pl. Aeth. Spermatoph.: p. 430–431 (1974)). In Ethiopia, all intermediates are found (Note 1).

1. *Slide number* 9-24(81–406) prepared from PJ 3170 (WAG).

Literature

1866: Mueller-Argoviensis, DC. Prodr. XV(2): p. 1016–1021. (tax.)
1919: Pax in Engler's Pflanzenreich IV.147.IX–XI Heft 68: p. 119–127. (tax.)
1931: Pax & Hoffmann in Engler's Nat. Pflanzenfamilien 19C: p. 149–150. (tax.)
1953: Larroque, Oléagineux 8: p. 125–129, 189–195. (agric., tax.)
1971: Weiss, Castor, Sesame, Safflower: p. 3–308. (agric.)

Vernacular names: gulo, gol, goulkoua, gulcuá (Amarinya); gobo (Amarinya near Jimma); uliru (Anyowak near Gambela); kobo, kobbo (Gallinya); tese (Kaffinya); gulè (Saho); balambai, balan, blon, mbalica, bor, tofoile (Somalinya); cuellé, gallá, kellã, qellã (Tigre); boullhey, gulleh, gulliė, bulleh, vulleh (Tigrinya); chakmá (Zegié near Lake Tana).
Trade names: castor, ricinus (English)[1]; ricin (French); ricino, higuerilla (Spanish).

1. In older literature, the oil is also referred to as palma-christi oil or tangan-tangan oil. The name 'castor' was apparently coined by English traders, who confused it with the oil of *Vitex agnus-castus* L., which the Spanish and Portuguese of Jamaica called agno-casto.

Geographic distribution (based mainly on Weiss, 1971)

Ricinus can now be found in all the warmer regions of the world. Although its origin is obscured by its wide dissemination in ancient times and its quick adaptation to many habitats, it is generally believed to have originated in the Ethiopian area. Domestication may have taken place where Africa and Asia meet (Arabia felix). This area must have had a comparatively lush vegetation in prehistory and until Roman times it remained a region with high agricultural production.

The plant can be found practically all over the continent of Africa except for regions which are too dry, too high or too wet. In Ethiopia, considered to be the original home of the species, it is widespread and frequent, only less so above altitude c. 2400 m, in the forested regions, and in semi-deserts and deserts.

The main producers of castor in Africa are Tanzania, Kenya, Ethiopia, the Sudan and South Africa. In Kenya, Uganda and Tanzania, the plant is a common crop in local agriculture, usually in mixed crops. In Ethiopia, it is hardly cultivated: the seed is mainly collected from volunteer and wild plants, but often some plants can be found close to dwellings. There are large areas, particularly in the C and N regions, which are well suited for castor production. I encountered it mainly on the E and W escarpments of the Highlands, in Gojam and in the Chercher Highlands. In the latter, there is even a village named after it: K'obo.

In India, the cultivation of castor and the use of the oil is so well established that its introduction has been forgotten. Already in writings dating from 2000 B.C., it was mentioned as indigenous, and forms with red and white seeds were described. It was used for lighting, as a purge, and as an insect repellent.

Probably from India and Kashmir, it was spread to other parts of Asia where it was grown mainly for lighting and medicine. In China, castor was not mentioned in the literature before about A.D. 600, and then as a cultivated plant, though Shen Nung (2723–2705 B.C.) is said to be the discoverer of the properties of the plant and its use.

Castor oil was frequently used medicinally in ancient Mesopotamia and the seeds were an important commodity in ancient Egypt, where seeds have been found in tombs dating from c. 4000 B.C. Here too, the oil was used in medicine and for lighting, and possibly as libation in certain religious ceremonies. It now has little economic importance in Egypt, but it can be found growing everywhere in that country if there is sufficient water.

The ancient Hebrews also knew the plant and its oil. Israel is now one of the leading producers of commercial 'hybrid' seed.

During the Roman Empire, castor was established in a naturalized state in E Europe, where the climate was more suitable than further west. Many modern commercial cultivars have their origin in Hungary or Rumania, which countries were once important producers of castor seed and oil.

Castor is a fairly recent introduction into the New World; it was probably introduced by slaves from Africa. It is now found growing in naturalized state all over the Americas wherever suitable conditions occur.

At present, the main producers are Brazil, the Soviet Union, India and China, but for export S America as a whole is the main supplier of the world trade. The United States, with a considerable production of its own, is the world's largest importer of castor oil. Other importers are the industrial nations of Europe, and Japan.

Description

Habit very variable but mostly erect, from almost herbaceous annuals to small trees and widely branching shrubs. In Ethiopia, the habit is usually that of a small tree or a shrub, reaching a height of c. $4\frac{1}{2}$ m, branching usually from 1 m upward.

Root system well developed, white to yellowish; taproot with thick, rather horizontal laterals.

Stem erect, usually up to 10 cm diam., cylindrical, with conspicuous nodes, partially hollow, smooth, glabrous, occasionally with some nectaries or conspicuous lenticels or echinate, extremely variable in colour: many shades of green and red or mixtures of both, or glaucous, epruinose or pruinose in varying degrees. Old stems may become woody at the base with a brownish to greyish bark. Branching usually starts when the first inflorescence appears: during its developement, lateral shoots appear, which behave likewise. The branches show the same characters as the stem, but they are mostly thinner and have shorter internodes.

Leaves spirally arranged, on the branches sometimes almost distichous, herbaceous, stipulate, peltate, palmately lobed and nerved, with a long and stout petiole. Stipules coloured like the petiole, concave, subtriangular, acute to acuminate, up to $4\frac{1}{2}$ cm × 3 cm, clasping the stem opposite the petiole, which remains free of the stipule, membranaceous, glabrous, smooth, soon deciduous, leaving a distinct scar. Petiole similar in colour to the branches, up to 50 cm long, glabrous, rarely echinate, terete, hollow, flattened to furrowed adaxially near the broad base, which is often provided with 1–3(4), usually flat and disk-shaped, sometimes shortly stalked nectaries on both sides, top of petiole above with a pair of stalked, flattened to almost ribbonlike nectaries (sometimes 1), between top and petiole base a varying number of glands is present (petioles of leaves subtending an inflorescence mostly show more nectaries than other ones in the same plant). The glands are pale yellowish-green, sometimes (partially) reddish on petioles which are not completely green. Blade above mostly rather glossy and dark green to brownish green, beneath lighter green, often red or reddish to brownish green in young leaves, both sides with red or greenish veins; up to 60 cm diam.; (7)8–11(12) lobes (number mostly varying in one plant). Lobes acuminate (to acute), mostly unequal-sided, the apical ones larger than the basal ones, often constricted towards the base, except the basal ones, with a strong midrib and pinnate laterals. Margin coarsely and usually irregularly serrate, sometimes almost crenate to dentate, with blunt glandular teeth, the glands prominent in young leaves. Surface glabrous, sometimes sparsely scabrid above in young unfolding leaves, quickly glabrescent, either side occasionally with a gland near the margin, older leaves sometimes with

Fig. 11. *Ricinus communis* L. 1. Apex of branch ($\times\frac{2}{3}$). 2. Inflorescence with young lateral shoot ($\times\frac{2}{3}$). 3. Male flower ($\times$ 3). 4. Branch of the androecium ($\times$ 4). 5. Anther ($\times$ 20). 6. Female flower, sepals partially removed ($\times$ 3). 7. Ovary, lengthwise section ($\times$ 2). 8. Detail of the base of the ovule showing the obturator ($\times$ 8). 1–2, SL 1948; 3–6, SL 1949; 7–8, SL 1947A.

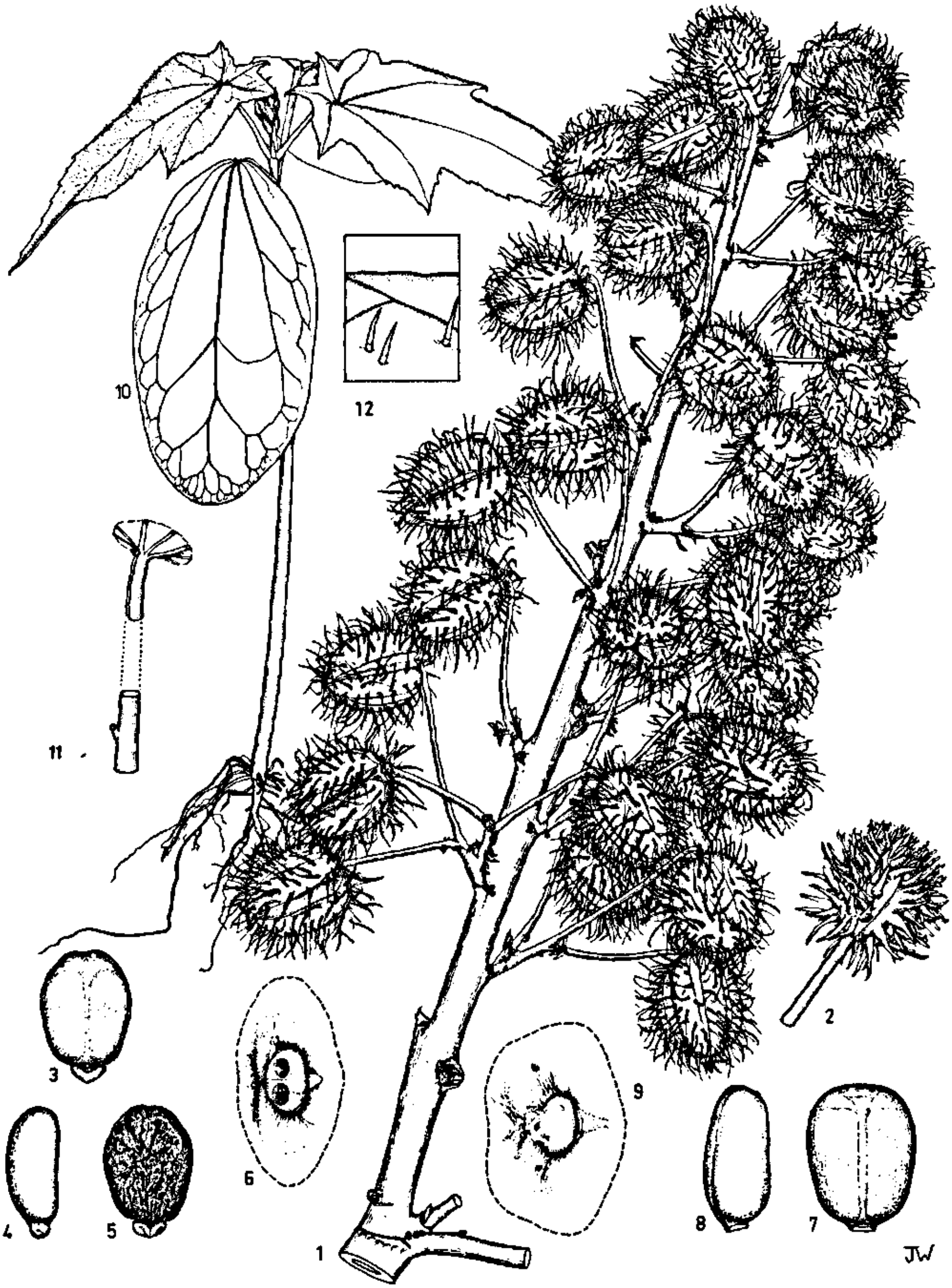
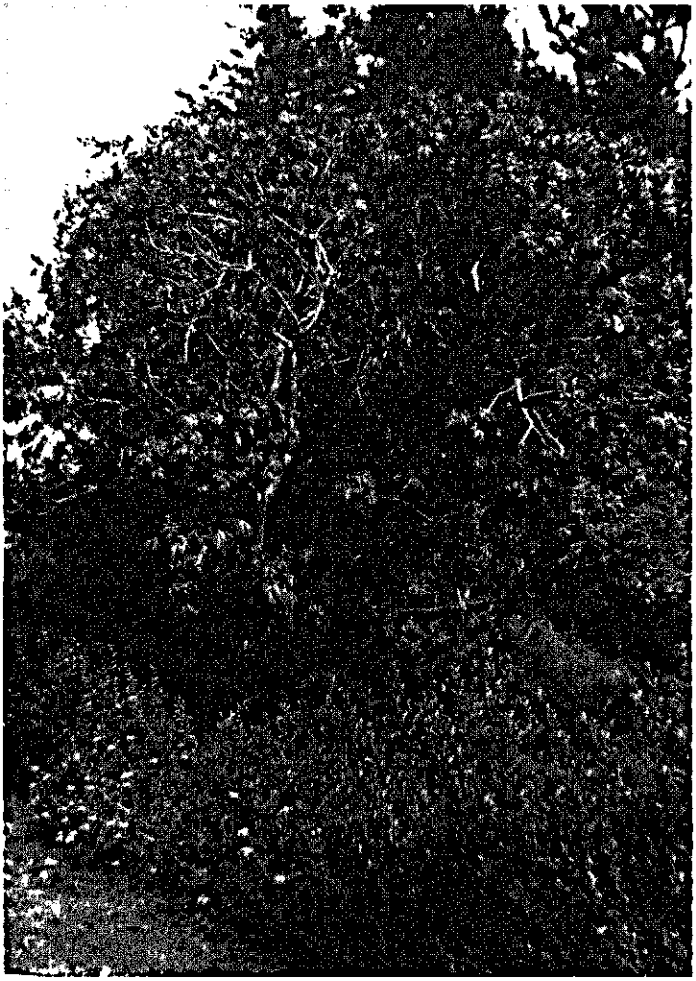


Fig. 12. *Ricinus communis* L. 1. Infructescence ($\times \frac{2}{3}$). 2. Young fruit ($\times \frac{2}{3}$). 3–5. Seed with large caruncle ($\times 1$). 6. Large caruncle in detail ($\times 2$). 7–8. Seed with small caruncle ($\times 2$). 9. Small caruncle in detail ($\times 2$). 10. Seedling ($\times \frac{2}{3}$). 11. Detail of leaf surface of seedling with hairs ($\times 14$). 12. Detail of glands on the petiole of the first leaves of the seedling ($\times 2$). 1, PJ 4372; 2, PJ 4224; 3–6, SL 634; 7–9, SL 948D; 10–12, SL 3950.



Photograph 22. Tree-like *Ricinus communis* in Ethiopia.

very fine punctation or very finely verrucose.

Inflorescences usually numerous, 0–½(5) cm long stalked, up to 40 cm long when fully developed, terminal, becoming somewhat lateral by development of a new shoot below it, thyrsoid, subcylindric in outline, the lateral cymes unisexual, spirally to almost decussately arranged, the lower ones male, the upper ones female, with some bisexual cymes between; larger cymes dichasial up to the second or third branching, continuing cincinnate or, less commonly, helicoid and then cincinnate. Male flowers open first, mostly more numerous then the female ones. Bracts and bracteoles quickly drying, broadly to depressedly ovate, up to 15 mm × 7 mm, with acuminate to cuspidate top, the basal bract accompanied by lateral nectaries, the other bracts and bracteoles less commonly so; in sessile inflorescences, the lowest cyme lacking its basal bract; all bracts light (whitish-)green, on red-stemmed plants sometimes (partly) red.

Flowers without a corolla.

Male flower-bud broadly ellipsoid to ovoid to very broadly so, up to 9 mm diam. and 11 mm high, with acuminate to apiculate top and obtuse to truncate base, coloured almost as the stem, with ± clearly distinguishable sepals. Male flower with glabrous, greyish to yellowish green pedicels up to 1½ cm long, articulate about a fifth from the base, deciduous after flowering; sepals 5, valvate, united at base, elliptic, concave, reflexed, up to 6 mm × 14 mm, acute to acuminate at top, purplish inside, with greenish base; stamens many, variously united in several dichotomously branched bundles, the biggest in the middle, the base of the smaller, external ones sometimes adnate to the sepals, the fully expanded androecium c. 1½ cm diam.; anthers split into 2 well separated, widely transversely ellipsoid, shortly stalked, pale yellow, basifixed thecae c. ½ mm diam. and ¼–½ mm thick, with a sterile lobe inbetween.

Female flower-bud ovoid, up to 8 mm long and 3 mm diam., with an acute to apiculate blunt top, coloured as the stem. Female flowers with a pedicel up to 2 mm long, articulate just below the calyx; sepals 5, free, narrowly subulate, c. 7 mm × 2 mm, glabrous, reddish to purplish green, persistent; ovary superior, trilocular, broadly ellipsoid in outline, rounded triangular on transverse section, up to 4 mm × 5 mm, glabrous, green, with 6 sometimes reddish ribs, covered with fleshy green spiky outgrowths usually terminating in a transparent pointed bristle; styles 3, red or green, persistent, up to 1½ mm long, connate, each with a bifid to bipartite, fleshy stigma up to 9 mm long, clearly papillose above; each locule with 1 epitropous pendulous ovule, with a small pinkish or reddish obturator.

Infructescence usually cylindrical to conical, long-stalked, rather open, up to 50 cm long, with groups of (1)3–4(12) fruits, 1–4 cm apart.

Fruit a tricoccous regma, (12)18–27(30) mm long and (12)17–24(27) mm wide on stalks (1)2–5(7) cm long, longitudinally trisulcate, glabrous, greyish, straw-coloured, or pinkish so, with 6 longitudinal ribs, covered with roundish to laterally flattened, usually tough spines c. 5–9(13) mm long, bearing a stiff bristle on top (often broken off), bent towards the apex.

Seed broadly ellipsoid to broadly obovoid, sometimes broadly ovoid, usually strongly flattened (ventrally stronger so, often even concave), c. (7.5)12–18(21) mm long (without caruncle), c. (4.9)8–15(16.8) mm broad and c. (3.4)5–10(13.0) mm thick, obtuse at both ends, dorsal base usually slightly extended over the caruncle, ventrally with a distinct raphe and chalaza; caruncle 2-lobed, c. 2–6½ mm long, c. 2–5 mm broad, from almost flat to c. 2½ mm thick. Testa glabrous, smooth, thin and brittle, and of varying colour: sometimes without, but usually with a very attractive mottling, varying from a sparse punctation to a pattern that exceeds the basic colour in cover. The basic colour could be classified as yellow to orange-white, greyed-orange, greyed-red, greyed-purple and brown (Note 3), on one seed often different basic colours are found. The colour of the mottling varies from clearly contrasting white, grey or pale brown to hardly contrasting in the same colour as the basic one. The colour is situated in a very thin outer layer of the testa, the inner layer being dark brownish–grey to black. Endosperm white, oily, split into planoconvex halves, covered by a white, felt-like tegmen. Embryo central in the endosperm, with 2 very thin cotyledons.

Seedling epigeal, forming a strong root system with many laterals, especially in the upper two centimetres. Hypocotyl cylindrical, often curved at the base, up to 15 cm long and c. 3–5 mm thick, sometimes waxy near the cotyledons, red(dish) or green, often differently coloured at base: red(dish) hypocotyls with a white base, waxy hypocotyls with a red one. Cotyledons: petiole up to 6 cm long, subterete, furrowed to flat above, base partially clasping the stem, usually bearing 2 nectaries above near the blade, and sometimes 1 in the middle; blades glabrous, light green, with yellow or red veins, broadly ovate, broadly obovate, broadly elliptic, or broadly oblong to almost square with rounded corners, up to 10 cm × 7½ cm, margin entire, usually obtuse, rarely shallowly retuse at top, truncate to shallowly sagittate or shallowly cordate at base, with 3(–5) strong palmate veins, the midrib with pinnate laterals, the other ones with strong laterals only towards the margin. Epicotyl c. 1–3 cm long, more or less showing the characters of the full-grown stem, its first leaves opposite, peltate, palmate with 5 to 7 nerved lobes, usually unequal in size; petioles up to 9 cm long; stipules deciduous, interpetiolar, narrow, acute c. 5–7 mm × 1½–2 mm; blade (3½)6–8(10) cm × (2)4–7(8½) cm, mostly sparsely scabrous, partly more densely so, especially on the lower lobes, or glabrous, usually darker green than the cotyledons, with reddish to red veins.

Notes

(1) *Ricinus* L. is a genus of the *Euphorbiaceae*; only one species is recognized, *Ricinus communis* L.

Linnaeus described *Ricinus* as monotypic but recognized 2 varieties. Because of the immense variability, there was, and still is, considerable difference op opinion about the number of taxa, and their status within the genus.

Since Linnaeus, more than 50 species (Index Kewensis lists 56) and many varieties have been described. In 1866, Müller Argoviensis (in DC. Prodr. XV(2): 1016–1021) treated the genus as monospecific again, although he recognized 17 varieties and several forms. Most authors since Müller have acknowledged the monospecific nature of the genus, but there are still authors who distinguish more than one species. The latter commonly apply agricultural rather than taxonomic criteria, do not adhere to nomenclatural rules too strictly and their taxonomic delimitations are generally uncertain. As a result, the epithets *'persicus'*, *'chinensis'*, *'zanzibarensis'*, *'africanus'*, *'sanguineus'*, *'microcarpus'*, *'macrocarpus'*, *'major'* and *'minor'* in combination with *Ricinus* are found, denoting a variety, a subspecies, or a species.

Dividing the only species into several taxa may lead to some practical classification of the population encountered in some areas. In Ethiopia, however, I found no morphologically distinguishable taxa showing any measure of constancy within the species, which renders it impossible to design a satisfactory classification although some phenotypes are more frequent than others. For this reason, I did not adopt the taxa distinguished for Ethiopia by Cufodontis.

The plants grown from Ethiopian seeds were studied during one growing season only, at Alemaya. A classification based on longevity, as proposed by Larroque (1953), could not therefore be checked.

Ethiopia is considered by many authors to be the area of origin of this monoecious, wind-pollinated species. It would not be surprising if a long-term study were to reveal the presence of a gradual transition from short-lived to perennial.

(2) As far as I know, no type has been designated. From the original material I have seen, I designate Sheet 450 from the Herbarium of Hortus cliffortianus (lectotype). It fits the description 'Ricinus foliis peltatis serratis: petiolis glanduliferis' very well.

(3) The basic colours of the seeds were compared with those of the Colour Chart of the Royal Horticultural Society of London. They usually almost matched N° 158 (yellow–white), 159 (orange–white), 165, 166, 175 (greyed-orange), 178 (greyed-red), 183, 187 (greyed-purple), or 200 (brown), mostly in intensities A and B.

(4) Weiss (1971, p. 65) indicated 3 types of dehiscence of the fruit. In my material, I only observed splitting typical to the regma, i.e. first from the base upwards into 3 cocci, usually soon followed by sometimes incomplete splitting of the dorsal suture, accompanied by a separation of the outer spinescent layer from the inner layers.

Schäfer (1964) remarks, however, that in castor in Ethiopia, two types are present: dehiscent and indehiscent.

(5) Weiss (1971, p. 56) observed that tetraploids in Tanzania produced a fairly dense pubescence on the upper surface of the leaf. He most probably stressed this character because his description of diploid *Ricinus*, like those by others, state that the leaf is glabrous. In the material I used, the first leaves of the seedlings were usually hispid, and the unfolding leaves of flowering plants were sometimes sparsely hispid too.

(6) According to Pajella (1938), the people of SW Ethiopia distinguish 4 cultivated and 1 spontaneous form. The spontaneous form has small dark-red seeds, a combination of characters not present in my collection. I have discovered no conserved material of Pajella's and doubt whether Pajella really studied the whole region metioned by him in the title of his article, as from the former Italian district of 'Galla e Sidamo' (comprising Kefa, Gemu Goffa, Sidamo, and Illubabor), I collected a considerable number of seed-types, not fitting his classification. So I cannot support or contradict Pajella's conclusions or statements.

(7) In some classifications (e.g. Müller Argoviensis 1866; Pax, 1919; Larroque, 1953) seed length (with or without caruncle) is used as a key character. Jaisani & Patel (1963) proved that seed width is a more constant character within seeds of one plant. Seed length in one plant seems to change much more in accordance with age of the plant producing successive inflorescences, than seed width, a nearly constant character throughout the plant's life-cycle. There are studies from Poland and the United States confirming this (Weiss 1971, p. 66).

(8) Weiss (1971, p. 57) concluded that there is a high variability in all vegetative characters used to delimit cultivars. Much cross-pollination takes place and the distinction of cultivars, based on vegetative characters, is somewhat arbitrary and nebulous.

(9) Larroque (1948) indicated that in general the best procedure for improvement of castor in a certain region is to select in the local population. This because the individual plants, or the regional populations to which they belong, have been selected for the area by nature, and usually fail to grow well under different conditions. An indication for this has been found in Ethiopia, where trials with American cultivars failed for unknown reason (Schäfer, 1964).

However such a high variability usually still exists in such regional populations, that excellent possibilities are available for local selection of more profitable types, even without a full-scale breeding programme (Weiss 1971, p. 75–78). This can be understood, when considering that the variability in a certain area, and especially so in a centre of diversity like Ethiopia, is qualitative in most, or even all characters. This does not necessarily mean that the maximum expression of a certain character could be found there. This is more likely so in areas where particular environmental stresses are great (Weiss 1971, p. 91).

(10) Description was based on the following specimens:

Bale	market at Goba: SL 1211; market at Goro: SL 1250; market at Robi: SL 1239; 7 km from Goro on road to Robi: SL 3114.
Eritrea	market at Adi Caieh: SL 877, SL 887A, SL 887B, SL 888, SL 889A, SL 889B.
Harergie	campus College at Alemaya: Bos 7523; cultivated at Alemaya: PJ 1141–PJ 1157, PJ 1159–PJ 1164, PJ 1915–PJ 1918, PJ 2792–PJ 2797, PJ 2865–PJ 2869, PJ 3142–PJ 3169, PJ 3170–PJ 3171, PJ 3445–PJ 3453, PJ 4213–PJ 4249, PJ 4419–PJ 4423, PJ 4761–PJ 4789, PJ 4843–PJ 4855, PJ 5120–PJ 5122, WP 239, WP 756, WP 3033; market at Alemaya: SL 25, SL 220A–SL 220D, SL 226, WP 25, WP 3036, WP 3178; between Alemaya and Harer: PJ 5141; market at Asbe Teferi: SL 2A–SL 2C, SL 481A–SL 481D, SL 482A–SL 482C, SL 483A–SL 483E, SL 484A–SL 484C, SL 485A–SL 485D, SL 486A–SL 486I, WP 1297A–WP 1297B, WP 1298; market 28 km E of Asbe Teferi: WP 3018A–WP 3018B, WP 3020; market at Assebot: SL 727A– SL 727B, SL 728A–SL 728E, SL 729A–SL 729C; field near Bati: WP 451; market at Bedeno: SL 332A–SL 332J; market at Bedessa: SL 682A–SL 682B, SL 683A–SL 683B, SL 684A–SL 684E, WP 3173–WP 3175; market at Chelenko: SL 253; Dakata Valley, College Farm: Bos 7909; market at Deder: SL 375A–SL 375F, SL 376, SL 377A–SL 377B, SL 378A–SL 378B, SL 382; market at Dire Dawa: Bos 8363, Bos 8389, WP 138; between Dire Dawa and Harer: W. de Wilde 9837; market at Ghelemso: SL 634, SL 635A–SL 635B, SL 636A–SL 636B, SL 637A–SL 637B; market at Harer: Bos 8058, WP 95; field 20 km E of Harer: PJ 4372, WP 998; market at Jijiga: SL 365; market at Karra: SL 595, SL 596A–SL 596B, SL 597A–SL 597C, SL 598A–SL 598G, SL 599A–SL 599C; market at Kuni: SL 548, SL 549A–SL 549D, SL 550A–SL 550E, SL 551–SL 553, SL 554A–SL 554G; field near Kurfachelle: Bos 9896; market at Langhe: SL 300; market at Mulu: SL 413–SL 414, SL 415A–SL 415E, SL 416, SL 417A–SL 417D; market at Waichu: SL 495, SL 496A–SL 496D, SL 497A–SL 497B, SL 498; market at Wotter: SL 202A–SL 202E.
Illubabor	near house in Gambela: PJ 4893.
Kefa	field near Bonga: PJ 2137, PJ 5590; market at Chena: SL 1429A–SL 4129B; field near Ghimbi (7°48′ N 36°47′ E): Meyer 8831, Meyer 8832; market at Jimma: WP 3293A–3293D; roadside 4 km W of Jimma: SL 2636.
Shewa	market at Adillo (50 km NE of Soddo): PJ 3670, PJ 3671; market at Kolito: WP 3240, WP 3241; market at Kuyera (near Shashemane): SL 1198A–SL 1198D, SL 1199A– SL 1199C; market at Shashemane: SL 1297A– SL 1297B; field 40 km N of Shashemane: PJ 3644.

Sidamo	market at Awasa: SL 1336A–SL 1336D; market at Neghele: SL 1380A–SL 1380D, SL 1385, SL 1386; market at Soddo: WP 2943, WP 2944.
Tigre	market at Adishow: SL 1020–SL 1022; market at Axum: SL 944, SL 946A–SL 846B, SL 948A–SL 948D, Sl 956, WP 4979A–WP 4979B, WP 4980.
Welega	market at Bekejama (near Nekempt): SL 1566A– SL 1566K, SL 1566M– SL 1566P.
Welo	market at Bati: SL 1050; market at Dessie: SL 1083A– SL 1083B, SL 1084; market at Gude Beret: SL 48; market at Haik: Sl 1112, SL 1113A–SL 1113C; market at Kembolcha: SL 977, SL 978, SL 979A–SL 979B.
Grown at Wageningen	SL 1947–SL 1949, SL 1965, SL 1974, WP 5690, WP 5933–WP 5936, WP 6098, WP 6099, WP 6138, WP 6139, WP 6769, WP 7020–WP 7022, WP 7050, WP 7135, WP 7452–WP 7456.

The numbers cited from Ethiopia, indicated with 'market at', are all seed samples; those indicated with 'grown at Wageningen', almost all seedlings. The description of the vegetative parts, flowers and fruits is mainly based on plants grown at the College of Agriculture at Alemaya. It proved almost impossible to obtain flowering plants at Wageningen from seeds of Ethiopian origin, either in a greenhouse, or outdoors, or by growing them at different daylengths or under rich or poor conditions, or by spraying them with morphactin. The latter compound was chosen because it had induced flowering in *Ricinus* before (Bohra & Shankla, 1973).

So a selection of 54 samples of my Ethiopian seed collection and 2 samples collected by Bos in Ethiopia, were sown at Alemaya. Of most samples, seedlings, flowers, (young) fruits and seeds were collected. Only 3 samples failed to germinate, and not all stages of 3 others could be collected. Plants that passed the seedling stage started flowering as follows: 4 samples after c. 100 days, 11 after c. 150 days, 20 after c. 165 days, 8 after c. 180 days, and 10 after c. 200 days. The first flowered at a height of c. $1\frac{1}{2}$ m, the last at c. $3\frac{1}{2}$ m.

Ecology (data mainly from Weiss, 1971)

Although castor shows great vigour under diverse growing conditions, the ecological requirements should all be met in order to obtain sufficient yield. Its requirements for cultivation should not be underestimated. Wrong conclusions are sometimes drawn about its suitability for profitable culture on the basis of lushness (Adam & Ferrand, 1958).

Castor is originally a warm-region perennial, with its cultivation area between 40° N and 40° S, but it is now cultivated up to 52° N in the Soviet Union. In general its ability to produce mature fruits is climatically limited by the incidence of frost, very high temperatures during flowering and excessive humidity. The more temperate regions with dry summers are in fact most suitable for maximum yields. There it has to compete with more favoured crops. Consequently it tends to be grown in areas less suitable for its production. Therefore the average yields of an area generally do not give a correct impression of yield potential (Weiss, 1971).

1. Temperature

The main temperature effects of importance to growers are those of low temperatures in the seed-bed and high temperatures at flowering. A seed-bed temperature of 15–18 °C seems most suitable. Low seed-bed temperatures extend the time from sowing to emergence and often render seeds liable to attack by fungi and insects; high temperatures shorten the time from sowing to emergence. In more temperate regions, solar radiation is not sufficient to warm the soil early in the growing season, whereas in drier areas the onset of the rains may depress the soil temperature so much that planting must be delayed until the soil warms up again. Time of sowing and temperature are therefore closely related.

The effect of high temperatures on growth of the plant has been little investigated, only in a wider context of time of planting, but optimum temperatures are in the range of 20–26 °C.

There is evidence of a relation between the pruinosity and the temperature requirements of the plant. In warm areas with much light, epruinose cultivars were observed to be generally less productive than pruinose ones, whereas in cooler areas this was not so. It is thus possible that the presence or absence of bloom is economically significant in warmer climates.

A frost-free growing period of 140–190 days, depending on the cultivar, is necessary. A few cultivars tolerate low temperatures to some degree and it is known that this character can be improved by breeding. In E Africa, plants were found growing between 2750 and 3000 m; they had very small hard black seeds with little oil. Frosts kill young plants, severely check older ones and defoliate mature plants. A temperature of −2 °C for 4 h is generally considered sufficient to kill castor plants.

During flowering, castor is susceptible to both high and low temperatures. Although such factors as plant nutrition, age of the plant and daylength can also influence the sex of the flowers, temperature is probably the main factor in this characteristic: moderate temperatures promote femaleness, high temperatures maleness. Pollen is shed readily between 26 and 29 °C with a relative humidity of 60%. A temperature of 15 °C delays shedding; lower temperatures still may affect the fertility of the pollen and thus reduce yields.

Sudden low temperatures may be induced by heavy rains. Weiss (1971) mentions a temperature drop in E Africa down to 1 °C after a daytime maximum of 35 °C. Temperatures over 41 °C, even for rather short periods, result in blasting of flowers and poor seed-set, and if the temperature remains over 38 °C for long during maximum flowering, especially if the soil moisture is low, a high proportion of light seed and 'pops' results.

Low temperatures and even frosts have little effect on the mature capsules and seeds, but affect the viability and the composition of the seed during development.

In plants grown at 10, 16, 21 and 26.5 °C with a daylength of 16 hours, protein content increased with temperature and content had a peak at 21 °C. The ratio of saturated to unsaturated fatty acids was the same at all temperatures.

In most agricultural areas of Ethiopia, the climate is such that temperatures low enough to kill castor persist for a few days per year at most, and then only for a few hours. Only the highest areas are not suitable in temperature for castor.

2. Water

Castor can survive under rather dry conditions because of its very strong root system, its resistance to water loss and its ability to withstand substantial water stress. In a trial where water uptake was reduced by root excision, the plant reduced its transpiration drastically with relatively small reduction in water uptake, but further reduction in transpiration when more roots were excised was slower. Excision of a quarter of the roots reduced the transpiration by more than half, while excision of half and three quarters of the roots reduced transpiration by nearly 75 and 95%, respectively. The drought-resistant qualities of the castor plant have led to its being used as a form of drought insurance: it is frequently interplanted to ensure that some crop will be available if the main crop fails.

In general, rainfall and time of planting are closely related to achieve maximum yields from many annual crops in the tropics. Castor, with its ability to withstand rainless periods, makes the relationship between rainfall and planting date less important than that between rainfall and insect-pest activity.

The development of the root system is strongly influenced by moisture conditions, so that plants under dry conditions have more root with respect to transpiring surface. Root growth under dry conditions is faster with local cultivars than with others. In spontaneously growing plants in areas without irrigation in Uganda, Weiss (1971) recorded taproots nearly 3 m long. The main difference in shape of the root system under dry and under wet or irrigated conditions is the depth below the soil surface at which it occurs and the horizon in which the greater part of it is contained. Under arid conditions, the systems proliferates at some depth and penetrates more deeply, but the total amount of this type of root in relation to the parts above the ground may be little greater than that of irrigated plants of much smaller stature. In the latter, however, the characteristic large and well formed taproot and laterals are often poorly developed or absent, as castor on a fertile moist soil invariably has a compact root system. Under irrigation, root formation is directly influenced by type of irrigation. Numerous small waterings can produce shallow-rooted plants. Substantial watering before planting, with appreciable intervals allow the plant a more normal root formation; overwatering depresses root formation, especially of major and lower roots, and may cause diseases. It can also raise the watertable, thus reducing the area available for rooting. Even too much water once, just before flowering, can appreciably lower the yields from a castor crop.

The ability of castor to produce substantial and deep roots quickly makes it a most suitable crop for subirrigation, either artificial or natural. An added advantage of quick root growth is that the subsoil in many of these dry areas is better supplied with nutrients than in more temperate or well watered areas. Good yields from crops grown on them may often be obtained at a lower level of added nutrients than would be required in neighbouring areas of higher rainfall.

Good yields are possible in areas with a minimum annual rainfall of 600–750 mm. Peasants can obtain economic returns from selected cultivars with as little as 250 mm, provided this rain falls mainly early in the growing season. About 400 mm of evenly distributed rain during the plant's first four months of life is desirable for optimum growth. An approximate guide for regions where the average rainfall usually exceeds 750 mm, is to allow for 400–500 mm of rain to fall on the crop in the period from sowing to main flowering, subtract this from the average, and plant accordingly.

As water is more readily available to plants on light soils than on heavy soils, minimum water requirements are usually higher on the latter. For castor, this may be illustrated by an example from India, where in the Jaipur region, castor produced a reasonable crop on sandy soils with a rainfall of 300–500 mm, whereas on clay soils 600–900 mm was required.

Perrennials are planted at any suitable time, depending on the availability of soil moisture, but for annuals the rainy season, its length, and therefore planting dates must be assessed locally. Where the total rainfall approaches the minimum required for castor, it is essential to plant after the first major rainfall, when soil moisture is adequate for germination and soil temperatures have not been depressed.

Sometimes hot sunshine and persistent dry winds after emergence prevent the testa from splitting open further. Unless sufficient rain falls in time, the seedling may die.

The plant is extremely sensitive to excess soil water at all stages of growth. Good drainage is therefore essential for maximum yields, High temperatures may increase damage caused by waterlogging.

Although there should be no moisture shortage at flowering, humid or damp air at this stage are undesirable. Prolonged high humidity causes deterioration of pollen and even its germination inside the anther. It may cause poor yields in certain areas. Prolonged heavy rains and cloudy weather often result in poor seed-set. A considerable drop in temperature under such conditions may be an additional unfavourable factor.

Only the lowlands in N and E Ethiopia lack sufficient precipitation for unirrigated castor. The SW highlands have a surplus of water, but castor can still be found there. In view of the absence of a pronounced dry season, it is doubtful whether castor will ever become a profitable crop in that area.

Taralleto (1935) made the following remarks on the situation in Eritrea, which could well apply to most of Ethiopia. 'The hot lowlands are less suitable for castor production because rain is lacking, though they have good temperatures. The escarpments are suitable, as is a part of the altiplane. But there the rain distribution is unfavourable: the time between onset of the rains and the cold season is too short for full development of the plant. Thus a perennial type is necessary and the treelike forms are most suitable because of their drought resistance'.

Castor wil grow in almost any type of soil, but it will yield best on a well drained sandy loam. Very heavy clays and marshy conditions are inimical to growth, as the plant is generally sensitive to excess water. In fact, type and structure of the soil appear to be of secondary importance when the other major factors like climate, control of pests and diseases, and supply of plant nutrients are adequate. Since castor is often chosen for cultivation in areas that are marginal for other crops, this adaptability is of considerable value. Crops grown in pure stands, instead of being intercropped or preserved where found growing, make heavier demands on soil nutrients or soil moisture. Castor is tolerant of low rainfall, not of low fertility, but extremely fertile soils favour vegetative growth at the expense of seed production.

Castor prefers slightly acid soils with pH 5–6½, but will grow in soils with pH as high as 8. With high pH, however, the type and structure of the soil are more important. Growth tends to be more restricted in alkaline clays than in other soil types, but exact data on the plant's reaction to high pH are lacking. The use of lime in the tropics in areas where castor is grown has given conflicting results.

Saline soils are unsuitable for growing castor for oil production. Castor is more sensitive to salt than cotton or maize, but there is considerable difference in sensitivity between cultivars. More resistant types of castor tend to be treelike; the dwarf cultivars are extremely sensitive. The salt tolerance of some castor 'hybrid' cultivars from the United States is quoted in terms of electrical conductivity as 0.4–0.8 S/m, or in the medium tolerance range.

Cultivars tolerant to extreme acidity or alkalinity usually have little importance for oil production, but are appreciated as ornamentals or as shade trees in areas where other plants will not grow.

Visual symptoms of nitrogen deficiency in castor are a bad guide in determining the nitrogen status of the crop: assessment should be based on fertilizer trials. The root system of castor is such that it penetrates the subsoil, which in many dry areas is better supplied with nutrients than in more temperate or well watered regions. This makes the customary sampling methods unsuitable.

If deficiency exists, nitrogen fertilizer induces the plant to form more flowers, and a general improvement in seed yield may result. Good results are usually obtained by a small N dressing at sowing (15–20 kg/ha) and an application at the onset of flowering. Total nitrogen requirements vary from 30–120 kg/ha (de Geus, 1973).

Phosphate often has a beneficial effect on root growth an may improve yield in areas poor in phosphorus, especially after fallow. In Kenya, an initial P dressing in the first year after fallow of c. 29 kg/ha gave the best results, in later years c. 10 kg/ha. Other figures mentioned by Weiss (1971) as initial dressing for different parts of the world, are about the same.

Potash deficiency is not often a problem in castor. The only visible effect of shortage of potash is a general reduction in growth, as may be induced by deficiency of any major nutrient. Problems may arise if considerable amounts of nitrogen and phosphorus are applied, increasing potash uptake.

According to Weiss (1971), 1000 kg of seed removes the equivalent of 29.4 kg of N, 5.1 kg of P and 7.8 kg of K, ignoring what is in the plant itself. Another estimate is that a yield of 1000 kg of seed and 666.5 kg of hulls removes 40 kg of N, 3.9 kg of P, 13.2 kg of K, 4.3 kg of Ca and 3.0 kg of Mg.

Little is known on the role of minor and trace elements and their effects on castor plants.

4. *Light*

Castor is basically a long-day plant, but it can be grown, with some loss of yield, in a fairly wide range of daylengths. Though many of the responses of the plants to photoperiod are vegetative, the effects, more or less independent of quality and intensity, are closely related to production.

A trial with artificial photophases showed that 12 hours or longer did not alter the development of the plant, but that shorter photophases retarded growth seriously (Weiss 1971, p. 115). This was confirmed by Henneman & van Ballegooijen (1973) in Wageningen. In a preliminary survey, they found that plants grown from Ethiopian seed samples (Sl 48, SL 202, SL 378, SL 485, SL 637, SL 729, SL 889, SL 1113) with a 9-hour day (natural light in a greenhouse) stayed visibly smaller than plants grown from the same samples under the same conditions with an additional 3 hours of low-intensity mixed fluorescent and incandescent light.

The growth and expansion of the large leaves of castor does not appear to be checked by prolonged sunlight. Data on leaf growth in California indicate that temperature and water stress are more important than sunlight in control of growth. However daylength can influence the ratio of male to female flowers: long day promoted the share of female flowers.

In the absence of wind and rain but with strong sunshine, emerging seedlings may be scorched. If a slight shower falls on a bright day with high temperatures, young leaves may suffer badly from scald.

5. *Other factors*

Hail damage is difficult to assess, since the leaves are usually holed or shredded rather than shed. Young shoots and developing racemes may be badly injured. Although hail can severely damage foliage, the effect on final yield, especially in the giant cultivars, is in general small. The dwarf cultivars are rather tolerant to defoliation up to flowering of the first racemes, but afterwards yield may be depressed. Seedlings are however extremely susceptible and losses by shattering of mature capsules during storms late in the season can be serious.

In Ethiopia, hail damage can be serious, as is illustrated by a report from the Bako region: the yields were generally reduced by the hail storm. The damage was so heavy, that the crop was not harvested (Bako Progress Report 1970-1971, p. 42).

Castor is susceptible to blast by strong wind, especially the giant cultivars. Such winds may damage foliage and cause the plants to lodge, while serious seed losses may be caused by shattering.

Castor is rather tolerant of salt spray, provided the soil water is fresh.

Development of the plant (data mainly from Weiss, 1971)

The germination of castor is epigeal, the cotyledons absorbing the endosperm. In hot climates, the time between sowing en emergence is usually 10–15 days; under cooler conditions, this period may extend to nearly three weeks.

The strong root system starts to develop immediately. In the adult stage, it is characterized by a large well developed taproot and by strong thick horizontal laterals. This habit is particularly obvious in the perennial tree-like plants. It provides the plant with anchorage in strong winds, which frequently occur in arid regions. A well developed secondary root system, much branched and deeply penetrating the soil to take maximum advantage of soil water is also usual in arid regions. Studies of the root-hair zone of castor have shown a characteristic structure of the root.

Usually the plant first forms an erect stem, which is terminated by an inflorescence. This inflorescence is mostly the largest on the plant and is also referred to as 'candle' or 'spike'. Just before and during flowering of this inflorescence, some side-branches start to develop under it, and those are terminated again by an inflorescence. The sequence of subsidiary branches and inflorescences continues through the plant's life. This growth results in infructescences in different stages of development on one plant, which is a disadvantage for mechanical harvesting.

Wild plants usually produce many branches from the original stem but seldom secondary stems. Dwarf plants, when grown on a field scale, normally produce 2-3 branches only, which originate at the nodes immediately below the first inflorescence. Each of those branches is itself terminated by an inflorescence, usually after 4-6 nodes. This growth habit makes mechanical harvestig possible.

Weiss (1971) states that the perennial tree-like types have been little studied, but that their initial growth is similar to that of the smaller forms. In a greenhouse at Wageningen, 12 market samples of Ethiopian castor of diverse geographic origin were sown (Sl 25, SL 365, SL 877, SL 944, SL 1020, SL 1050, SL 1084, SL 1250, SL 1336A, SL 1385, SL 1429A, SL 1566), nine of which developed into small trees that did not flower, even after almost a year. They branched freely, however, and both primary and secondary branches were formed. The three samples that flowered formed smaller trees with thinner stems. They all formed their first inflorescences on the main stem. This suggests that the only difference in growth habit between the early types and the tree-like types is the lapse of time between branching and flowering, the lapse being much longer in the small trees.

Generally, giant castor forms its first inflorescence at about the 12th node of the main stem. In 'wild' plants from some parts of the world, the first flowering may occur up to the 17th node. The node of first flowering is an important agronomic characteristic, since it is associated with quick maturity. In dwarf-internode hybrids, flowering usually occurs after 6-12 nodes, but in segregating populations, the number of nodes may vary from 6 to as many as 45. The number of nodes between the inflorescences is also important, as it affects the time between ripeness of the first and last fruits.

The plants usually produce their first flowers after 40–70 days, depending on cultivar and climate. The plants sown at Alemaya needed considerably more time to reach flowering (Note 10). They stopped growing during the cold months of the dry season, losing their foliage; regrowth took place with the onset of the rains.

The characteristics of the nodes are highly variable. Some giant forms have relatively large stems that thicken considerably with age. These stems are usually solid at their base but hollow in the higher parts. Individual plants vary greatly in extent of hollowing and the age at which it occurs. Practically all castor plants I encountered of Ethiopian provenance had hollow stems from c. $\frac{1}{2}$ m upwards.

The true colour of the stem is often obscured by a bluish white bloom. This bloom can also occur on the other vegetative and on reproductive parts of the plant. There are indications that the amount of bloom and the thickness of the stem are correlated with some agronomic characteristics of the cultivar. In a trial in Australia, plants with thin stems tended to be earlier than thick-stemmed similar types, and the few plants of Ethiopian origin that formed flowers at Wageningen were also relatively thin-stemmed. The effect of presence or absence of bloom (pruinosity) was mentioned on page 215. There is also evidence that plants with bloomy inflorescences are less infested by some pests.

The leaves are often large, usually glossy green and with prominent veins beneath. Their area can be estimated ($r = 0.997$) by the following equation: Area = 0.55 × maximum length × maximum width.

In different cultivars, the proportion of female flowers may vary from over 99% to less than 5%. Hermaphrodite flowers may be present too, though I never saw them in Ethiopian material. The proportion of female flowers in different inflorescences on one plant may be unequal. If so, the younger inflorescences have a higher proportion of male flowers than the older ones; the reverse has not been reported. This was also clearly visible in some of the Ethiopian material I saw.

Pollen is normally shed from 2–3 hours after sunrise until late in the afternoon, but there is often a peak in the mid-morning. Shedding is influenced by temperature (p. 215) and humidity (p. 217).

Castor is normally a cross-breeding plant with wind pollination. Natural outcrossing can be as high as 90% in dwarf-internode plants in the Texas High Plains, where winds range from 8 to 48 km/h in the pollination season. I have no data on wind speed in Ethiopia, but know that it is usually windy on the escarpments. That even then the majority of the seed harvested at Alemaya is similar to their parent seeds indicates that the major proportion of seeds traded on Ethiopian markets is from non-segregating plants. This would suggest that cross-fertilization in Ethiopian castor is less frequent than self-fertilization. It could be expected: (a) if the tree-like types have less cross-breeding, which could be explained by the relative abundance of pollen of the plant itself in its own canopy, caused by its numerous inflorescences; (b) as the traded castor in Ethiopia is usually collected from plants near dwellings and in fields, areas which are cleaned, no unwanted plants are available for pollination; (c) if cross-barriers are present; (d) if all seed characteristics of the mother plant are dominant over those of the father plant. The presence of samples of seeds, completely different from their parent seed, eliminates, in my opinion, Cause c. Cause d seems unlikely in view of the diversity of forms, sizes and colours of the parent seeds.

In India, a distance of 30 m is considered a safe spatial isolation, but Weiss (1971) indicates 450 m as minimum. Apparently there are large regional differences in the proportions of cross-breeding and selfing.

The time to (first) harvest usually ranges from 140 to 160 days, but the variation is very large (compare with data on flowering in Note 10). The number of capsules in an infructescence varies from as little as 2 or 3 to as much as 80. The whole infructescence may reach a length of nearly 90 cm, but since there is wide variation in the distance between the fruits, length is not necessarily correlated with fruit yield.

The ripening of the fruits on one peduncle is not even: the lower fruits mature first, the upper last. In many wild plants, the period between the first and the last mature fruit on one peduncle may be several weeks. When the fruits ripen, they become brittle. In wild plants and in a number of cultivars, but not generally in dwarf-internode cultivars, the fruit splits at maturity and the seeds are shed individually. The mode of dehiscence varies; shattering appears to be dominant over non-shattering. Schäfer (1964) remarked that castor grew wild in many parts of Ethiopia, but those plants were usually unfit for cultivation because they had a long ripening range and were dehiscent, or they were indehiscent but then had strong fruit-walls, that made the seeds difficult to separate.

There is, thus, considerable variation in the thickness and the properties of the capsule hull. Those characteristics are important at hulling and are usually taken into consideration in a selection programme. For mechanical harvesting, early and even ripening with an indehiscent fruit in dwarf cultivars is the ideal combination.

Husbandry (mainly based on Weiss, 1971)

As a peasant crop in the warmer regions of the world, castor can be grown almost anywhere if land is available, and this is perhaps its greatest virtue. A saleable crop can be produced with the most primitive husbandry. It grows best in areas with clear sunny days and without untimely frosts. In such circumstances, it will be found growing from sea-level at the coast to high inland mountains, the limits of its range often depending on the amount of official support the crop receives.

A large proportion of the castor seed that finds its way into the international markets from many of the less developed regions of the world, like Ethiopia, derives from wild or semi-wild plants, the systematic cultivation of pure stands of castor by peasant farmers being the exception. More often castor is interplanted with other crops, sown round the borders and margins of fields, planted on areas unsuitable for other crops, or merely protected when found growing. These last may be merely scattered clumps of plants in a particular area, or odd plants growing on the sites of temporary or semi-permanent camps used by pastoralists in the course of normal seasonal stock movements. In such instances, normal agricultural procedures cannot be said to apply and the collection of seed from such sources can be related more to the primitive hunter and forager, than to the true farmer.

Resettlement of surplus populations or the need to encourage nomadic tribes to establish more permanent quarters has resulted in some fairly large schemes, often under direct official control with varying degrees of centrally operated machinery pools. In these circumstances, expert advice is available and the standard of production depends mainly on the personality and authority of the individual supervisors.

Giant and indigenous forms of castor were sown initially with varying success, but often with small profit to the grower. The introduction of high-yielding types has made the crop much more attractive financially, and this has stimulated interest in the crop. With the low costs to the producer, castor is much more profitable now than it used to be. Often costs are further reduced by hidden government subsidies in the form of free, essential services as transport, local advice and marketing organizations. In these circumstances, it can compete with traditional cash crops and consequently attracts more attention and interest.

Most data on yield from unirrigated peasant crops indicate that seed yield of castor is c. 200–600 kg/ha under such conditions. Yields of commercial plantings under dry conditions usually average 400–900 kg/ha. The introduction of irrigation and assistance of agricultural specialists, often increases yields markedly. In one region of the Sudan, for instance, peasant crops average c. 250 kg/ha, whereas irrigated crops average c. 1000 kg/ha. In Tanzania, seed yield of irrigated crops of giant castor was 1636 kg/ha, and of 'hybrids' 2399 kg/ha. In irrigated plantings in Israel, a total of 500–600 mm of water are stated to be optimum with a growing period of 150–160 days and yields of 2800–4000 kg/ha.

As the plant is capable of growing on many soils, the rate and type of added plant nutrients and methods of application vary as much as the conditions under which the plant is grown. There must always be a correlation between the standard of husbandry, however, and the amount of fertilizers. In Ghana and Kenya, growth and yield were improved much more by increasing the frequency of weeding and planting at the optimum time, than by fertilizers. These results suggest that improvement of peasant farming can be obtained initially by persuading farmers to care more for crops cultivated by traditional methods.

If fertilizer is considered for a field on which castor was not previously grown, the requirements for high yields of maize will generally be suitable for high-yielding dwarf 'hybrids' of castor. To promote early growth, castor presscake is often a valuable source of nitrogen for seed-beds.

The seed-bed required for castor is similar to that prepared for maize or cotton, but for even germination, castor requires a moist soil over a longer period than the other crops. The seed-bed should be moist to a depth of 15–20 cm, and the seed planted at least 5 cm deep. On light or sandy soils, and where strong drying winds are normal during planting and emergence, press wheels should be used to pack down soil in the planted rows. Quite often, land preparation is no more than a shallow ploughing, regularly combined with sowing.

To ensure rapid germination, castor should be planted into a seed-bed with a temperature of at least 17 °C, if germination is to be uniform. Germination is not materially improved by higher temperatures, but seedling development is accelerated. Some cultivars appear to need fluctuating temperatures for initiation of germination.

Where castor planting as a main crop is not officially encouraged, it is generally planted as an intercrop with more popular crops. Thus it receives no special attention, and the amount of crop care is related to that of the major crop. This often results in neglect of the castor plants, once the basic work on the major crop has been completed. As castor is often interplanted after the first weeding of the major crop, the seedlings suffer from competition, both from the crop and from weeds. This competition diminishes yields. Where it is grown around field margins, higher yields may be obtained and the crop receives more attention.

In arid regions where rainfall is barely adequate to sustain a castor crop, or where much of the rainfall comes as intense storms, methods of conserving rainfall are of major importance. Cropping in alternate years may be possible, as practised in N America and Australia, the fallow year being used to store moisture for the next crop. To make the system effective, the land should be bare, or protected from wind and water erosion, if those are dangers. Tef (*Eragrostis tef* (Zucc.) Trotter) can be planted for this purpose as it is sown densely and consumes little water.

Seed rates for monoculture should be determined locally and carefully. Too close a spacing may result in damage during cultivation and in spindly plants liable to wind damage. Too wide a spacing encourages weeds against which castor is a bad competitor, and in much-branched plants with an extended flowering period.

In mechanical sowing, the usual row-width is 1 m. The plant density is then determined by the spacing between plants. Where there is both mechanized and manual production of castor, the total plant density may be similar, but the spacing different. In mechanical sowing, row width suits the equipment, while in hand-sown plots planting in the square often gives best results.

A reduction in the potential weed population can often be achieved by choosing the right moment for planting. This moment may affect the growth habit of the crop. In the United States and Trinidad, the number of nodes to first flowering was affected for some cultivars. But Weiss (1971) found no general difference in the node of first inflorescence in time-of-sowing trials in E Africa. There, a significant difference in node-length was noted: later sowing resulted in shorter plants.

Mechanical planting can best be done with special equipment; in drills designed for grains, often modifications are necessary to prevent damage of the seed. Whatever drill is chosen, even depth of planting is of paramount importance to ensure good germination and regular stands.

Baldrati (1950, p. 366) indicates for Eritrea that there should be no more than 5000–6000 plants per hectare if low plants are cultivated, and that 2 m × 3m (c. 1500 ha^{-1}) is optimum for tree-like types.

The young castor seedling is very susceptible to damage and to attacks by insects at emergence. In recommending seed rates, this should be kept in mind: more seed should be used than is necessary to produce the optimum stand. The seedlings may be thinned to the required stand later, but this is not generally considered necessary since a slightly high plant population is preferable to one that is too low and the cost of the additional seed is negligible compared to the increased yields obtained by having a full stand. Of course, seed dressing is highly recommendable.

It has been stated that cracked seed coats and other damage cause no measurable difference in germination of castor seed, but Weiss (1971) had different experience. Much is known about the germination and early stages of castor, as its seedlings are easy to handle and thus are often taken as an experimental plant.

Speed of germination, emergence and a quick attainment of the four-leaf stage can be significantly correlated with yields: plants that emerge quickly and grow well between 2 and 4 months give higher yields than slower-growing plants. Therefore, quick and even emergence are of considerable importance to large-scale commercial growers. Plants from such stands grow more uniformly to maturity and harvest, and render weed control and harvesting more easy and therefore more efficient. In some cultivars, dormancy factors are present, which may influence the viability at sowing. Careful removal of the caruncle and the testa just under it leaves the endosperm intact and breaks the dormancy. Normal-internode types usually emerge earlier and with a higher germination than dwarf internode cultivars.

Transplanting of castor is unusual and difficult (brittle). In Italy with sowing in compost blocks, plants developed a more fibrous root system, without the characteristic taproot, and with quicker development of the plant.

As young castor plants are very susceptible to competition, weed control is of considerable importance in obtaining high seed yields. Effective weed control often results in a relatively bare soil surface within the cropped area, offering little protection against erosion by wind or rain. This, combined with the low soil-binding ability of castor, makes it often necessary to include conservation measures in the cropping system and to be careful in selecting sites for large plantings of castor.

Two tillages are normally sufficient. The second tillage is delayed to kill as many weeds as possible. The plants are then usually big enough to shade out any but the most tenacious weeds.

Castor should always be tilled with considerable care, for the young plants are extremely susceptible to mechanical damage, and when plants are older, damage to leading shoots may cause branching with consequent harvesting problems. As the stems of most cultivars become hollow at maturity, the danger of damage to plants by fracturing stems and branches increases with age.

The major proportion of castor crops grown on a large scale are mechanically weeded for a variety of reasons, which differ from region to region. In developing countries, the expense of the special equipment for herbicide application, if it is not manufactured in the country, frequently precludes its purchase. In others, the use of hand-labour may be socially or politically desirable, water may not be available, and rainfall may be insufficient to activate the compounds used. The use of animal-drawn implements for inter-row tillage can be hazardous. The quality of the work is often extremely variable, and considerable damage to plant roots may result. The plants may not have time to replace the roots in the season.

In pure stands, a system of cultivation in which the soil is raised in ridges usually gives best results: in areas where rainfall is marginal, effective water conservation by tie-ridging has consistently raised yields above these with cultivation on the flat, both in E and in W Africa, except in unusually wet seasons. Where waterlogging may occur, planting on ridges is necessary. In abnormally dry years, it is possible to obtain some yield by cutting out alternate plants, and mulching with their foliage together with that of any vegetation present.

The most difficult and time-consuming operation in the growing of castor was, until recently, harvesting. When the crop is grown on a peasant scale with manual operations only, this is usually of little importance. There is often no competition from other crops with high labour demands, since castor is usually grown in areas unsuitable for other cash crops or harvesting of the other crops is completed before the castor matures. When grown as an intercrop or on odd scattered patches, the labour required for harvest is small and the crop can be harvested at the owner's convenience.

Where castor seeds are merely collected from wild or volunteer plants, their harvesting involves sometimes no more than collecting the seeds scattered under the plant. It can also involve picking the clusters, knocking them against some tree or rock, and collecting the released seeds, or the clusters can be trodden under the horny foot of cattle until they shatter.

Where a number of clusters is collected by women or children, they will be brought back to the homestead for threshing. Then they are either placed in a sack and beaten until hulled, or laid on the ground and beaten with a stick.

Frequently, the clusters are merely thrown on the ground to shatter in the sun, the seeds being collected daily until there are sufficient to warrant a visit to the nearest market or trading post. The price for such seeds is often low, as is the quality.

In Ethiopia, the seed is mainly collected from self-sown and wild plants. There is little systematic cultivation on any scale. The harvesting operations described can all be seen in that country. The quality of the seed offered is very variable.

Increasing interest and world demand for castor oil encouraged large-scale planting. In parts of the world where labour is available, harvesting and hulling can be on traditional lines, the operation then becoming a full-time job during the period. The clusters are usually stripped by hand, the unshelled fruit being taken to a central place for hulling.

For this hand-harvesting, some methods have been developed. The whole infructescence may be cut and later stripped by drawing it through a U-notch in a plate covering a basket. It is also possible to strip the infructescence from the growing plant. It can be done with heavy leather gloves or mittens, but is most effective with a reaping jug or stripping cup. This is a metal container, shaped like a cone or large beer mug, 20–30 cm high and about 20 cm across the open end. Opposite the handle is a slot, extending 10 cm from the mouth of the cone, tapering from $2\frac{1}{2}$ cm wide at the top to $1\frac{1}{4}$ cm at the bottom. The edges of the slot may be reinforced, if necessary with a more hardwearing metal plate. Such reinforcement allows the cup to be made of thinner material, thus reducing its weight. Clusters are stripped by guiding the base of the spike into the slot and drawing the jug upwards, so that the capsules fall into the jug. In this way, a man can harvest 250–300 kg of capsules in a day.

Handstripping the fruits from giant plants is very difficult and mostly damages the plants. Long-handled shears are very efficient for cutting the whole infructescence, but are quickly out of order if not handled properly.

To make hand-harvesting easier, new cultivars have been developed that combine a high production with fruits that are less irritantly spiny or without spines.

In areas with a shortage of labour, mechanical harvesting is essential for castor production. The first commercial harvesters became available in the late 1950s. For these harvesters, strains with short internodes were selected that are less shattering under the influence of strong winds. Unfavourably, the short internode character is highly dependent on the growing conditions: with irrigation on fertile soils, the plants may become twice as tall as under dry conditions on the same soil in the same season.

The majority of machines available are designed to harvest seed when the capsules and plant leaves are dry and the relative humidity is below 45%. At harvest, the plants may be still growing, and the later-flowering inflorescences may bear immature capsules. These green fruits must be dried, and the leaves removed before harvesting. This may be accomplished naturally by killing frosts in temperate regions; the seed is then ready for harvest some 10 days after such frost. When frosts do not occur or are too late, chemical defoliants can be applied 10–15 days before harvest.

Pruning to reduce height or number of major branches may increase the yield but the cost of this operation is usually high because of the care required. It exceeds the increase in yield. The plants usually stand pruning very well, and even stand ratooning if the stump is not too short. Weiss (1971) mentions an increase in yield of 10% and a delay in flowering. He suggests a yield reduction after delayed flowering in perennial plants. Patel et al. (1976) describe a trial in which two castor cultivars were kept free from all side-branches. In close spacing (60 cm × 30 cm), the yield increased by c. 30% and shortened the maturation of the fruits by more than a month. In crops with wide spacing (90 cm × 60 cm), yield was not affected but maturation was still accelerated.

Evenness of ripening is useful for hand-harvesting and essential for mechanical harvesting. Indehiscence of the fruit can remove this problem, as too early harvest to avoid shattering often results in seeds with low oil content.

Selective harvesting each week gives the highest yield. Harvesting at 4-week intervals results in a depreciation of 6%; 6-week intervals result in a loss of 12% and 8-week intervals of 24%.

In rather large plantings, the transport to a central depot may create problems, as unhulled seed has about four times the volume of hulled seed.

It is vital that hullers be available before harvesting begins, since it is impossible to leave ripe clusters on the plants or to allow a build up of reaped capsules, without incuring substantial losses. Hullers may be small and hand-operated or large power-driven machines, capable of handling several tons per hour.

Introduction of hullers in regions with their local cultivars often gave problems, as the hulls of local cultivars often vary greatly in thickness and strength and fruits with either thick or very thin hulls are difficult to shell. These differences in character of the hull resulted in uneven shelling with unshelled and damaged seeds. The differences in strength of the hull are mainly determined genetically, but may be strongly influenced by field conditions. Weiss (1971) found, that E African giant castor usually produces thick-shelled fruits, without differences between spiny or spineless fruits.

Clusters stripped slightly green or with wet hulls must be dried before hulling. In the tropics, they can be spread in the sun, but elsewhere they may require artificial heating. Overlong exposure to sun or heat may reduce the oil content of the seed, and increase the danger of insect damage.

In some countries, it has been arranged that a mobile or portable huller visits areas or districts on a fixed shedule; growers bring their crop to be hulled either for cash or for a portion of the hulled seed. This system has the advantage of reducing the distance unhulled crops have to be transported, and the number of hullers.

After hulling, the seed should be cleaned of all debris and dust, and stored in a clean airy shed. Storage of the seed on the farm should be avoided. If the atmosphere is still humid, the seeds should be stored in upright open-necked sacks, and not in contact with the soil. Where rain is not expected, they may be stored in the open but again off the ground, and preferably shaded. Since truck and rail transport is usually less expensive in big loads, a certain amount of storage is unavoidable, but the period should be as short as possible.

The hulled seed should be handled with care, since the thin and often brittle testa is easily damaged. Broken or cracked seeds rapidly turn rancid, resulting in a poor quality of oil and a quick reduction in viability. If the seeds are handled and stored carefully, they deteriorate slowly, retaining 75% viability for 10 years, and first-grade seeds retain their grading after 2 years, becoming third grade after 5 years (Doughty, 1958).

When seed is to be immediately processed for oil, no grading or selection is necessary. All operations should be integrated in order to minimize the period between hulling and processing. Seed for export must be cleaned, and all damaged and broken seeds removed. Severe penalties and even rejection of the consignment may result if the preportion of sullying and broken seed is greater than 2–5%. So the seed should be bagged with care and the seed should be handled as little as possible.

There is little information on the specific pests infesting stored castor seed or presscake, and less on suitable control measures. This is partly because the problem is a minor one, as the seed is little attacked if it is whole and dry. Infestation of the presscake is of no practical importance, as it is normally used as fertilizer or fuel.

After harvest, the plants should be destroyed, for this operation can substantially reduce the severity of succeeding insect infestation and disease. The dry stalks may be a valuable source of fuel in treeless areas, and if so their use for this purpose may be allowed up to a certain date before planting the next crop. By that time, all must have been used and the remainder should be burnt. To control erosion, however, it can be necessary to leave crop residues on the field; if so, they should preferably be broken up to limit pest survival.

Castor is subject to a multitude of insect pests. Even insects that normally do not attack the species eat it with avidity. Adequate control of insect pests is probably more important in profitability of castor production than any other factor, provided of course the ecological factors are within the limits for castor. This applies particularly to regions where large pure stands of castor are cultivated.

In general, the same or related species of insect pests are found attacking castor wherever it is grown, but the severity of attack and their relative importance vary. Frequently, it is only after the crop has been grown in a certain area for several successive seasons that it becomes apparent which insects are the most damaging. Many of the major pests of castor also attack other common tropical arable crops such as sorghum, cotton, soya and maize, and castor planted near large stands of any of these will be liable to greatly increased insect attacks. Since few of these annual crops, except cotton, are systematically sprayed, a large-scale programme over a wide area covering all crops would not be economic. Maintaining a phytosanitary cordon around extensive castor plantings can be very effective in reducing potential infestations.

Among the pests, two broad groups can be distinguished: the chewing and the sucking insects. The chewing insects usually do relatively little damage to the crop unless they occur locally in extremely large numbers. They are easily killed by insecticides. The damage caused by sucking insects is more subtle: the plants weaken and the puncture made by the insect whilst feeding allows entry of fungi and bacteria. Additionally, the insect itself may be a vector for virus diseases. Sucking insects are particularly harmful during flowering and the setting of the fruits because, as was demonstrated in several experiments, even the mechanical damage like puncturing the pedicel is often enough to cause the flower or fruit to drop.

Reports on the resistance of castor to nematode attack are conflicting. There is evidence of castor having some resistance and even some nematicidal properties. On the other hand, stunted growth has been reported, especially of young plants, and roots with dark lesions.

Diseases in general do not limit production to the same extent as pests. Insect pests are more important in the Old World, diseases in the New World. In the majority of regions where castor grows naturally, diseases are rarely a limiting factor, although some 150 organisms are known to be pathogenic on the species. They only assume importance where commercial production is attempted in areas basically unsuitable for large-scale production or under humid conditions, notably in the seed-bed and in the seedling stage, and at flowering or shortly afterwards.

The ability of castor to show only slight yield depression with chewing insects and diseases can be partially explained by the slight effect on yield of varying degrees of defoliation.

If possible, such sowing time should be chosen that the most susceptible periods coincide with periods of (relative) absence of the most important parasites or with periods in which the circumstances are unfavourable for the parasite to attack. Cultivation, rotation, burning the harvested plants, other sanitary measures and the chosen cultivar are thus all extremely important in the control of pests and diseases.

In Ethiopia, I never saw any extensive cultivation of castor; the same situation is indicated in nearly all publications on Ethiopian agriculture. But Bridges (1960) indicated that 20234 ha were planted with castor in Ethiopia. This made castor rank 15th in area among Ethiopian crops.

The only descriptions of an indigenous cultivation I found were the following. Pajella (1938) stated: 'castor plants can be seen near the huts, but real cultivation is not practised except for the region of Kamketti near Jimma, where it is sown in February in holes about 1–2 m apart, where 2–3 seeds are sown together. The seed germinates in a few days and the plants develop rapidly, without much trouble with the weeds. The first season they reach c. 1 m and give their first capsules. They keep on growing and finally reach a height of 3–4 m or more. The plants live c. 10 years under those conditions. The natives do not tend the plants'. Baldrati (1950, p. 365) suggests that castor is planted for shade in new coffee-fields around Harer. Huffnagel (1961) says that in the hot lowlands and in the more temperate regions castor is sown in May–June, and harvested in November–December in the hot lowlands, and in September–October in the more temperate regions. There is no cultivation in the colder regions. Weiss (1971) remarks on Ethiopia that the small size of the farms and the often rugged nature of the fields requires mainly manual operations, but that draught animals are employed where possible. On larger farms, some mechanical implements are used in the culture of castor, but herbicides are hardly ever applied; those are only used on the official farms and on some of the irrigated estates in the Awash Valley. Small unofficial trials on those farms indicate that castor grew well with an irrigation of 650 mm. Weiss also mentioned that a system had been introduced involving minimum cultivation. Lines or circular areas were cleared of indigenous grasses, which were not of the pernicious type, and castor was dibbled into the cleaned areas, two or three seeds on a hill. Cultivars were semi-dwarf or selected local types. The areas between the rows or circles were not clean-weeded, but merely slashed when growth became excessive, to form a dense mulch. The sites selected were often flood plains or seasonally waterlogged areas, and were cropped in the dry season. No crop protection was carried out, and yields were 280–1233 kg/ha.

The Italians did some experimental work during the time they occupied the country. According to Tozzi (1943), experiments with cv. Sanguigno di Verona, imported from Somalia, showed that excellent growing conditions are present in the region of Bacà (near Asbe Teferi), at altitudes of 1600–1900 m. It can be grown there with or without irrigation. With irrigation, 2 harvests are possible per year. In higher parts of the area, rainfall is more than 1000 mm per year and the plants tend to form more vegetative parts and less fruits. In the first experimental year, seed yields were 800–1000 kg/ha. Sowing should be done at the beginning of the small rains. The plants could be used a second year if they were pruned back during the dry period. According to Baldrati (1950, p. 367), the cv. Sanguigno di Verona was also used in Eritrea and crossed there spontaneously with local castor, resulting in a very valuable hybrid.

Taralleto (1935) described a cultivation method with which he had the best results in a dry part of Eritrea. He had the fields superficially ploughed twice. In February–March, when the soil was still very dry, shallow holes 50 cm in diam. were dug 2 m × 2½ m or more apart. Immediately after digging, fertilizer and seed (of tree-like castor) were placed in the earth: the dry soil did not harm the seed for many months. Thus the very first rains became available to the seed, which emerged promptly. Taralleto also indicated that Baldrati achieved yields of 2200 kg/ha in Eritrea, and that Saccardo believed that 3700 kg/ha should be possible there.

Siegenthaler & Wilson (1958) reported a complete failure of imported cultivars in Jimma. From Bako (Shewa Province), yields of dry cleaned seed of 45–500 kg/ha were reported; the lowest yield being produced by the local selection (Bako Res. Stn Prog. Reports, 1970; 1971). At Debre Zeit, the cv. Pacific Hybrid had an average yield of nearly 1600 kg/ha, while the maximum yield achieved by a selection of local perennial castor was 639 kg/ha in the first harvest (Agric. Ethiop., 1964). Castor sown at Alemaya in the first half of July, 1970, was killed by frost and yielded nothing (Brhane, 1971). In view of the results with my collection (Note 10), the latter result is most probably due to late sowing.

Shiberru Wolde Mariam (1966) indicated that one of the main reasons for castor not being planted more widely in Ethiopia was the difficulty of shelling, as the price was favourable and official support was given. He published the design for a sheller, mainly made of wood and old car tyres, which gave good results in Ethiopia.

The following pests were noted in Ethiopia: the scarab beetles *Anomala egregaria* Gah. and *A. plebeja* O., the bollworm *Heliotis armigera*, the caterpillar *Pericallia geometrica* Obth., the green shieldbug *Nezara viridula*, and termites (Weiss, 1971); *Drepanoptera antinorii, Cossus* sp., *Epitetranychus altheae* (Jannone, 1940); *Eurystylus kivuensis* Schout., *Pitarcha* sp., *Thalasso desdigressa* Wlk., *Xylentes capensis* Wlk. (Hill & Tesfaye, 1965); *Agyroploce wahlenbergiana* Zell. (Jannone, 1949); *Nezara pallidospersa* Staal, *N. viridula* L., *N. viridula* var. *torquata* (Jannone, 1952); *Phymateus viridipes* St. (de Lotto, 1951); *Phycita diaphana* and locusts (Taralleto, 1935); *Taylorilygus vosseleri* (Schmutterer, 1971).

The only fungi mentioned in the literature I have seen are *Melampsora ricini* Pass. (Candussio & Scabardi, 1953; Ciccarone, 1940) and *Melampsorella ricini* Biv. (Jannone, 1952).

Uses

Castor seed is mainly cultivated or collected for the oil which is the major component of the endosperm. The oil was, and is, used as a medicine and for lighting, but nowadays it is an important oil for industry too. Castor oil is, like other vegetable oils, a triglyceride of fatty acids. Its special properties are caused by the presence of c. 85% of ricinoleic acid, a hydroxy fatty acid not commonly found in such oils (Weiss, 1971).

The medicinal uses can be divided into internal and external. Internal application is based on irritation of unprotected human tissues by ricinoleic acid, which is liberated from the oil by intestinal hydrolysis. It causes copious liquid stools, about 6 hours after ingestion of the oil (Weiss, 1971).

The irritant action of the oil is not restricted to the intestine alone, but it spreads to the adjacent organs, and should be used with caution by menstruating and pregnant women. On the other hand, it is common practice to induce labour in women whose pregnancy is at term, or even to induce abortion (Weiss, 1971).

External application, in which the oil does not hydrolyse, usually has to do with treatments of the skin, to which it is an emollient without any irritant action, even if the skin is soft, as on babies, or broken. In W Africa, for instance, the oil is used in the native treatment of leprosy (Weiss, 1971). I was told that in regions of Ethiopia with such a water shortage that regular washing of the body is impossible, the oil is sometimes used to keep the skin supple.

The oil may be used as a carrier for other medicine. Weiss (1971) indicates that it may be used in eyewashes.

Castor oil is also used in veterinary medicine; its uses are comparable to those in man (Weiss, 1971).

Traditionally the oil is often prepared by cooking the pounded seeds with water, after which the oil is skimmed off. Modern preparation of medicinal oil is at temperatures of 32–38 °C. The pale straw-coloured oil so prepared is bleached by ultraviolet radiation and filtered. Contamination of the oil with the poison, which is also present in the seed, is avoided by either means of preparation (Weiss, 1971).

Probably because of the easy availability of castor in most warmer countries and its purging properties, which make it unsuitable as a cooking oil, its use for lighting is widespread. It is the only oilseed used in Ethiopia for this purpose. The only other traditional means of lighting is a small fire. I was told several times that 'people in the west' made a hole in a seed and put some twisted cotton fibres through it as a wick, a procedure also mentioned by Siegenthaler (1963). I never succeeded in obtaining a lasting flame that way and therefore have more confidence in the procedure described by Pajella (1938) and Wittmack (1907). They tell that decorticated seeds may be threaded 9 or 10 on thin sticks of wood, c. 15 cm long. The seed on top is lit, and the fire creeps slowly downwards.

Another common use of castor, or its oil, also found in Ethiopia, is as (an ingredient to) hair tonics. I only know of the use of the oil locally in Ethiopia for this purpose, but according to Pajella (1938), castor seed is decorticated by careful pounding in a mortar in SW Ethiopia. Later the kernel is crushed to a paste and fermented. This paste is then rubbed into the hair, which stays soft.

Griaule (1930) mentioned that castor was used in Ethiopia in a mixture with herbs to treat syphilis. The only other traditional uses of castor in Ethiopia I know of are in the preparation of a new mitad (frying platform for unleavened bread) and in greasing it before frying, either as oil or just by rubbing a broken seed over it. The latter use is also mentioned by Siegenthaler (1963), who adds that a medicine is prepared from the fresh roots of castor, which helps a woman to expel the placenta after the birth of a child. He also describes how the leaves of castor are used to line a pit in the ground, in which barley malt is prepared. According to Baldrati (1950), pounded decorticated seed is used in Ethiopia to darken wood.

Weiss (1971) sums up some traditional uses of castor from other parts of the world: the oil may be used cosmetically as a carrier of colorants, to repel insects, to tan leather, the seed may become edible by fermentation and is often used in magic; the leaf may be used to feed silkworms and cattle; dried mature leaves may even be eaten by men as a vegetable; the plant is used as shade tree or as windbreak in areas where few other trees can grow; its stem is sometimes used for hut-building or fuel. He also indicates that castor is resistant to the root parasite *Striga* spp. and could well be used in a rotation based on maize and sorghum.

In modern industry, several hundred applications for the oil are known, and new uses are still being discovered. The oil is used in paints, varnishes and soap. It is the chief raw material for the production of sebacic acid, the basic ingredient for the production of some synthetic fibres and plastics. From the earliest days of internal combustion engines, it has been a lubricant, and this use may gain new impetus if ethanol becomes a more common fuel. It has so many uses that a continuing world demand can be expected, especially if the oil can be marketed at a low price (Weiss, 1971).

The presscake is known as castor pomace, poonac or castor seed-cake. It contains a deadly poison and an allergen. The poison is a protein called ricin, which causes symptoms of poisoning in mammals (burning sensation in the mouth and throat first, followed by nausea and vomiting); even a few small particles in an abrasion of the skin or in the eyes may be fatal, and 2 seeds can be fatal to cattle. The action of the poison in insects ranges from harmless to fatally toxic (Weiss, 1971). Baldrati (1950) suggests that some birds are less sensitive to ricin.

It is possible to immunize people and animals to a high degree by administering small but increasing doses of the poison, but still the presscake cannot be used so easily for cattle feed as the cakes of other oilseeds. The extreme toxicity of ricin makes the detection of castor seed or pomace in feedstuffs important (Weiss, 1971).

The ricin can be inactivated by heating with water, but then the allergen is still present. The allergen is often called castor bean allergen (CBA); it is extremely potent. Contrary to the poison, subjects become more sensitive by repeated contact with it. This often creates difficulties to labourers in places where much seed or seed-cake is handled over a longer period. It causes conjunctivitis, pharyngitis, dermatitis or asthmatic bronchitis (Weiss, 1971).

The allergen cannot be easily removed. The use of the meal for feed or food is therefore dependent on the discovery of either a cheap means for inactivation of the allergen, or of plants that do not contain the allergen. Polit & Sgarbieri (1976) published a method of making the proteins edible. They extracted the proteins at 45°C with a strongly alkaline aqueous solution, precipitating them later under acid conditions. After heating at 100°C for 5 minutes, the proteins could be filtered out and were completely free of both the poison and the allergen.

Weiss (1971) indicates that a resistance or tolerance to the allergen may be present in individuals or groups. There must be many such persons in Ethiopia, as I have never heard of allergic reactions there, despite greasing of the mitad being commonly done by rubbing a broken seed over the surface.

The cake is a valuable fertilizer that even shows some nematicidal effect. A dressing of 400–600 kg/ha can replace a normal treatment with Chile saltpetre ($NaNO_3$) or ammonium nitrate (Canecchio Filho, 1961). Also the damaged seeds and hulls can be used as a fertilizer. A compost made from them has the same fertilizing qualities as farmyard manure. As it is costly to prepare the compost and return it to the field, the garbage and the pomace are often burnt; in processing factories, they are usually used as fuel (Weiss, 1971).

Many production data from countries like Ethiopia, where the seed is mainly collected from a few cultivated or wild plants, are inaccurate and vary widely. Ethiopia exports castor mainly as seed; only a small portion of the locally prepared oil is exported to neighbouring countries (Weiss, 1971). Since 1961, the Ethiopian annual production has varied between 10 and 15 Gg (Weiss, 1971; FAO Prod. Yearb. 1973–1980).

Chemical and physical properties (main source Weiss, 1971)

The mass ratio of hull to seeds and of seed-coat to kernel are both determined genetically and influenced by the growing conditions. They vary from 1:2 to 1:4. The ratio of hull to seed may also be different in successive infructescences on the same plant. Ferrara (1943) found the two values as extremes in 17 Ethiopian seed samples.

The average weight of a seed may vary from less than 0.1 to more than 1 g; in most of the commercially grown dwarf-internode cultivars, it is around 0.3 g (Weiss, 1971). Ferrara (1943) found a range from 0.1 to 1.7 g, with an average of c. 0.79 g, within his samples.

The oil is mainly found in the kernel, the fibre in the seed-coat. Castor seed with an oil content of 47% had a mass fraction of fibre of 15%. When the seed was hulled, the kernel was found to contain 66% of oil and less than 1% of fibre, the seed-coat containing less than 1% of oil but nearly 50% of fibre. Of the whole seed, 40–60% may be oil. The oil content and the characteristics of the oil are influenced by the growing conditions and the cultivar, but there is no clear difference in these respects between seeds from successive infructescences on the same plant. The oil content of seeds resulting from self-fertilization and from cross-fertilization are equal.

Table 56. Composition of Ethiopian castor seeds (Ferrara, 1943; Weiss, 1971; mass fractions in g/kg).

	Weiss	Ferrara
Kernel	660	(667)760(824)
Oil in whole seed	470	.
Oil in kernel	.	(612)655(700)
Moisture in whole seed	65	.
Moisture in kernel	.	(36)45(60)
Protein in whole seed	221	.
Ash in whole seed	29	.
Average seed mass (g)	.	(1)8(17)
Bulk density (kg/m³)	.	(4520)5243(6070)

The Government Analyst of Ethiopia (quoted in Weiss, 1971) mentions 66% as the average mass fraction of the seed, supplied by the kernel, but the kernel contributed on average 76% to the seed in samples investigated by Ferrara (1943). Table 56 shows the average composition of castor seed from Ethiopia, as listed by Weiss (p. 76) and Ferrara.

It is striking that the lowest proportion of kernel found by Ferrara is about the same as the average stated by the Ethiopian Government, whereas the calculated oil contents of the kernel ($47 \times \frac{100}{66} = 71.2$) is ± equal to the maximum found by Ferrara. Within 56 market samples of castor from my Ethiopian collection, the whole seed was found to contain, on average, c. 51% of oil, with a minimum of c. 40% and a maximum of c. 61% (on an oven-dry basis).

Castor oil is a nearly colourless or faintly yellow, viscid, transparent oil, with a slight odour; its taste is bland at first, turning slightly acrid afterwards. At 20°C, it is soluble in 2½ parts of 90% ethanol, miscible with dry ethanol, methanol, ether, chloroform and with glacial acetic acid. It can be identified by its miscibility in light petroleum (boiling range 40 to 60°C): it is miscible with half its volume and only partially soluble in two times its volume. On cooling to c. −18°C, it congeals to a yellowish mass.

Castor oil has a very high stability to oxidation and, therefore, excellent keeping qualities. The antioxidant principles in castor oil are, as in other vegetable oils, tocopherols. Their content in crude oil is 220–500 mg/kg and in refined oil 30–120 mg/kg. Refining and degumming the crude oil thus reduce its stability to oxidation. Castor germ oil contains 18 times as much tocopherols as the oil of the whole seed.

Castor oil consists almost entirely of triglycerides, containing only a very small proportion of other constituents. Unsaponifiable matter usually constitutes about 0.5%. The oil contains only small amounts of saturated fatty acids as the bulk of the fatty acids is ricinoleic acid. This acid can be described as oleic acid, with a hydroxyl group at the C-12. The presence of this group gives castor oil the property of being soluble

Table 57. Ranges and means of component fatty acids in total fatty acids of castor oil (substance fractions in %, modified from Weiss, p. 70).

	Mean	Range
Ricinoleic acid	92.69	91.4-94.9
Linoleic acid	4.44	4.0-5.0
Dihydroxystearic acid	0.79	0.6-1.0
Oleic acid	0.62	0.1-1.8
Saturated fatty acids	0.62	0.3-2.5

Table 58. Some characteristics of castor oil (data from several tables given by Weiss, 1971).

Relative density at 20 °C	0.953–0.964[1]
Solidification point	c. −18 °C
Unsaponifiable matter	< 1%
Acetyl value	c. 140–150
Hydroxyl value	c. 156–169
Reichert-Meissl value	< 0.5
Polenske value	< 0.5
Refractive index	n_D(20 °C) = 1.477–1.481
	n_D(25 °C) = 1.473–1.477
	n_D(40 °C) = 1.466–1.473
Acid value	⩽ 2 (British Pharmacopoeia)
	3– 10 (industrial)
Saponification value	177–187
Iodine value (Wijs)	81– 91
Optical rotation	⩾ +3.5°
Dynamic viscosity[2] at 25 °C	0.6–0.8 Pa.s
Flash point	230 °C
Ignition temperature	449 °C
Temperature, critical to solution in ethanol	< 0 °C

1. The relative density was found to vary linearly from 0.972 at 0 °C to 0.870 at 154 °C.
2. Viscosity is highly variable.

Table 59. Composition of pressed or solvent-extracted castor seed-cakes and meals (after Weiss, 1971; mass fractions in g/kg).

	Castor seed-cake		Castor seed-meal	
	whole	hulled	solvent	expeller
Moisture	98	104	118	68
Oil	52	88	11	44
Crude protein	204	464	306	321
Crude fibre, carbohydrates	494	240	140	.
N-free extract	.	.	.	275
Ash	150	105	60	62

in ethanol, and makes the oil dextrorotatory. The data from a number of sources, as cited by Weiss, indicate a composition of the component fatty acids in castor oil as given in Table 57.

In the analysis of 56 seed samples from Ethiopian markets, I found the following approximate composition (%):

	Mean	Range
Ricinoleic acid	88.3	81.2–91.8
Linoleic acid	4.6	3.4– 8.0
Oleic acid	4.1	2.6– 7.6

Other fatty acids each less than 1%. The values were estimated by gas-liquid chromatography of the methylated esters after hexane extraction.

A survey of some characteristics of the oil is given in Table 58.

The composition of the cake remaining after pressing or extraction is influenced by the way oil is extracted and by hulling the seed before extraction; the average values of its constituents are given in Table 59.

Based on a collection of samples, Weiss indicates an average ash content of 8.89%, range 4.75–14.65. In view of the preceding figures, this could indicate that these data are an admixture of data of samples that had a different treatment for oil extraction. The mean mineral composition of these samples can be seen in Table 60.

Table 60. Mineral composition of castor presscake and of ash of presscake (after Weiss, 1971; mass fractions in g/kg).

Component		In sample	In ash
N total		52.0	
	ammonia	0.6	
	nitrate	1.8	
	soluble organic	3.4	
	active insoluble	27.5	
P total		8.0	89.8
	available	7.9	88.8
K		9.0	101.8
Ca		4.1	46.1
Mg		3.2	36.0
Cu		0.05	0.6
Mn		0.002	0.022
Zn		0.48	5.4
B		0.13	1.5

Table 61. Amino acid content in presscake and in crude protein of castor (mass fractions in g/kg; after Weiss, 1971).

	In presscake	In crude protein
Crude protein	397.9	1000.0
Arginine	39.9	100.3
Histidine	6.7	16.8
Isoleucine	18.5	46.5
Leucine	22.5	56.5
Lysine	12.0	30.2
Methionine	5.8	14.6
Phenylalanine	18.6	46.8
Threonine	12.9	32.4
Tryptophan	4.4	11.1
Valine	21.5	54.0

The protein content of presscake of decorticated seed is about 40%. The amino acid composition of castor presscake is given in Table 61. Comparison of these data with the amino acid ratios normally recommended for pigs and poultry, suggests that the use of castor presscake as only source of protein for those animals might induce deficiencies in the essential amino acids methionine, lysine and tryptophan.

The highly toxic protein ricin forms c. $1\frac{1}{2}$% of the oil-free meal.

The mass ratio of carbon to nitrogen in castor cake is c. 9. This ratio is important when the cake is used as a fertilizer.

2.15 Salvia spp. (Labiatae)

'Salvia': the old Latin name for this genus.

In 1904 and 1905, Suzzi indicated that there were many *Salvia* species in Eritrea, and that they were widespread. Cufodontis (1974), on the other hand, listed only 11 species for the genus in Ethiopia, including the cultivated and naturalized species, and indicated his doubts on the identity of some of them. And according to Hedge (1974), only 4 of the 59 he described as indigenous to Africa can be found in Ethiopia.

Suzzi investigated two 'unidentified' *Salvia* species from Eritrea, because they were used as an oil plant. The names he mentioned and his descriptions of the plants give us a clue to the species he examined.

The first species Suzzi called abahadera. This is apparently *Salvia schimperi* Benth. All three, Rocchetti (1958), Cufodontis (1974) and Hedge (1974) gave abahadera as an Eritrean name for this species. The description Suzzi gave ('Plant with large villose, glaucous green leaves, strongly scented') fits the description of the species rather well too. In support of this view should be mentioned that nutlets of this species were collected by Westphal and his wife (No 5565) as oilseeds at the market of Debre Birhan (Shewa) under the name 'debarak'. Those fruits are greyish brown with brown reticulate veins. This again well fits Suzzi's description of the fruits ('The seeds are ash-coloured, have a smooth surface with a reticulate invenation').

The second species was called entatiè vallaha by Suzzi. This could very well be the same as Cufodontis' 'entatie wollakha' (*Salvia merjamie* Forsk.), or 'antate wollakha' (*Salvia nilotica* Jacq.). The similarity of the indigenous names for both species, of the nutlets, of the distribution, altitude range and habitat may suggest the indiscriminate use of the two species. However Amare (1974) indicated only *S. nilotica* as a food plant in Ethiopia. I thus take it for granted that Suzzi examined this species. Suzzi's description of the plant fits *S. nilotica* rather well: 'A plant with coarse leaves, smaller flowers and a very different habit; the seeds are smaller and darker' (than abahadera).

The four species indigenous to Ethiopia, can be distinguished easily, be it that some of the leaf-forms and habits of *S. nilotica* are close to some of *S. merjamie*. The calyces are very characteristic for the species, though.

Key to the *Salvia* species indigenous to Ethiopia (after Hedge, 1974):

1a Plant densely branched, suffruticose, calyx c. 5 mm, corolla less than 8 mm . . . . *S. aegyptiaca* L.
1b Plant sparsely branched, commonly only in the upper parts of the stem, or with basal leaf rosette, herbaceous, calyx more than 7 mm, corolla more than 9 mm . . . . 2.
2a Plant with conspicuous bracts covering about half the verticils, calyx c. 20 mm *S. schimperi* Benth.
2b Plant with small bracts hardly covering the verticils if at all, calyx c. 8–10 mm . . . . 3.
3a Calyx with 3 subequal, cuspidate teeth on upper lip . . . . *S. nilotica* Jacq.
3b Calyx with 3 very short incurved teeth on upper lip . . . . *S. merjamie* Forsk.

2.15.1 Salvia schimperi Benth. Fig. 13

'*schimperi*': in honour of W. Schimper, a German-born plant collector, who died as a naturalized Ethiopian citizen in 1878 or 1879 in Adua.

Bentham in DC., Prodr. 12: p. 282 (1848).
Type: mountains of Abyssinia, Tigre, Hazabo near Axum, 2000–2400 m, 17x, Schimper ser. 3 n. 1916 (K, holo.).

Synonym

Salvia hypoleuca Hochst. ex Fiori, nomen nudum, non Benth. in DC. (1848), N. Giorn. bot. Italia 23: p. 491 (1916).

Literature

1904/5: Suzzi, Boll. agric. commerc. Colon. Eritrea 2(8/9): p. 283, 3(4): p. 452. (agric.)
1974: Cufodontis, Facsimile Enum.: p. 820. (tax.)
1974: Hedge, Notes R. Bot. Gard. Edinburgh 33(1): p. 17, 89. (tax.)

Vernacular names: abbadera, abahadera (Asmara); mai-sendedo (Tigrinya); debarak (Amarinya).

Fig. 13. *Salvia schimperi* Benth. 1. Flowering branch (× ⅔). 2. Flower (× 2). 3. Anther (× 4). 4. Calyx in fruit (× 2). 5. Nutlet with mucilaginous layer (× 6). 1–4, JdeW 4456; 5, WP 5565.

Geographic distribution

S. schimperi is indigenous to the N and C highlands of Ethiopia and to N Yemen (Hedge, 1974).

Description

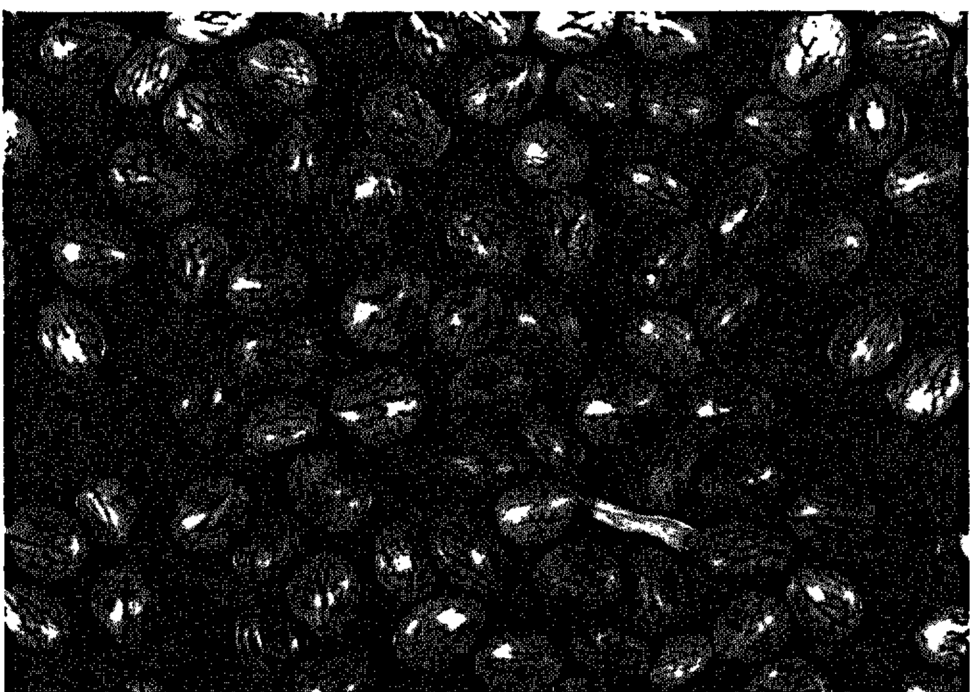
Herbaceous aromatic or foetid perennial with sturdy rhizome.

Stems quadrangular, stout, usually only branched apically, up to 80 cm long and up to 8 mm across, light green, with arachnoid to lanate hairs, towards the base usually mixed with some short capitate glandular hairs and sometimes with globules as well, further upwards with numerous thick-stalked capitate glandular hairs, non-glandular hairs, and oil globules, at nodes often more like the basal part.

Leaves opposite, lower leaves with petioles up to $6\frac{1}{2}$ cm, upper sessile, ovate–elliptic to ovate, narrowly so or not, up to 22 cm long and up to 10 cm wide, grey-green to greenish white, apex acute, base cuneate to obtuse, margin crenulate, both surfaces equally densely arachnoid to lanate or less densely so above, beneath mostly with oil globules, sometimes sticky, penninerved with up to 13 main veins each side.

Verticils distinct, up to 10 per branch, with 2 to 5 flowers.

Verticillar bracts broadly ovate, up to 3 cm long and up to 2 cm wide, base cordate,



Photograph 23. Nutlets of *Salvia schimperi* (WP 5565; × 5).

apex setiform-acuminate, more or less enclosing the verticils, white, with green entire margin fringed with flat, often multicellular hairs, with capitate hairs beneath and some globules all over, on veins also with hairs as on margin, sometimes nearly glabrous, without globules or apically lanate, with short capitate hairs above near margin and on central vein, seldom also between, palminervate.

Floral bracts not always present, oblong to linear, usually 2–3 mm long and $\frac{1}{2}$ mm wide, sometimes much larger: up to 20 mm × 5 mm, and then like the verticillar bracts, with capitate and stiff non-capitate hairs.

Pedicels erect to spreading, up to 7 mm long, terete with many multicellular hairs and short glandular hairs.

Calyx tubular-campanulate, up to 21 mm long, usually shorter, 13-veined, (dark grey-)green, with multicellular non-glandular hairs, mainly on ribs, and with very short glandular hairs and a few or no globules outside, inside as outside but without globules and with shorter hairs; teeth of upper lip 3, c. 4 mm long, the two of the lower lip up to 8 mm long, spinulose.

Corolla up to 40 mm long, with straight clearly exserted tube, widening upwards, constricted at the base of lower lip, white, lobes usually flushed pale blue or lilac, glabrous inside, outside with 2–3-celled capitate hairs on the falcate upper lip, often with globules laterally near the base of the lips, lower lip 3-lobed, 2 lateral lobes ovate, slightly undulate, central lobe orbicular, concavo-convex, upper lip slightly falcate.

Stamens 2, with white filaments c. 2 mm long, and white connectives c. 15 mm long, upper thecae violet-brown, lower thecae hatchet-shaped, sterile, cohering, white.

Staminodes 2, implanted at the base of the upper lip, c. 1 mm long, hooded.

Style gynobasic, filiform, glabrous, white, up to 45 mm long.

Stigma bifid, white, lower lobe longest, up to $2\frac{1}{2}$ mm long, canaliculate, upper lobe up to $\frac{3}{4}$ mm long.

Ovary quadrifid, implanted on a 4-lobed disk, the upper lobe of which is transformed in a 3-lobed nectary.

Ovule, 1 per part, anatropic, basally axillary.

Fruit a nutlet, rounded triangular on transverse section, ± broadly elliptic on vertical section, greyish to very pale brown, with coarse dark brown reticulation, dorsally with 2 to 6 palmate veins, up to $3\frac{1}{2}$ mm long and up to 3 mm in diam., mucilaginous on wetting.

Note

Description was based on the following specimens.

Beghemder	Near Sankaber, Simien Mountains, 3150 m: JdeW & M. G. Gilbert 196; Simien Mountains National Park near Dihuara, 3250 m: M. Verfaillie 342.
Shewa	Along road to Debre Zeit, 25 km from Mojo, 1830 m: WP 1934; market of Debre Birhan: WP 5565; near Debre Zeit, c. 1900 m: WdeW 6142, WdeW 8134, WdeW 8991; near tunnel between Debre Birhan and Debre Sina, Debre Birhan side, 1900–2000 m: WdeW 9666.
Tigre	55 km S of Quiha, 2350 m: JdeW 4456.

Grown at Wageningen SL 3946.

Ecology

According to Hedge (1974), the altitude range of the species is 2100 to 3200 m. The specimens I saw were found between 1830 and 3150 m. Those specimens were nearly all collected on sloping terrain and the soils were described as volcanic, black loamy, and sandstone soil. Apparently the plant prefers open places and, for most of the year, rather dry growing conditions.

Husbrandry

The fruits are collected from the wild.

Uses

The use of *Salvia* seeds in Ethiopia is similar to that of linseed.

Chemical and physical properties

Suzzi (1904 and 1905) found that the bulk density of the nutlets was c. 640 g/l and they contained c. 228 g of oil per kilogram. The cold-pressed oil was clear and viscous, with the same colour as linseed oil and without much taste, the relative density was 0.9273. The solidification temperature range was −16 to −20 °C and the oil was highly drying with an iodine value of 157.1 (Wijs). The mucilaginous layer of the fruits could bind more water than that of linseed.

2.15.2 Salvia nilotica Jacq. Fig. 14

'nilotica': from the region of the Nile.

Jacquin, Hort. vindob. 3: p. 48, t. 92 (1776).
Type: Hortus vidondobonensis 3, Plate 92 (1776) (photo!).

Synonyms

Salvia abyssinica Jacq., Ic. Pl. rar. 1: p. 2, t. 6 (1781) non L. f., Suppl. (1781).
Salvia parviflora Salisb., Prodr. Stirp. Chapel Allerton 74 (1796), nom. illegit.
Salvia hochstetteri Baker in Thiselton-Dyer, Fl. trop. Africa 5: p. 459 (1900).
Salvia macrorrhiza Chiov. in N. Giorn. bot. Italia, new series 36: p. 369 (1929).

Literature

1905: Suzzi, l.c. (agric.)
1974: Amare, Agro-ecosystems 1: 45–56. (agric.)

Fig. 14. *Salvia nilotica* Juss. ex Jacq. 1. Habit (c. $\times \frac{2}{3}$). 2. Flower ($\times$ 6). 3. Stamen ($\times$ 12). 4. Fruiting calyx ($\times$ 6). 5. Nutlet ($\times$ 20). 1–4, after Hedge, 1974, Notes R. Bot. Gard. Edinburgh, p. 64, Fig. 16 (modified); 5, JdeW & M. G. Gilbert 178.

1974: Cufodontis, l. c.: p. 819. (tax.)
1974: Hedge, l.c.: p. 16, 62. (tax.)
1975: Bohannon & Kleiman, Lipids 10(11): p. 704. (chem.)

Vernacular names: antate wollakha, entatiė vallahà, fereshei (Tigrinya); basobila (Amarinya); šokoksa (Gallinya).

Geographic distribution

Salvia nilotica is indigenous to the N, C and SW highlands of Ethiopia and to the highlands of Uganda, Kenya, Zaire, Rwanda and Burundi (Hedge, 1974).

Description

Perrennial herb, aromatic or foetid, with brownish cream to (creamy) brown stolons or rhizomes.

Stem erect, quadrangular, in larger plants often with swollen ribs, branched, up to 120 cm long and up to 8 mm across, often much smaller, green, often with red or brown shades, sometimes more red than green, basally with multicellular flattish non-glandular hairs, shorter capitate glandular hairs, and a few or no oil globules, towards the apex with similar but denser indumentum, in plants with clearly swollen ribs, the ribs commonly more hairy than between them.

Leaves herbaceous, opposite, often in basal rosettes, the basal ones usually petiolate with petioles up to 9 cm, the upper sessile; petioles semiterete, shallowly canaliculate above, coloured and haired as main vein of blade, or purplish; blades (ob)ovate to elliptic, usually runcinately lobed to lyrate, up to 20 cm × 8 cm, above light to dark (greyish) green, sometimes purplish tinged, beneath lighter than above, main veins up to 9 at each side of midrib, sometimes yellowish both sides, with crenate, serrate, or irregularly dentate margin, acute-apiculate apex, and cordate, auriculate, truncate to cuneate or attenuate, often oblique base, with an indumentum of simple multicellular hairs above, beneath with similar hairs mainly on the veins, and nearly always with oil globules.

Verticils up to 15 per branch, with 6 to 8 flowers, distinct below, approaching above, in fruit all distinct.

Verticillar bracts broadly lanceolate, up to 15 mm × 8 mm, base cordate, apex caudate, margin entire, pilose, green, sometimes purplish-tinged, indumentum beneath as leaf beneath, above usually glabrous but for the margin, palmately veined.

Floral bracts lanceolate to linear, up to 8 mm × 3 mm, with unicellular and multicellular hairs at margin, on apex and on the only distinct vein, sometimes with oil globules beneath at base, green, purplish tinged.

Pedicels erect to spreading, up to 6 mm long, usually c. 4 mm, terete, pale green to almost white, densely covered with multicellular hairs.

Calyx campanulate, up to 10 mm long, pale green, usually purple at lobes, apex or veins, sometimes (very dark) purple all over, expanding to 12 mm in fruit, 13-veined, outside with non-glandular hairs, glandular hairs and oil globules, inside with shorter hairs only; upper lip with three subequal cuspidate teeth, 1½–2 mm long, lower lip with two cuspidate teeth c. 4 mm long.

Corolla up to 12 mm long, tube exserted, with a non-falcate cucullate upper lip and a 4-lobed lower lip, with the 2 central lobes protruding, blue, lilac, purple, violet, pinkish red, or white, occasionally with white dots on either lip, externally with few to many, short, 1-celled to 2-celled hairs, internally with some white single-celled hairs at base. [According to Hedge (1974), a thin annulus should be present c. 3 mm from the base. In my material I found hairs either from the base upwards or c. 3 mm from the base only, but then on the distal side.]

Stamens 2, implanted at the base of the throat, with c. 3 mm long, white to blue (violet) filaments and c. 4 mm long connectives of the same colour, both thecae fertile, upper thecae c. 1¼ mm long, lower thecae free, smaller than the upper ones, pale yellow to blue with white to blue pollen.

Staminodes 2, implanted opposite to the stamens, hammer-shaped, the filaments c. 1½ mm long, the head c. 1 mm.

Style gynobasic, filiform, glabrous, c. 10 mm long, with an apapillose bifid stigma, the upper lobe c. ¾ mm long, the lower lobe c. 1 mm long, white to blue.

Ovary with 4 white separate obovate parts, c. 1 mm × ¾ mm, each with an anatropic basally to axillary ovule, implanted on a slightly lobed yellowish disk, the lower lobe of which is largest.

Fruit triangular with rounded back in transverse section, elliptic to obovate in vertical section, glabrous, c. 2 mm × 1½ mm, brown, mucilaginous on wetting.

Notes

(1) In some of my specimens, a few flowers had developed into greenish white, velvety, globular galls of c. 1 cm diameter. This indicates most probably that diseases should be reckoned with, if ever *S. nilotica* were to become a crop plant in Ethiopia.

(2) As in most African *Salvia* species, the stamens of *S. nilotica* are mostly enclosed in the upper lip of the corolla (Hedge, 1974). But M. Verfaillie noted explicitly with her number 419 that pistil and stamens protruded.

(3) The species is very variable in shape, size, and indumentum of the leaves, in habit and in the indumentum of the stem.

(4) Where no type specimen can be traced, Art. 9 of the Code prescribes the indication of a description or plate. The combination of description and plate is not desired. I agree with Hedge (1974) that either the description or the plate of Jacquin, suffice for type and choose for the plate.

(5) Description was based on the following specimens.

Arussi	W slope of Mount Boruluccu, c. 25 SE of Asella, 3800 m: WdeW 8075; E slope of same mountain, 3600 m: WdeW 10072.
Beghemder	Between Kaba Wanz and Sankaber, Simien Mountains National Park, 3150 m: M. Verfaillie

419; Sankaber Camp, SMNP, 2200 m: M. Verfaillie 420; Simien Mountains, ? m: JdeW & M. G. Gilbert 178.

Harergie — Campus of the College of Agriculture, Alemaya, 2000 m: Bos 7563; between Deder and Hirna, 2500 m: Bos 8346; campus of the College of Agriculture, Alemaya, 2000 m: J. J. Kokwaro 499; c. 4 km W of Kulubi, 9 25 N, 41 41 E, c. 2450 m: JdeW 4202; foothills of Gara Mulatta, near Bedeno, 9 08 N, 41 39 E, 2300 m: JdeW 4359; NE side of Lake Alemaya, 9 24 N, 42 01 E, 2100 m: JdeW 4846; S face of Gara Mulatta, near Kurfachelle, 9 12 N, 41 46 E, 2600 m: JdeW 5092; c. 65 km from Asbe Teferi along the road to Kulubi, 2430 m: PJ 1301; Gara Mulatta, 2400 m: PJ 4284; road from Kulubi to Kulubi Church, 2350 m: SL 2315; campus of the College of Agriculture, Alemaya, 2060 m: SL 2378; Gara Mulatta, 2800 m: WdeW 9919; 1 km from Alemaya along the road to Kembolcha, 2030 m: WP 505; road from Alemaya to Asbe Teferi, c. 55 km from Alemaya, 2400 m: WP 859; road from Alemaya to Asbe Teferi, c. 36 km from Kobbo, 2500 m: WP 1258; 64 km from Asbe Teferi on road to Kobbo, 2380 m: WP 1327; road Bedeno-Langhe, 3 km from Bedeno, 2300 m: WP 2403.

Kefa — About 5 km from Bonga along the Jimma road, ? m: Bos 8411; 38 km S of Jimma, Shehi-Gojeb River, 2600 m: I. Friis, Getachew A., F. Rasmussen, K. Vollesen 1613; Bonga, near Roman Catholic Mission, 1870 m: PJ 2104, 1800 m: PJ 2298; about 25 km from Bonga along road to Dekja, 1950 m: PJ 5555.

Shewa — About 5 km N of Addis Abeba, 2400 m: WdeW 5924; about 15 km ENE of Addis Abeba, near road to Asmara, 2200 m: WdeW 6041; near tunnel between Debre Birhan and Debre Sina, c. 200 km NNE of Addis Abeba, c. 2900 m: WdeW 7377 and WdeW 9627; Mount Zuquala, c. 60 km S of Addis Abeba, 2900 m: WdeW 8591; W slope of Mount Wochacha, 15 km W of Addis Abeba, 3100 m: WdeW 9601.

Welega — About 20 km W of Lekemti [Nekempt], 1900 m: WdeW 7213.

Ecology

My specimens were collected at altitudes of 1800 to 3800 m . Hedge (1974) indicated the altitude range of *S. nilotica* to be 1000–3800 m. The plant seems to prefer some moisture: several of my specimens were collected near water or even in swampy places. It can be found in full sun and in the shade, along the road, on open grassy places and in forest understoreys. The soil types indicated on the labels of the specimens were brown loamy, red loamy, dark loamy, dark brown clayish (pH 6.5–7.8).

Husbandry

Like *S. schimperi*, the nutlets are collected from the wild.

Uses

The use of *Salvia* seeds in Ethiopia is comparable to that of linseed. The name 'entatiè vallahà' even means: flax of dark soils (Suzzi, 1905).

Chemical and physical properties

The nutlets investigated by Suzzi (1905) contained c. 275 g of oil per kilogram. This oil, either cold-pressed or extracted with ether, had a nice green colour and started

Table 62. Mass fractions of fatty acids in oil from seeds of *Salvia nilotica*. (After Bohannon & Kleiman, 1975.)

	Mass fr. (g/kg)
Palmitic	82
Stearic	45
Oleic	101
α-Hydroxyoleic	6
Linoleic	358
α-Hydroxylinoleic	43
Linolenic	287
α-Hydroxylinolenic	56
Arachidic	10

to solidify at −8 °C. It had a relative density of 0.932 and an iodine value of 159.3, and was highly drying.

Bohannon & Kleiman (1975) investigated a sample of oil of *Salvia nilotica* whose provenance they did not mention. Their results are given in Table 62, in which fatty acids with a mass fraction less than 5 g/kg have been omitted.

2.16 Sesamum indicum L. (2*n* = 26) Fig. 15

'Sesamum': Latinization of the Greek sêsamon, the fruit of the sêsamê plant.
'indicum': from the East Indies.

Linnaeus, Sp. Pl. ed. I: p. 634 (1753).
Lectotype: Linn. Herb. 802.3 from India (designated by Rechinger, 1978).

Synonyms

Sesamum orientale, Linnaeus in Sp. Pl. ed. I: 634 (1753)
S. luteum, Retzius in Obs. VI: 31 (1791)
S. oleiferum, Moench in Suppl. Meth. Pl.: 174 (1802)
Sesamum edule, Hort. ex Steudel in Nom. ed. 1: 769 (1821)
ibid. ed. 2, Vol. 2: 571 (1841)
S. brasiliense, Velloso in Fl. flumin., V.6, plate 90 (1827)
S. indicum var. *grandidentatum*
var. *subdentatum* },De Candolle in Prodr. 9: 250 (1845)
var. *subindivisum*
Anthadenia sesamoides, Lemaire in Fl. des Serres 2: 9 + plate 6 (1846)
Volkameria orientalis (L.), Kuntze in Rev. Gen. Pl. 2: 481 (1891)
V. sesamoides (Lem.), Kuntze l.c. p. 482 as *V. sesamodes*
S. foetidum, Afzelius ex Engler in Bot. Jahrb. XIX: 156 (1894)
S. indicum var. *integerrimum*, Engler in Bot. Jahrb. XXXII (1): 115 (1902).

Literature

1932: Hiltebrandt, Bull. appl. Bot., Genet., Pl. breed. IX(2): p. 1–114. (tax.)
1950: Baldrati, Trattato Coltiv. trop. subtrop.: p. 414–425. (agric.)
1953: Bruce, Kew Bull. 67: p. 417–429. (tax.)
1962: Mazzani, Monografia No. 3, C.I.A. Venezuela. (agric.)
1971: Weiss, Castor, Sesame, Safflower: p. 311–525. (agric.)

Vernacular names: selit, salid, sselit, in S Shewa: mencha (Amarinya); nime (Gambela); zedi, in Gursum sallet (Gallinya); hokusa, omezia (Gumuz, Beghemder); sinsin, sisin, sisim (Somalinya); angada, angoda (Tigrinya); semsim, simsim (Arabic); ufuta (Swahili).
Trade names: sesame[1], til, gingelly, beniseed, simsim (English); sésame (French); ajonjolí (Spanish).

1. The name sesame oil is sometimes given to oil obtained from the cruciferous seed of *Camelina sativa* Cr.

Geographic distribution (mainly based on Weiss, 1971)

Sesame is certainly one of the oldest oilseeds known. It has been in use for so long that it is impossible to indicate where and when domestication took place and thus where the plant originally came from. It was known to the Assyrians and even in their times it was known to be an old crop, as they believed the gods prepared a drink from it before the Earth existed. It was an important oil plant in many of the ancient civilizations of the Afghan–Persian–Iraq region like Ur and Babylon and the oldest records of the plant are those from Babylon and Sumeria, where it was known in 2350 BC. From this region, its cultivation spread eastwards and westwards. The spread to India and China must have taken place very early, as both areas now have a wide and characteristic genetic variability. It is not certain whether sesame was known in the first era of ancient Egypt, but it has certainly been known there since about 1550 BC. At later dates in the Graeco-Roman period, it was in common use in Italy, the Iberian Peninsula and N Africa. Despite its ancient use in Sumeria, it seems that sesame was not commonly grown in the Palestine region until the 2nd Century AD.

De Candolle in his 'Origin of Cultivated Plants' was inclined to believe that sesame came originally from the Sunda Islands. His opinion was based on a description of a sesame plant from Java, and on historic and linguistic arguments. The problem of the origin of sesame was generalized to the whole genus, without careful analysis of the different species and their groups of varieties.

Hiltebrandt (1932) based his studies on morphological, biochemical and physiological differences between groups of sesame and identified distinct morpho-geographic units. He reconstructed the history of the ecological differentiation of the species and of the different influences of mankind and concluded that the primary centre was not in Asia but in Africa, where more primitive types and the majority of wild *Sesamum* species can be found (Mazzani, 1962).

Vavilov (1951) noted the following centres: 1, the Abyssinian region including Somalia: the basic centre of the species; 2, the Indian region including Assam and Burma but excluding NW India: basic centre of the cultivated varieties; 3, the Chinese region: a secondary centre distinguished by dwarf forms; 4, C Asia including NW India, Afghanistan, Tajikistan, Uzbekistan and Tien-Shan: one of the centres of origin; 5, Near East (Turkey, Iran, Turkmenia): a centre distinguished by ssp. *bicarpellatum* Hilt.

The views of Hiltebrandt and Vavilov form the basis of the present common opinion on the origin of sesame. But Murdock (as cited by Westphal, 1975) indicates that sesame was brought into Ethiopia from the west around 3000 BC.

Sesame seems not to have been cultivated in Africa south of Ethiopia to any great extent until the 19th Century, when demand by Arabs and Indians created a market. Although commonly believed to have been reintroduced from India and Pakistan, cultivars of that origin have in fact proved not to be as successful as local types.

The Portuguese introduced sesame into Brazil, most probably from their Indian colonies, and later it became well established in S and C America. It now forms a common component of local agriculture, especially in Venezuela, Mexico and Colombia. Towards the end of the 17th Century, it was brought into the United States by slaves.

It is difficult to estimate how much sesame is cultivated because a high proportion of the product is consumed by local farmers. In fact, not more than about 10% of the crop enters world trade. The crop is grown from the Tropic of Cancer almost to the Cape of Good Hope, often in such scattered or small plots that total production cannot be calculated in Africa.

India and China are the major sesame producers of the world; in Africa, the Sudan is the largest producer, Ethiopia the second. The importance of sesame in international trade has diminished in favour of cheaper oilseeds, which are mainly used for industrial purposes.

Of the world's sesame, 60% is produced in Asia, but less than 2% of this total is exported. Africa too has a large internal market, but supplies about 80% of the world exports. The principal African exporters in order of magnitude are the Sudan, Nigeria, Ethiopia and Tanzania. Europe, excluding the Soviet Union, is the main importer of sesame seed.

Weiss states that sesame is cultivated mainly in the low-lying regions of Ethiopia, bordering the Sudan and Somalia. The main growing areas in Ethiopia are in the provinces of Harer, Welo, Beghemder and Tigre. In the N provinces, large farms specializing in oilseed production have been established.

I saw extensive stands of it along the banks of the Baro River too. The latter region is also mentioned by Westphal (1975). This suggests that W Illubabor is a main growing area. According to Kline et al (1969), soils along the Baro River are most suitable for crop production. The depth available for rooting is 1½ to 2 m. The soils are sandy clays to clayey loams, neutral to moderately acid, but mostly slightly acid. They have a medium to high content of organic matter, a high content of available phosphorus, and a low content of salt.

In Harer Province I only saw sparse plantings of sesame in and near the highlands. Westphal (1975) indicated that infrequent cultivation takes place in the sorghum-plough complex of Harergie, and Tozzi (1943) describes this situation in the Chercher Mountains near Mieso. Tozzi adds that Arabs used to cultivate it. This would indicate that the major production in this province comes from the banks of the rivers in the Ogaden Area. This area is mainly inhabited by Somali tribes who, also in Somalia, cultivate sesame on such places (Rocchetti, 1960; Tozzi, 1961). This area also contains one of the biggest Ethiopian irrigation schemes at Godie. However one does not see sesame plantings in and near Godie in the rainy season (Dr J. J. F. E. de Wilde, pers. commun.). My opinion is that sesame is certainly grown in that region, but that it is not a major producing area.

In the Provinces of Welo, Tigre, and Beghemder, most of the sesame I saw grew near the base of escarpments, but one can find sparse plantings of sesame all over the country if local conditions make cultivation possible. Westphal (1975), for instance, also mentions cultivation between Setit and Angoreb in NW Beghemder, and southerly in the adjoining area of the Gumuz people between Metema (Beghemder) and the Blue Nile. It is also infrequently cultivated in the grain-plough complex of E Kefa. Mrs Westphal (1975) encountered sesame on markets in eight of the eleven distinguished agro-ecological areas.

Surprisingly enough, the Borana, Ogaden and Tana regions, where sesame was not found on the markets, seem to suit sesame production better than some of the other areas. All three have a nomadic population which is highly dependent on its animals. There are few markets and the commodities there are little known.

Description

Habit herbaceous, annual, stout, erect, moderately leafy, moderately to well branched, (35)100–150(200) cm tall.

Root system well developed, strong tapering taproot with many laterals.

Stem firm, up to 1 cm diameter at base; square with ribs at each corner, less clear when young; soft pith; bright pale green; ribs (sparsely) pilose, more densely so on young parts and near axils; between ribs sparsely pilose to glabrous, glabrescent when older; characteristic hyaline glands present on all parts, except the oldest, mostly composed of 4 globular cells and a basal one, becoming white with drying ('globules').

Leaf petiolate, herbaceous; lowest leaves (sub)opposite, decussate, higher leaves mostly subopposite, highest leaves spirally arranged in 4 rows. On one plant, as many as 4-5 leaf forms may be present, from the base upwards:

(1) Ovate to broadly ovate leaves with acute (to acuminate) top, truncate (to obtuse) base, and entire or, at least near the base, crenate to serrate margin; (9)11–16(21) cm × ($5\frac{1}{2}$)7–10(12) cm with petioles 7–$15\frac{1}{2}$ cm long.

(2) Leaves with 2–3 broad (unequal) lobes with acute to acuminate tops, a truncate (to cuneate) base, and a coarsely crenate to serrate margin, at least near the base of the lower lobes, elsewhere entire; 13–17 cm × 10–13 cm with petioles 10–17 cm long.

(3) Trifoliate leaves; top leaflet petiolulate, narrowly obovate to narrowly elliptic with acuminate to acute top, cuneate base, and entire to serrate margin, where serrate at

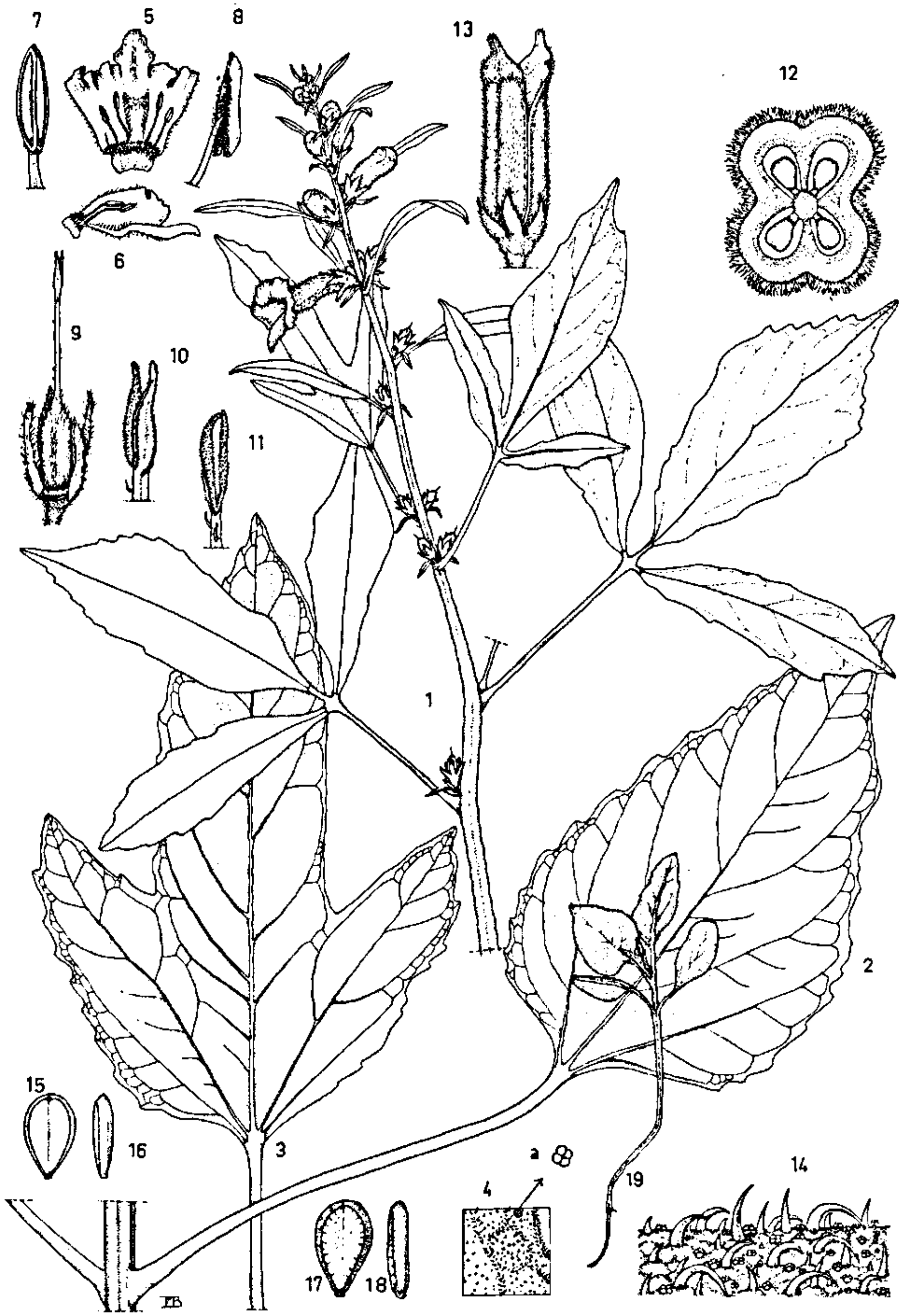
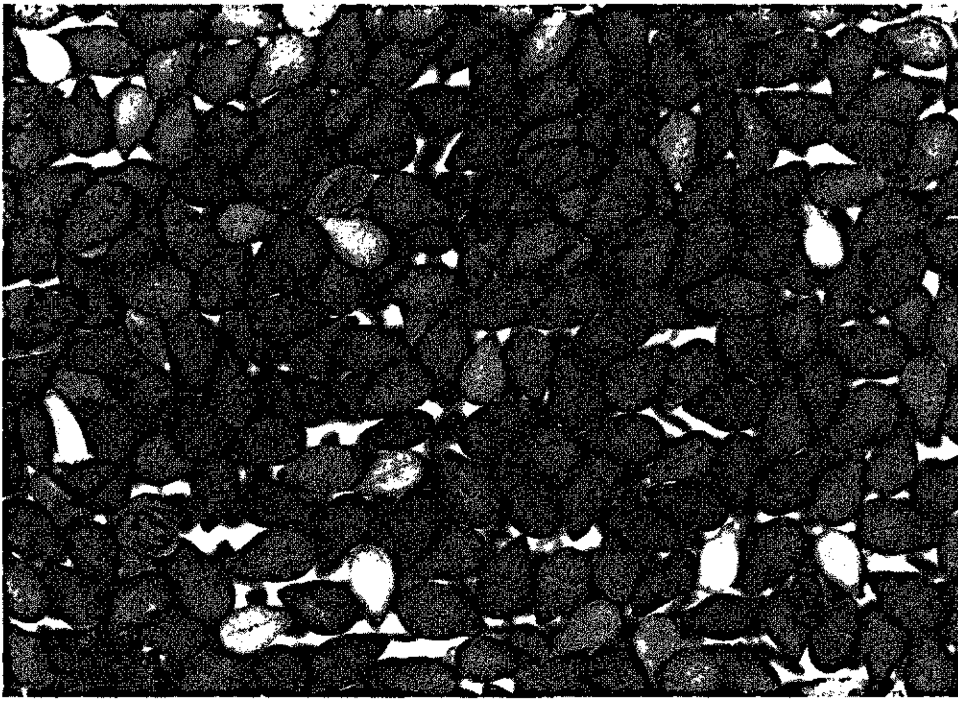


Fig. 15. *Sesamum indicum* L. 1. Habit, flowering branch (× ½). 2. Ovate basal leaf (× ½). 3. Three-lobed basal leaf (× ½). 4. Detail of underside of leaf (× 6), one gland ('globule') extra enlarged (× 48). 5. Corolla-tube laid open (× ½). 6. Corolla-tube, lengthwise section (× ½). 7. Anther introrse (× 3). 8. Anther laterally (× 3). 9. Pistil in calyx (one sepal removed) (× 1½). 10, 11. Stigma (× 5). 12. Ovary, cross-section (× 12½). 13. Mature fruit (× ¾). 14. Detail of fruit surface (× 24). 15. White seed, flat side (× 4½). 16. White seed laterally (× 4½). 17. Brown seed, flat side (× 4½). 18. Brown seed laterally (× 4½). 19. Seedling (× 1). 1–4, SL 1956; 5–12, SL 1958; 13, 14, WP 7494; 15, 16, SL 1510; 17, 18, SL 1053; 19, WP 755.



Photograph 24. *Sesamum indicum* seed, darkest mixture (SL 3; × 5).

least apically so; $3\frac{1}{2}$–7 cm × 9–17 cm, petiolule up to 2.2 cm. Side-leaflets oblique, narrowly elliptic to narrowly obovate with acuminate (to acute) top, obliquely cuneate base, and margin entire or serrate, at least near the apex of the lower side. The upper half of the lamina often does not reach the petiole; (6)$7\frac{1}{2}$–13(15) cm × (1.8)$2\frac{1}{2}$–5(7) cm, with petioles (4)$5\frac{1}{2}$–12(15) cm long.

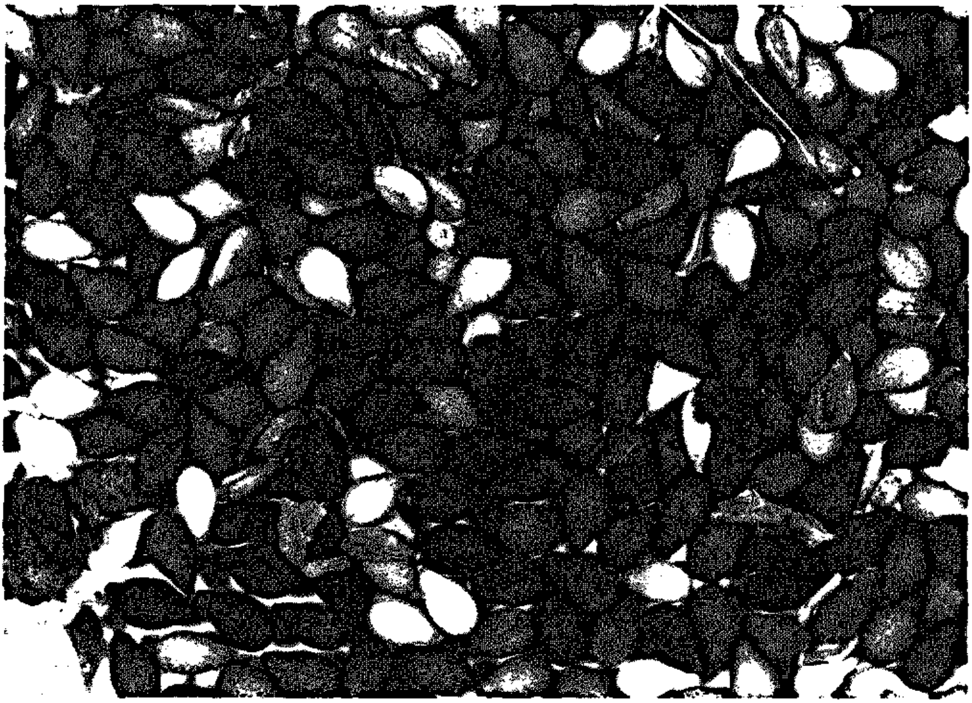
(4) Leaves with 2–3 lobes, often bearing the first flowers in their axils. Those leaves are deeper cleft and lanker than Type 2. They have an acute to acuminate top, a (broadly) cuneate base and entire to ± serrate margin; (6)7–$12\frac{1}{2}$(15) cm × ($2\frac{1}{2}$)4–12 cm on a petiole ($2\frac{1}{2}$)$4\frac{1}{2}$–9 cm long.

(5) Bracteolar leaves, narrowly elliptic to narrowly ovate, acuminate to acute top, cuneate base, entire slighthy undulating margin; ($5\frac{1}{2}$)7–12(15) cm × (0.8)1–$2\frac{1}{2}$(2.7) cm (fully grown), on a petiole ($\frac{1}{2}$)1–2(4) cm long.

Only Type 5 was present in all specimens and Types 3 and 4 were not found on specimens grown in Ethiopia.

All leaves densely pilose beneath on the veins and near margin with few globules as on stem, between veins sparsely pilose with many globules; above sparsely pilose, more densely so near margin, globules mainly on veins, much smaller than beneath. Petioles hemicylindric, canaliculate, at least at base; (densely) pilose, hairs longest near stem, few to many globules; pale green.

Flower in the axil of a bracteolar leaf, the first flowers are bigger than the later ones. Pedicel 3–4 mm long, pilose with globules, brownish to bluish dark green with



Photograph 25. *Sesamum indicum* seed, medium dark mixture (SL 325; × 5).

two lateral bracteoles less than ½ mm from base, narrowly ovate to linear, c. 3 mm × 0.5 mm, pale green, pilose, deciduous; in axil of each bracteole a yellowish, cup-shaped to disk-shaped gland, apically 5-lobed, diam. c. 1 mm, with short hairs. Calyx 5 slender lobes with acute top, slightly connate at base, c. 4–7 mm × 1–1½ mm, pilose outside, densely so near and at margin, hair c. 2 mm long, inside glabrous except at apex, there sparsely pilose, pale green, darkening towards apex. Corolla campanulate, horizontally flattened with a slightly bent and widened base and an undulate 5-lobed rim; c. 2–2½ cm long and c. 1½–2½ cm wide; lowest lobe widely ovate with acute to retuse top, revolute, c. 0.7–1.1 cm long, other lobes c. 1 mm long; outside pilose with globules, inside pilose only at the neck of widened base and on base of the large-lobed petal (Fig. 15. 5); lowest lobe with darker purple stripes but at base pale yellow, adjoining area of the tube also pale yellow, darkening to about half-way down the tube, from there to the base of the tube some purple-blue stripes, the other parts of the tube and lobes purplish white. Stamens 4, the upper 2 shorter than the lower 2, implanted in the ring of hairs in the tube; filaments subcylindric, glabrous, c. 8–9 or 12–13 mm long and c. ¼ mm diam.; white to slightly purplish; anthers with 2 yellowish to yellow thecae with introrse longitudinal dehiscence and a wide light-green (fresh) to brownish yellow (old) connective; at the transition of connective and theca a row of hairs and globules, absent near the apex; on top of the connective, a small ± ovoid glabrous yellow appendage; filaments implanted in dorsum, c. a third

Photograph 26. *Sesamum indicum* in field near Gambela, March 1983.

to half-way from the base; theca c. 1–1¼ mm × 3–3¼ mm; pollen white; between the upper stamens, a staminode of variable length, sometimes bent towards the base of the tube. Ovary superior; ± rectangular longitudinally and rounded to quadrangular in cross-section, c. 5 mm × 2 mm, with greyish, velutinous to woolly hairs, bicarpellate, 4-loculate by intrusive growth of parietal placentae; ovules central in the angle, anatropic. Style terminal, simple, subcylindric to 4-ribbed; glabrous, c. 9 mm × ½ mm, with bifid stigma, lobes elliptic with acute top, receptive area introrse, densely papillate; c. 3 mm × ¾ mm.

Fruit a 4-loculate capsule, c. 2½–3 times as long as broad, in cross-section rectangular, with 4 deep grooves, and a short triangular beak; stipe 4–5 mm long; densely covered with multicellular hairs ½–1½ mm long, and few to many glands (as on stem); greyish brown when ripe, dehiscent loculicidally from the top, one split introrse, one extrorse; (1.5)2.0–2.5(2.6) cm × (0.5)0.7–1.0 cm.

Seed ovate, flattened, the flat area of one side (upper side in fruit) mostly (partially) bordered by a well defined narrow ridge, that of the other side sometimes too; often slightly wrinkled, especially near the ridge; surface slightly to moderately rough, white, greyish, creamy or light to very dark-brown, often with vein-like darker discolorations; $1\frac{1}{2}$–$2\frac{1}{4}$ mm × $2\frac{1}{2}$–$3\frac{1}{2}$ mm × $\frac{1}{2}$–$1\frac{1}{4}$ mm.

Suzzi (1904 & 1905) found seeds from Eritrea to be longer but narrower than I found. Eritrean samples investigated by him, both white and brown, were c. 3 mm long, 2 mm wide, and 1 mm thick.

Seedling epigeal, forming a fine and extensively branched root system. Hypocotyl cylindrical, up to 6 cm long, smooth, very pale green, pilose with colourless, up to $\frac{1}{2}$ mm long hairs, less pilose to glabrous near both ends, with globules between, especially at apex (Note 3). Cotyledons: petioles very light green, 1–7 mm long, semiterete, sometimes grooved above, with hairs and globules as at the apex of the hypocotyl, usually less pilose beneath; blade (yellowish) pale green, broadly ovate, up to 12 mm × 9 mm, obtuse to shallowly retuse at top, truncate to obtuse and slightly cuneate at base, midrib basally with 2 strong laterals, and usually with 2 smaller laterals in the upper half, globules all over, sparsely pilose to glabrous above, pilose or glabrous beneath, with entire, ciliate margin. Epicotyl very pale green, up to 6 cm long, terete to slightly quadrangular, with 4 very shallow, longitudinal grooves, globules all over, pilose, less densely so or wanting in the grooves. First leaves opposite; petiole very pale green, up to 3 cm long, (densely) pilose, with globules; blade pale green, ovate to elliptic (seldom trapezium-shaped and constricted towards the top), up to 5 cm × 3 cm, obtuse to acute at top, obtuse to cuneate at base, the midrib with 5–7 pinnate laterals on either side, pilose and with globules as described above for the leaves of the flowering plant, margin densely ciliate.

Notes

(1) *Sesamum* L. is a genus of the *Pedaliaceae*. This family consists of about 16 genera and 64 species. Seventeen *Sesamum* species occur in Africa, two of which also grow wild in India (Weiss, 1971).

Bruce (1953) summarized the history of the genus. Since it was described by Linnaeus, the genus *Sesamum* has been divided by various authors into different genera or sections. By characteristics of the seed and the calyx, division into two or three taxa was proposed by different authors. Endlicher (cited in Bruce) divided the genus into two sections (*Eusesamum, Sesamopteris*), but later, presumably after seeing Bernhardi's proposal for three genera (*Sesamum* L., *Simsimum*, *Gangila*), he divided the genus into three sections (*Eusesamum, Simsimum, Sesamopteris*). De Candolle divided *Sesamum* into two genera: *Sesamum* L. and *Sesamopteris*. He also united the two cultivated species described by Linnaeus (*Sesamum indicum* and *S. orientale*), and named it *Sesamum indicum*. Bentham & Hooker distinguished three sections, which were taken over by Stapf. Stapf later revised his ideas and presented a division into two sections. According to Bruce (1953), the limits of the sections of the genus *Sesamum* are unsatisfactory, and little can be gained by maintaining them.

Interspecific hybridization within the genus has been widely studied. Several wild *Sesamum* species are cross-fertile and cross with *S. indicum*. In crosses between species with the same chromosome number, proportion of seed set was frequently high and the hybrid was usually fully fertile. The literature on cytology is rather confusing, mainly because a good revision of the genus is lacking. There is a need for such a comprehensive work, with an indication of what further work is necessary (Weiss, 1971).

(2) There are many sesame cultivars in the world differing greatly in size, habit, colour of flowers and seed characteristics. However practically all vegetative characteristics of a sesame cultivar are subject to wide variation under different ecological conditions. The most stable characteristics are the colour of the corolla and the colour of the seed-coat (Weiss, 1971).

African sesame cultivars tend to ripen late in the season (Weiss, 1971); those of Ethiopia are characterized by extreme lateness (Hiltebrandt, 1932). Weiss also mentioned that African sesames had above-average oil contents, but on this subject different views are found in literature. Hiltebrandt, for instance, found the region with maximum oil contents to be situated in Palestine, while Mazzani (1962) mentioned India, and Yermanos (1972) did not find a clear-cut pattern at all in the geographic distribution of seed-oil content.

Mazzani (1962) indicated that sesame cultivars from the African continent were commonly more resistant to bacterial infections and had a higher potential production than cultivars from other parts of the world.

(3) The type of branching is characteristic for the cultivar. Division into broad classes of 'branched' and 'unbranched' habits is satisfactory and in general use (Weiss, 1971).

The sesame I encountered in Ethiopia should be classified as 'branched'. This characteristic is particularly visible if the plants are cultivated under good conditions.

Although differences in growth habit and flower induction were noticed under long-day conditions in a regulated Wageningen greenhouse, those differences disappeared almost completely under short-day conditions. This suggests physiological differences in Ethiopian sesame. The small number of data on habit and flower colour do not suffice to distinguish cultivars, although their existence is likely.

The only characteristics in which there were clear differences were seed colour and the distribution of hairs on the seedling. The seed characteristic is apparently correlated with the geographic area the seed originates from. The following two groups could be distinguished:

1. 'Brown', originating from E, C and N Ethiopia, with one sample from Jimma (SL 116)
2. 'White', roughly restricted to the area W of the line Gonder (Beghemder) to Jimma (Kefa).

The brown-seeded group consists of mixtures of very dark-brown, dark-brown, pale-brown and very pale-brown seeds. Within it, samples with only about a tenth of their seeds in the lightest colour (Sl 3, SL 21, SL 31, SL 43, SL 116, SL 181, SL 243, SL 373, SL 426, SL 427, SL 504, SL 600, SL 640, SL 678, SL 712, SL 981, SL 982, SL 1053, SL 1079, SL 1159, SL 1300, SL 1341, Bos 8042, WP 94, WP 4014) were easily distinguishable from samples consisting for about a quarter to a third of the lightest-coloured seeds (Bos 8361, SL 325, SL 547, SL 641, SL 739, SL 753, SL 769, WP 2994). Intermediate samples were not found.

As the light-coloured seeds are fully mature, and usually germinated well, the colour is apparently brought about by genetic differences, and not by differences in ripeness at harvest.

The colours were compared with the Colour Chart of the Royal Horticultural Society of London: very dark-brown matched 200B, dark-brown 165A or 200D, pale-brown 164A or 165B and very pale-brown 164B or 165C.

The white-seeded group consists of mixtures of white, very pale-brown and pale-brown seeds. The pale-brown colour of this group is more greyish green than the pale-brown colour of Group 1. Group 2 consists of SL 55, SL99, SL 929, SL 1428, SL 1487, SL 1510, SL 1513, SL 1535, SL 1547, SL 1567 and WP 3389.

On the RHS Colour Chart, white matched 159A, 159B, 159C or 164D, very pale-brown 164B, 165C or 165D, and pale-brown 199B or 199C.

In my material, two types of hairiness of the seedling could be seen. In one group of specimens, the hypocotyl was clearly pilose up to the cotyledons bearing relatively few globules. The cotyledons of those plants had relatively densely pilose petioles and hairs on the lower surface of their blades (SL 3517, SL 3519, SL 3520, SL 3542, SL 3543, SL 3545, SL 3921, SL 3922, SL 3925, SL 3962, WP 241, WP 311, WP 5704, WP 5705). In the other group, the apical part of the hypocotyl was glabrous or occasionally hairy but densely covered with globules. Such plants had cotyledons with a few hairs on the petioles and a glabrous but globule-bearing lower surface of their blades (SL 3516, SL 3518, SL 3544, SL 3923, SL 3924, WP 755, WP 7492). Only 2 seed samples gave rise to seedlings of both types: SL 116 (corresponding with seedlings SL 3518 and SL 3519), and SL 678 (corresponding with SL 3920).

A correlation could not be established between the type of hairiness of the seedling and the geographic origin of the seed samples, nor with the hairiness of the plants in later stages of growth. No relation was found between the seed colour and the hairiness of the seedling, but the seedlings grown from white-seeded samples nearly all belonged to the first group, i.e. with pilose hypocotyls; the second group consisted mainly of seedlings grown from brown-seeded samples.

(4) Hiltebrandt (1932) studied 9 seed samples from Eritrea and an equal number from the rest of Ethiopia; all samples were brown-seeded. He grew 272 plants from the 18 Ethiopian samples, and compared them with 4352 plants grown from 374 samples from other parts of the world (mainly from the Middle East and adjoining Soviet Republics, India and China). He concluded that in Ethiopia there was little variation in the characteristics he studied, except for the pubescence of the stem. He found 14% of the plants from Eritrea to have a glabrous stem, while the others and all those

from the rest of Ethiopia were shortly pubescent.

He divided his plants into 2 subspecies and 111 varieties. In view of the number of plants he studied, this taxonomic diversity seems exaggerated, unless his varieties be taken as cultivars. Even then, sesame being subject to natural hybridization, most cultivars are mixtures of similar plants. This renders such a detailed division more a description of all plant phenotypes found, than a varietal distinction.

Hiltebrandt contradicts himself on the number of varieties he found in Ethiopia. His Table 14 (p. 87–88) indicates that he encountered 2 varieties from Eritrea and 1 from the rest of Ethiopia, whereas his Table 15 (p. 98) indicates the presence of only one variety in each of the regions.

Hiltebrandt's findings about Ethiopian sesame accord with my own, but I found more seed colours than he did (Note 3). The seed samples Hiltebrandt studied even led him to conclude that sesame seed from Africa was brown, with few exceptions (p. 41,47). This is not the view of Greenway (1944), who indicated that the majority of African sesame cultivars had light-coloured seeds. But he agreed with Hiltebrandt that Ethiopian sesame was characterized by brown ones.

As Hiltebrandt compared sesame from Ethiopia and from elsewhere, he could add that the the corolla was 'normal shaped', that the fruits were 'average-sized', had well developed dissepiments, and are laxly arranged along the stem, the stem being relatively thick. He also remarked that the plants from Eritrean seed samples were shorter than those from other Ethiopian samples, and that both remained slightly shorter than the average height of the whole sesame collection he studied.

(5) According to Baldrati (1950, p. 416), Ethiopian and Somalian seeds of *S. indicum* are more like those of *Sesamum radiatum* Schum. than sesame seeds from other parts of the world.

(6) In a particular area, a specific seed colour may predominate, not through deliberate selection but through environmental influences (Weiss, 1971).

(7) Description was based on the following specimens.

Arussi	market at Bedessa: SL 678.
Beghemder	market at Gonder: SL 55, SL 929.
Gojam	market at Dejen: Sl 753, SL 769; market at Lumane: SL 739.
Harergie	grown at Alemaya College: PJ 1902–1903, PJ 2785–2786, PJ 3409–3410, WP 241, WP 311, WP 755; market at Alemaya: SL 21, WP 35; market at Asbe Teferi: SL 3; 100 km E of Asbe Teferi: F. G. Meyer 8712; market at Assebot: SL 712; market at Bedeno: SL 325; market at Chelenko: SL 243; market at Deder: SL 373; market at Dire Dawa: WP 94; field 10 km W of Dire Dawa: WP 1225; market at Feddis: SL 181; market at Gelemso: SL 640–641; market at Gursum: PJ 4467; market at Harer: Bos 8042, WP 78; market at Karra: SL 600; market at Kuni: SL 547; market at Mulu: SL 426–427; market at Waichu: SL 504.
Illubabor	market at Buro: SL 1510; market at Gambela: PJ 5109, SL 1513; market at Metu: SL 1487; 5 Km SW of Teppi: F. G. Meyer 8898.
Kefa	market at Agaro: SL 99; market at Chena: SL 1428; market at Jimma: Bos 8361, SL 116.
Shewa	market at Nazret: WP 2994; field between Nazret and Metahara: SL 138; market at Robi: SL 1159; market at Shashemane: SL 1300.
Sidamo	market at Awasa: SL 1341.
Welo	market at Bati: SL 1053, WP 4014; market at Dessie: SL 1079; market at Haik: SL 43;

	market at Kembolcha: SL 981–982; market at Robit: SL 31.
Welega	market at Alem Teferi: SL 1547; market at Bekejama: SL 1567; market at Dembidolo: SL 1535; market at Nekempt: WP 3389.
Grown at Wageningen	SL 1953–1962, SL 1966–1970, SL 1977–1991, SL 3516–3520, SL 3542–3545, SL 3918–3919, WP 5704–5705, WP 7491–7494.

Ecology (data mainly from Weiss, 1971)

1. Temperature

Sesame is sensitive to practically all ecological factors. The influence of sowing date and variations from the usual weather are therefore crucial.

It is a crop of the warm regions of the tropics and subtropics. Its main distribution is between longitudes 25° N and 25° S but it can be found growing up to 40° N and 35° S.

Its upper altitude is commonly 1250 m, although local cultivars are adapted to greater altitudes. These high-altitude types are usually small and less branched; they grow quickly and frequently have only one flower per axil; their seed yields are low. The plants I saw near the Sudanese border (altitude c. 600 m) were indeed much more vigorous and branched than the plants from higher altitudes, but when grown in a greenhouse at Wageningen, the differences disappeared almost completely. Within cultivars, increasing altitude always lowers yields and oil content.

In Ethiopia, sesame is mainly produced in the higher part of the altitude range mentioned by Weiss. Westphal (1975) indicated that sesame in Ethiopia was grown at altitudes of (500)1000 to 1300(1500) m. This range is correct in my opinion, but in view of the altitudes of some markets I visited, the geography of the regions and the distances sellers could possibly walk in half a day, I am inclined to raise the upper limit from 1500 to 1700 m. Tozzi (1943) mentioned that at Bacà (near Mieso) small plantings could even be found at 1800 m.

Comparing the remarks of Weiss on 'high altitude types' with the notes of Miss D. van Ballegooijen and Mr R. Henneman on the growth of plants from Ethiopian seeds under long-day and short-day regimes, one gets the impression that the number of branches in Ethiopian specimens depends mainly on daylength (Note 3).

Sesame requires fairly high temperatures during growth to produce maximum yields. The temperature-time product required during the total period of growth is 2700 °C·d. A temperature of 25–27 °C encourages rapid germination, initial growth and flower formation. Should the temperature fall below 20 °C for any length of time, germination may be inhibited or will at least be delayed. A temperature below 18 °C after emergence severely retards growth. These seed-bed requirements may be a major factor limiting the planting period, during which the crop can be sown to produce good stands. A seed-bed temperature of 24 °C is normally adequate provided that wet cloudy periods are not expected after sowing. However seed will germinate up to seed-bed temperatures of 32 °C. Smilde (1960) even found optimum temperatures for germination to be more than 30 °C.

Ideal seed-bed conditions will not be encountered in the major part of Ethiopia. In the highlands, the temperature of the seed-bed may be too low in the wet season, and adequate but too dry in the dry season. Optimum conditions will only occur locally. In the hot lowlands, optimum conditions may exist only while the soil is wet.

Vernalization has been little studied in sesame. The trials were small and somewhat contradictory. According to Chakravarty (1958, cited by Smilde, 1960), chilling of the seeds does not markedly shorten the vegetative period. Smilde (1960) reported that flower initiation was usually later in the cold-treated groups than in the control groups. Dikshit (1976) found earlier flowering of the vernalized plants of one of two cultivars. Unfortunately, Smilde and Dikshit used different chilling temperatures, cultivars and growing conditions, and terminated their experiments at different stages. Dikshit studied the whole growing cycle. He found an increased plant height and a higher seed yield in most of the treated plants. One cultivar showed also an increase in seed-oil content. Smilde terminated his investigation after 60 days. He found that, with later initiation, the flower was situated at a higher node on the plant. The height above ground of the first flower in sesame is highly and significantly correlated with high yields (p. 267) so that the findings of Smilde and Dikshit may agree on that point.

During vegetative growth, higher temperatures are beneficial. Heat is probably the major climatic factor influencing height. Flower initiation is optimum at constant temperatures of 24–27 °C. Delays with higher temperatures during the day are counteracted by lower temperatures at night and lower ones during day are countered by higher ones at night.

Low temperature at flowering can result in sterile pollen or premature flower dropping. Too high temperatures during flowering reduce fertilization and the number of fruits.

Higher temperatures during vegetative growth do not occur for long in the Ethiopian Highlands, but are frequent in lower areas. Near the Baro River, temperatures of c. 40 °C are common. As far as I could see, these high temperatures did not hinder seed-setting.

A frost-free growing period of c. 150 days is required. Severe frost at maturity kills the plants and reduces seed and oil quality. A markedly lower content of sesamolin and sesamin in oil from frozen seeds has been observed.

I never heard of frost damage to sesame in Ethiopia, perhaps because frost does not occur in the areas of sesame cultivation during the growing season. In areas where frosts occur, in Ethiopia in valleys above c. 1000 m, only quick-growing cultivars are grown and are harvested by the time of the frosts around December.

2. Water

Sesame is a fairly drought-resistant crop, but this does not mean good growth and yields can be obtained on a very low rainfall. Once established, however, sesame can withstand more severe water stress than many other cultivated plants. If soil moisture is adequate, the crop flourishes and is almost independent of rainfall. An example of cultivation almost exclusively on soil water is the cropping on banks of rivers after a flash flood. A common method of cropping is also to impound rain-water in fields, to allow it to percolate and then to sow sesame in the drying surface soil. In areas where most of the rain falls when the temperatures are too low for sesame to be grown successfully, planting is delayed until the soil temperature is higher. The crop then grows almost entirely on conserved soil moisture and, with only an odd shower during early growth, on fertile soils good yields are obtained. According to Baldrati (1950, p. 419), the absorption of dew can also be a considerable source of water for sesame. This may be valuable where cultivation takes place at minimum water supply and where the air transports moisture from elsewhere.

Sesame plants that have the first part of their cycle in a humid period are badly prepared for dry periods in later stages of their life. They make more stomata on their leaves than plants that grow under relatively dry conditions from the very beginning (Mazzani, 1962).

Usually a rainfall of 300–750 mm is considered necessary for a growth cycle. In the lower range, a fairly fertile and well prepared soil is necessary and the seedlings are susceptible to local drought. In the higher range, the soil should be well drained. If more water is available, other crops are planted.

Sesame is extremely susceptible to waterlogging. Heavy continuous rains during growth greatly increase the incidence of fungal diseases. In areas with such rainfall, good crops are possible if the soil drains freely enough to avoid standing water. For maximum yields, the best relative distribution of rainfall is 34% from germination to the first flower bud formation, 45% from the first flower bud formation to main flowering and less than 20% from main flowering to maturity (before the fruits start opening).

When grown in areas with a short but intense rainy season, sesame is best planted after the main rains have fallen and when soil temperature has risen.

The two stages that are most sensitive, both to excess and to shortage of water, are seedling and flowering. The seedling is so susceptible to drought that planting techniques may have to be modified where showers, after emergence, are likely to be scattered and erratic. Baldrati (1950, p. 419) indicated that 160–175 mm of rain during the first month after sowing was sufficient. He saw experimental plantings at Agordat (altitude 500–1000 m, Mesfin, 1970, Map 11). There, sowing in the beginning of July gave excellent results. The precipitation of July and August together is c. 170 mm, the average annual rainfall being 400–500 mm (Baldrati, 1950; Mesfin, 1970, Map 26).

At flowering, an incorrect amount of water will greatly reduce yield. Heavy rain at flowering will drastically reduce yields. If cloudy wet weather persists for any length of time, crops can fail. But when sesame is grown under irrigation, one watering at the commencement of flowering often gives higher yield than one at any other time of plant growth. A further watering when fruit is setting makes little difference to yield.

The rate of water uptake by sesame and the amount of water required for the various stages of the plant's growth have not been so thoroughly studied as in other crop plants, mainly because of the very large number of local cultivars and their markedly different behaviour under similar ecological conditions.

Much more detailed information is required on the factors affecting water uptake and utilization by the plant if optimum use is to be made of irrigation water. Usage is often empirically derived and suited only to local conditions.

Under irrigation, substantial watering before planting is preferable to application immediately after emergence. Although highest yields from sesame are obtained when the crop is grown under irrigation in arid regions, introduction of irrigation in a certain locality often means that results with the local sesame cultivar are disappointing and another crop is chosen. With improved cultivars, one can often get a very good yield of sesame. In trials at the Melka Werer Research Station on the Awash, for instance, variety T85 yielded 1410 kg/ha of seed when given 100 mm of water 5 times at 3-week intervals. The effective rainfall during the growing season was 98 mm (Amare Retta, 1976).

Within the whole of Ethiopia, except for the extreme north, northeast, and east, the average annual rainfall is above the minimum as indicated by Weiss (Mesfin, 1970, Map 26; Westphal, 1975, Map 3). Thus water could not be the limiting factor for the major part of Ethiopia. In some of the drier areas, the presence of rivers should make cultivation possible. Of course the rains influence the sowing date. In areas where the rain is near the lower limit, sowing will proceed at the onset of the rains, whereas in areas with abundant rains, sowing will be delayed towards the end of the rainy season. For cultivation on the banks of rivers, sesame can be sown even after the rainy season, when the water of the river has drained off the fields.

Near Jijiga, I saw a clever way of exploiting rain-water to the utmost. On a slow sloping terrain, long shallow ditches had been dug with their outlets in a diked field to collect running water.

3. Soil

Although one can obtain high yields from sesame crops in suitable conditions, sesame is not generally grown under these conditions. Rather infertile sandy soils, frequently slightly saline and unirrigated, are more often used.

Sesame grows well on a variety of soil types but it thrives best on those that are moderately fertile and freely drained. Chemical composition seems to be less important than water-holding capacity as the plant is extremely susceptible to even short periods of waterlogging at any stage of growth. The wide range of soils on which sesame can be grown reflects the diversity of local types with their specific adaptations rather than the adaptability of any one cultivar.

Shallow soils with an impervious subsoil or saline soils are not suitable. In hot places, the temperature of shallow soils can affect root growth. Plant growth is then often more stunted than would be expected if lack of soil moisture were the only cause.

Sesame is extremely sensitive to salinity; salt concentrations that have little effect on safflower or cotton are fatal to sesame, but there is a considerable variability in this characteristic. The soil should preferably be neutral, but soils with a pH of 5.5–8.0 are suitable; at higher pH, soil structure becomes overriding. The rather acid tropical red earths are generally not suitable for sesame production.

On the lighter more gravelly or sandy soils in the drier zones, growth and yield are often depressed, mainly because of their poor moisture retention. The low average yields, often quoted for such areas are rather an indication of low soil fertility than of yielding capacity. That such soils are often cropped with sesame, as in Ethiopia, is not because they are the most productive, but because other crops grow even worse. More fertile soils are usually sown with sesame only in districts where water becomes the limiting factor for other crops. According to Mazzani (1962), sesame needs much more water on poor soils than on rich ones to produce an equal amount of dry matter. Unfortunately he does not indicate whether he means total dry matter of the plant or only that of aerial parts.

The soil type and soil moisture considerably influence the relative rate of root growth. The shape of the root system of a particular cultivar can vary greatly with soil conditions. Roots develop more profusely in sandy than in clay soils. The drought resistance of the plant is partially due to its widely ramifying root system. Its susceptibility to standing water has reduced the value of the crop on many large irrigation schemes, which are frequently situated on semipermeable clays.

The fertilizers most frequently applied to smallholder crops are organic. They are usually effective in increasing yields of the local cultivar and are of general benefit for all crops grown in the rotation. Artificial fertilizers with sesame are rare, so little is known about its fertilizer requirements. As Weiss has shown on several occasions, fertilizers, especially nitrogen topdressings, have a pronounced effect on the appearance of plants on poor soils. Yermanos (1971) advises the same type and amount of fertilizer as is normally used for cotton in the area.

One reason that fertilizers often do not have the expected result is the adaptation of the local cultivar to local conditions. Altering these conditions mostly makes another cultivar necessary. Genetic and environmental influences that increase protein content of the seed adversely affect oil content. Perhaps protein synthesis is favoured at the expense of oil synthesis as the nitrogen supply to the seed increases.

Smallholders in Ethiopia rarely apply fertilizers to the crop. Observation plots of the Ministry of Agriculture have demonstrated that phosphate can often profitably increase yields but the low standards of husbandry generally preclude its use.

In some areas of Ethiopia, it is customary to burn the soil after some years of cultivation. This practice almost quadruples available phosphorus and makes a moderately acid soil neutral (Kline et al., 1969).

In Venezuela, cultivation of sesame on the same field for several successive years compacted the soil to such an extent that the soil dried quicker. As it is difficult to restore the condition of the soil, sesame seems less suitable for continuous cropping (Mazzani, 1962). In view of the variety of crops in traditional agriculture and the role of sesame in it, soil compaction caused by the crop will not create problems in Ethiopia but the effect may become important in large single-crop schemes.

4. Light

Sesame is basically a short-day plant. Plants exposed to short days flower earlier, grow less vegetatively, bear more fruits and show less trifoliation of the leaves than plants grown under longer days (Weiss, 1971). Day-neutral cultivars exist (Smilde, 1960; Kotecha et al., 1975). This is also clearly visible in Ethiopian sesame (Note 3). With a 10-h light phase, sesame will normally flower in 42–45 days, but many cultivars have become locally adapted to other light periods. If cultivars are transferred to areas with a similar daylength but different rainfall or temperature pattern, there is frequently considerable variation in growth and yield from that in their provenance. According to Kotecha et al. (1975), most of the variability in reaction to light is due to genetic effects, at least 3 loci being involved. Weiss (1971) described a trial over some years with several cultivars, which proved that shorter days generally result in a lower oil content of the seed.

The occurrence of adaptive reactions to shade, and also the change in productivity and in oil content of the seed, indicate that light intensity has a significant effect on habit. However rainfall has a major modifying influence on the effect of light and there is evidence that temperature differences have a modifying effect too. Sesame from higher latitudes is usually less sensitive to daylength than that from lower latitudes.

Sesame can be shaded by intercropping with taller plants. Slight shade can be beneficial in the seedling stage, but in later stages it reduces yield. The greatest reduction in yield and oil content of seeds is with suboptimal light from initiation of the primordial flower buds up to formation of pollen tetrads. The spectral distribution of the light is important, as was shown in a trial. The content of oil in seeds increased with increasing photophase beyond 10 h, provided that the light was natural daylight. Photophases with various ratios of artifical and natural light produced oil contents directly related to the natural daylength component (Kluijver & Smilde, 1960).

As was shown in greenhouses in Wageningen, sesame of Ethiopian origin usually reacts strongly to light phase. With natural summer days of c. 16 h at Wageningen, the plants hardly came into flower and sometimes even showed malformed axillary leaves instead of flowers (Note 3).

5. Other factors

Sesame is susceptible to damage by strong winds after the main stem has elongated. It is highly susceptible to hail damage at all stages of growth and recovery is slow.

Development of the plant (mainly based on Weiss, 1971)

Sesame germinates moderately slowly and the seedlings have a slow initial growth until they reach some 10 cm height. Afterwards, they grow rapidly and can quickly shade out most weed seedlings. According to cultivar and especially ecological factors, the first branches may start developing when the plants are 25 cm high. During the complete cycle of the plant, the main stem reaches higher than the tops of the side-branches. In most of the herbarium samples collected in Ethiopia, branching was only first order, whereas plants grown from Ethiopian seed in a Wageningen greenhouse bore branches of second order too.

The pubescence of the stem is variable within but especially between cultivars. There is probably a correlation between this pubescence and the drought resistance of the cultivar. The amount of branching often indicates the maturing habits and drought resistance of the cultivar; generally cultivars that branch little mature early, whereas tall branching cultivars mature late and resist more drought.

Leaves on sesame plants can be very variable, both on the same plant and between cultivars. All leaves are inclined to be pendulous but the length of the petioles is also variable. Though generally dull darkish-green, plants may be much lighter and leaves sometimes have a yellowish tint. The arrangement of the leaves is variable. It affects the number of flowers, and thus the yield per plant. Decussate arrangement of leaves encourages multiple flowering.

The flowers arise in the leaf axils on the upper parts of stem and branches. They usually occur singly, as in the inspected Ethiopian samples, but groups have been reported in the literature from other parts of the world. The number of the node on the main shoot at which the first flower arises is characteristic of a cultivar and is highly heritable, though influenced by the environment. With close cropping, the first flowers are borne higher up the stem than with wider spacings. A longer light phase can induce this phenomenon too.

The flowers open early in the morning, wilt after noon and usually shed in the evening. The anthers release their pollen shortly after the flowers open. The stigma becomes receptive the day before the flower opens and remains so for a day after opening. Sesame is usually self-pollinated but insect pollination is common. Under field conditions, about 5% of the seeds are the result of a natural cross, but lower and higher values have been found (Weiss, 1971; McGregor, 1976). In breeding trials in Texas, a distance of 160–320 m between two fields was sufficient for almost complete genetic isolation of the fields. Although depression of vigour as the result of inbreeding is not apparent in sesame, trials with crosses between parent plants from different origins showed that hybrid vigour was usually present, particularly in seed yield.

Under optimum conditions, the plants produce an extensive much-branched fibrous root system. There is a well developed taproot, but it is not conspicuously elongated. There is a relationship between habit of vegetative growth, region of origin of a cultivar, and shape and extent of normal root system. Root growth reflects aerial growth to a certain extent: roots of single-stem cultivars usually elongate quicker and roots of branching cultivars spread wider.

The crop is ready for harvest 80–150 days after sowing, according to cultivar. At maturity, stems and leaves often turn from green to yellowish at first, then to a reddish tint. The plants are usually cut when yellow.

The seeds from fruits in lower axils seem to be significantly bigger than those from higher axils. High seed yield is correlated with tall branched plants that flower and ripen late, bear many flowers and fruits relatively high above the soil, and produce many seeds. The size of the seeds is less important than their number (Weiss, 1971; Gizouli Osman & Khidir, 1974; Delgado & Yermanos, 1975). Seed yield does not seem to be related to oil content. Thus selecting tall plants will generally result in high seed yield but not necessarily in high oil yield (Mazzani, 1962).

Under favourable conditions, a sesame plant forms 80–100 fruits, but plants with 400 fruits have been reported (Baldrati, 1950, p. 424).

Husbandry (main source: Weiss, 1971)

Sesame is still mostly produced in a traditional way. Modern cropping on a commercial scale had only limited success because of the high losses at harvest and therefore the high labour requirements. The average oil yields frequently quoted as evidence of the crop's inability to compete are misleading, however. That it produces less under existing cultivation cannot be denied (Table 63). What is usually lacking in these comparisons is an indication of the conditions under which the crop was grown. This is invariably to the disadvantage of sesame, for it is frequently grown in places or on soils unsuitable for other crops like peanuts. When sesame and peanut are grown under similar conditions and the newly developed high-yielding indehiscent cultivars of sesame of high oil content are sown, a different relationship emerges. The average yield of sesame seed in the world is c. 300 kg/ha (van Rheenen, 1973), but seed yields of 2300 kg/ha were reported from Venezuela (Varma, 1958) and new cultivars from Mexico have even yielded c. 2750 kg/ha (Samuel Muñoz Burgos, 1978). Thus much higher yields of sesame seed and oil are possible than are presently obtained. The quality of the oil would soon gain it a place in international trade if the price were competitive.

Sesame can be stored easier than peanut and the losses are less. Weiss was sure that sesame could often be grown with greater profit to producer and producing

Table 63. Estimated yields of oil from principal oilcrops of the world (after Weiss 1971, p. 324).

Crop	Yield (kg/ha)	Crop	Yield (kg/ha)
Peanut	270	Rape	185
Sunflower	225	Sesame	140
Soya	200		

country, provided the necessary official support and encouragement be forthcoming.

Smallholders usually save seed from the harvest for sowing the following season and seldom purchase it annually. Traditionally, an unselected portion of the harvested seed is retained for planting. Where the whole crop is retained for domestic use, the part remaining at planting time will be sown. Such seeds may be a mixture of many colours and strains. They vary considerably in such characteristics and in potential yields. Rapid increases in yield can often be obtained by simple selection on local cultivars. The quality of the seed will often be moderate, containing unripe and immature seeds. The difficulty in cleaning small particles of soil from sesame seed produced by smallholders is notorious and such contamination is invariably followed by infection with fungal diseases. Even though the crop is stored with great care in several countries like India and Indonesia, viability is poor. There it is kept in the driest part of the house, mixed with wood ash and covered by strong smelling herbs like *Tagetes minuta* L. to repel insects. With the introduction of non-shattering cultivars, storage facilities and seed dressings become even more critical as these tend to take longer to emerge than the shattering cultivars.

In airtight containers, seed remained viable after being stored for three years in Madras (India). In the United States, germination of machine-threshed seed, which is often slightly damaged, was reduced from 97 to 65% after six days and to 59% after 170 days. Trials have shown that the seed should be very dry to keep well. With a mass fraction of moisture of 4%, seed viability was essentially the same after two years, even if it was stored at a temperature of 32°C. The data showed that for safe storage 10% moisture is too high at any temperature, and even in sealed metal cans at 7% moisture, temperatures above 10°C drastically reduce viability.

Much sesame is grown as an intercrop and in land preparation no particular attention is paid to the requirements of individual crops. Usually the tillage required for small grains suffices for sesame grown on a commercial scale. Breaking of hard layers in the root zone is recommended. Level land is important to ensure that no splashes are formed. Lands may be ridged to prevent damage in those areas where heavy rain is common.

Brown-seeded cultivars are preferred where sesame is grown mixed with tall-growing cereals, since they withstand shading better; white-seeded cultivars produce better in pure stands and mixed with small grains (Baldrati, 1950, p. 417).

Tillage for hand-grown crops is as varied as the cultivars planted. As for other crops with a long history of domestication, traditional methods have evolved that are well suited to local conditions and tillage implements. In Africa south of the Sahara, sesame is grown almost wholly be hand. The land is broken with a hand-hoe immediately after the onset of the rains or even earlier if the soil is not too hard to be worked. It is then broken down to a reasonable tilth during the weeding before sowing.

The depth of planting should be uniform for maximum yields; it is usually 2–5 cm but may be as much as 10 cm. Seed should be planted shallower in light soils than in heavy soils. The local type can mostly be planted deeper than introduced cultivars. Yermanos (1971) recommended only 1.2 to 2.5 cm as depth of sowing for most areas.

This could mean that sesame is usually sown too deep.

When sown as an intercrop, the spacing and seed rate will be at the convenience and experience of the local grower, as is the proportion of the crop in the mixture. As root growth is often slower than for other cultivated crops, interplanted sesame can suffer considerably from competition with the other species. In pure stands, plant density depends greatly on environment, for the seed is small and susceptible to unfavourable seed-bed conditions. Smallholder crops are broadcast at various seed rates: in the Sudan and E Africa, usually 5 to 10 kg/ha; in India, usually 2 to 6 kg/ha.

Fairly high seed rates may be necessary to compensate for loss of plants between emergence and harvest. Such losses can be greater than is realized until specific counts are made. Counts in Venezuela and Tanzania showed the losses in the field to be c. 20–30% of the plants. Although freely branching cultivars produce best with a wide spacing, high yields are directly correlated with a close spacing, irrespective of local average yield; the traditional spacing is often too wide. In Brazil, for instance, a spacing of 175 cm × 88 cm used to be common. Trials showed that maximum yields were obtained at 90 cm × 40 cm. In regions with fluctuating rainfall like Israel, high seed rates may be used to ensure a dense stand; the stands then later can be thinned. In seasons with high rainfall, thinning can be less severe than in years with normal or low rainfall.

On the other hand, too close spacing may be detrimental to growth. It stunts growth whereas most crops are etiolated. An example of this can be found in the Sudan, where it is sometimes practice to plant 6 seeds together in one hole and to allow thinning by death from natural causes. Consequently, the number of plants is often more than the soil water can support and probably more crop is lost by excessive plant population than from all other causes together.

In more branched cultivars, tolerance to closeness of planting is high with relatively little yield difference. In Uganda, trials with such cultivars showed a rather small yield difference between plant densities of 25 000 and 500 000 per hectare. Osei Bonsu (1977) had similar results in Ghana: yields at densities varying from 55 550 to 2 222 200 per hectare were equal.

As sesame seedlings grow slowly for some time after emergence, the seed-bed should be free of weeds during this period. Cultivation among the young and delicate seedlings is difficult as the fine fibrous superficial roots are easily damaged. Handweeding of broadcast crops is normally impractical before the plants are some 15 to 20 cm high; at that time, the seedlings already suffer from weeds. It is therefore important that the seed-bed be as clean as possible. Pure sesame crops can only be weeded by machine if sown in rows, but weeding can start at a much earlier stage. The results with chemical weeding are very variable, depending on region and cultivar. Usually the results are inferior to hand or machine weeding.

Normally, seed is scattered and hoed in, for an intercrop perhaps during weeding of the already sown crop, unless that has been weeded before to provide a clean seed-bed. Because of its small size, sesame seed is often mixed with sand, ash or old seed before broadcasting to help make distribution more even.

Sesame is usually harvested by hand; the plants are cut before the fruits are fully mature and allowed to dry in stooks. Occasional light rain during drying does not seriously damage the seed.

The plant is threshed by beating with canes or sticks on some suitable clean flat area. Harvesting before plants are mature is necessary because of the serious seed losses that can occur if the plants are left standing in the field until the capsules burst. This loss can be up to half the crop. The capsules ripen irregularly from the base upwards; the topmost are often only half-mature at harvest. The drying period before threshing allows the greater part of the seed to ripen without major loss. Seed of plants that have been cut unripe and left to dry is harder than that ripened completely on the plant. This is an advantage at threshing. The moment of harvest has to be chosen carefully as the seed yield per plant and the oil content of the seed can increase considerably in the last 10 days before optimum time of harvesting.

Though indehiscent fruits have reduced seed losses, they are often difficult to thresh. This results in more damage to seed, especially with machine-threshing. So breeders combined indehiscence with the 'papershell' characteristic.

In mechanical harvest, the plants should be handled carefully and with accurate setting of the equipment. Also in this type of harvesting, the practice of cutting the plant unripe and windrowing is often practised. Mainly because of the high labour requirements at harvest, sesame is a higher-cost crop than other oilseeds. The height above the ground of the first capsules is crucial if the plants are to be machine-harvested. This is a characteristic of the cultivar, but the height can be increased by close planting in the row or by varying the planting date.

Although modern bulk storage of uncontaminated and undamaged seed is easy and efficient, the seeds are readily attacked by insects or eaten by animals. Storage is therefore often ingenious, but losses and deterioration can be considerable. In Ethiopia, sesame is stored inside the house in leather sacks if the amount is small, or in manured barrels (my observ.; Brooke, 1958). Nowadays metal containers with tight-fitting lids are often used. In Ethiopia, the beetles *Gnathocerus cornutus* F. and *Tribolium castaneum* Herbst were found in stored sesame (Walker & Boxal, 1974).

During growth, sesame can be attacked by many insect pests but mostly they have little effect. Schmutterer (1971) lists the green peach aphid (*Myzus persicae* Sulz.) and the simsim webworm (*Antigastra catalaunalis* Dup.) on sesame in Ethiopia. De Lotto & Nastasi (1955) found *Agonoscelis versicolor* F. and *Graptostethus servus* F. as insect pests on sesame in Eritrea. Le Pelly (quoted in Weiss, 1971) lists for E Africa 30 insect species feeding on sesame, but only 6 of them are of any importance. The pests can cause much damage. Weiss estimated the losses in E Africa from insect pests at least a third of potential yield and that these losses and those from shattering are the major reason for the very low average yields obtained by smallholders. Little is known about the susceptibility of sesame to nematodes.

Birds can be particularly harmful to irrigated crops grown out of the normal season in the arid tropics.

Sesame is known to be susceptible to some fungal diseases and is attacked by many more of minor economic importance. It is also susceptible to viruses and bacterial diseases. The sesame I saw in Ethiopia always looked healthy and free of pests; Brooke (1958) made the same observation. The only disease specifically mentioned was *Oidium erysiphoides*, which attacked sesame at Holetta (Ciccarone, 1940).

In Africa south of the Tropic of Cancer, sesame is usually grown in the drier regions. It is replaced by peanuts wherever they produce a reasonable crop. It is planted after the first rains where these are of short duration or later to allow the crop to mature in the dry season. The actual date in any year is mainly dependent on the time of onset of rains.

In Ethiopia, sesame is mainly cultivated in the low-lying areas of the west and east. An important production area is found near Humera (Beghemder) on the Tekazze River, where 25% of the fields is under sesame. The area consists of slightly undulating terrain with dark argillous vertisols at an altitude of c. 500 to 700 m. The temperatures are high throughout the year and the rain, 500 to 700 mm/year, falls between June and October, with maximum precipitation in July and August (Bigi, 1969).

Kline et al. (1969) gave the following description of the agriculture of this area. The average farmer cultivates 800 ha of land, commonly 45% of the area with sorghum, 30% with sesame and 25% with cotton. Usually, the farmer grows all three crops every year. No rigid rotation is followed. If a field becomes too weedy, sorghum is planted the next year. Fallowing is not practised. Tillage is mechanized and is identical for all crops. As soon as the weeds start growing (early to mid June), a disk plough is pulled over the field, penetrating the soil no more than 8 cm. Deeper tillage is not required because the self-mulching characteristic of the soil produces a good natural tilth. If more weeds appear, the field may be disked a second time after 1–2 weeks. Seed of sesame is still broadcast by hand. It is sown as soon as possible after the rains have started, usually early in June. This assumes ripening during a relatively mild time before extremes of high temperature and low humidity can cause sudden shattering of fruits. Cotton is planted immediately after sesame, mid July being considered the safest date. Sorghum is sown last.

After hand-sowing, mechanical cultivation is not possible. All weeding is by hand-hoe and harvesting with a sickle. Sesame is harvested into small sheaves, four of which are stooked together, with 100 stooks forming a 'hilla', the basis of payment to harvesters. Yield of seed is up to 1000 kg/ha under those conditions. Storage is hazardous because of the presence of a sesame seed-bug.

In the west, the main sowings are in May and June, but may start with the first rains in early April, and may be as late as July (Weiss, 1971; Yermanos, 1971; Westphal, 1975). In the lowlands, planting depends almost entirely on the advent of rains, any time from September to November (my observations; Weiss, 1971). This is certainly true for dryland cultivation. On riverbanks or other areas that get inundated during the rainy season, the rains must of course end before sowing is possible. The Somali tribes even prefer to cultivate it on terrain that dries late so that the whole vegetative cycle can take place in the dry period. Under these conditions, sesame produces 700 to 800 kg/ha, as compared to the 200 to 300 kg/ha obtainable with sowings under natural rain assisted by some irrigation (Tozzi, 1961). In the E highlands, sesame is sown with the onset of the main rains in June (my observations; Brooke, 1958).

The land is roughly hoed or ploughed before the rains, and weeded before sowing. This operation also assists in breaking down the larger clods and produces a reasonable seed-bed. On sandy soils, the area is only weeded, seed being broadcast and lightly hoed, trampled in, or left for the rains to cover. A twiggy branch is sometimes substituded for the hoe and pulled over the land to cover the seed. In the highlands, it is sown just before the fourth ploughing (Weiss, 1971; Baldrati, 1950; Kline et al., 1969). In cultivation on the riverbanks, a very superficial cultivation is all the preparation needed, as the soil is rather free of weeds after inundation (Tozzi, 1961). The Somali tribes have another traditional way of growing sesame. With their hoe, they prepare patches c. 20 cm in diameter at distances of 40 to 50 cm. In each of them, some seed is sown, after which the soil is slightly pressed by hand, foot, or piece of wood. This ensures maximum seed economy and easy maintenance (Baldrati, 1950).

Broadcasting at sowing means practically always the use of twice as much seed as would be needed for optimum stands. So the farmers commonly use a much higher seed rate than necessary (Kline et al., 1969).

In the west, sesame is mostly sown as a separate crop, but also mixtures with grains and beans or with cotton and sorghum are sometimes planted. In mixtures, the different crops can be sown successively. In the east, the situation is similar, but the fields cropped with sesame alone are usually small (my observations; Brooke, 1958). Baldrati (1949; 1950) described the same situation as in the east for Eritrea. Sesame is often intercropped with dagussa (*Eleusine coracana* (L.) Gaertn.), a low-growing small-seeded grain but also with taller crops like sorghum and cotton (Baldrati, 1950; Brooke, 1958). Seed from a mixed crop is usually retained for domestic use, while that from a single crop is usually sold (Baldrati, 1950). In the Chercher Mountains, sesame is a cash crop and domestic consumption is very small (Brooke, 1958).

Harvesting is by hand as described above, sometimes simply by inverting the dried plants and shaking them (Brooke, 1958). In Ethiopia, very few mechanical harvesters and shellers are available (Kline et al., 1969). The yield in Ethiopia averages 490 kg/ha (Westphal, 1975). For the area west of Lake Tana, Westphal (1975) mentions December as harvesting time. I saw harvesting near Korem (Welo) in January, but near Gambela (Illubabor) I saw sesame plants in full bloom in March, so that harvesting time should be much earlier in that region. Generally, sesame is sown in April, May or June and harvested in January or February in the lowlands. In the highlands, sowing time is June or July and harvest follows in December or January (Huffnagel, 1961; Kuls, 1962; Brooke, 1958).

Uses (most data from Weiss, 1971)

Practically all world trade is in the form of seed, only very minor amounts of oil and cake are shipped. Exports are, however, usually small, even in relation to those oilseeds with which sesame directly competes. Over 70% of world exports of sesame

Table 64. Area (A in 1000 ha), average yield (Y in kg/ha) and total production (P in Gg) of sesame in Ethiopia during the period 1965–1980. (Source: FAO Production Yearbooks).

Year	A	Y	P	Year	A	Y	P
1965	82	400	33	1973	163	569	93
1966	96	390	37	1974	165	669	110
1967	95	390	37	1975	165	606	100
1968	97	410	40	1976	100	600	60
1969	97	410	40	1977	70	643	45
1970	97	410	40	1978	70	571	40
1971	155	600	93	1979	79	482	38
1972	156	673	105	1980	88	510	45

originate in Africa, which grows less than 20% of the world's total. Ethiopia is one of the largest exporters of sesame seed in the world.

Ethiopian sesame area, average yield and total production (1965–1980), as given by FAO Production Yearbooks, are surveyed in Table 64. This Table shows that the sesame area showed a large expansion between 1965 and 1975, but also that the area in 1980 was similar to that in 1965 again.

The minor proportion of oil and cake in world trade is mainly caused by transport problems. With fluctuating temperatures, both the oil and the cake become rancid, although they are very stable under normal conditions and at constant temperatures.

The general decline in exports of sesame seeds since the beginning of this century and the general increase in production superficially suggest overproduction and internal surplus. In fact, world demand is frequently greater than production. The stability of demand reflects the relatively specialized market.

Almost the total world production is used for culinary purposes, mainly in the country of production; only a minor proportion of low-grade oil is used industrially. The seed is a rich source of oil, protein, calcium and phosphorus; it has a high food value. It is often decorticated by light pounding or rubbing on a stone or wooden block. White seed is preferred where there is a choice. The local uses for sesame over the world are numerous.

The most important reason for cultivation is the production of oil. Light-coloured seeds are considered to yield a better-quality oil than dark seeds, although the latter may have a higher oil content. The oil is highly suitable for cooking. It is too expensive for lighting or industrial use. In general, the oil keeps well for the periods between extraction and use. In a test with storage at a temperature of nearly 38 °C, the oil became rancid only after two to three months.

In modern mills, continuous expellers are used. The oil is obtained by 3 successive expressions. The first is in the cold. It yields a high-grade oil, which can be used for cooking after filtration. The second expression is usually hot. It yields an oil with more colour, which is refined and used for food. The third expression, also hot, yields oil of an inferior quality and is used for making soap (Nayar & Mehra, 1970).

In different countries, the seed is expressed by a variety of methods, the purity of the oil depending on the method of expression and the purity of the expressed seed. The method of extraction does not materially affect the nutritive value of the oil.

In some countries including Ethiopia, it is common to re-use the oil for frying. Rats offered a diet with 15% (w/w) of oil which had been heated for 8 h at 270 °C showed growth depression, congested livers and extensive periportal fatty infiltration.

Although sesame stems have little stockfeeding value, the oilcake is highly valuable as cattle feed and is also fit for human consumption. It is seldom used for manure. In general, it is considered equal to cotton oilcake or soya bean oilmeal as a protein supplement for livestock and poultry. It is especially high in certain amino acids, such as methionine, but low in lysine. Materials like soya bean meal, meat scraps and fishmeal are high in lysine and thus can be combined with sesame cake to balance a ration. It is well liked by stock and keeps well in storage. If it forms too large a proportion of the ration of dairy cows or pigs, it induces soft butter and pork. The cake makes a good human food too. Decortication of the seed before extraction of the oil is then preferred, since the testa imparts a slightly bitter taste to the meal.

Decortication considerably reduces the content of minerals, oxalic acid and fibre, and increases the palatability, digestibility and protein content of the meal. For rats, sesame meal proved nutritionally inferior to sesame seed.

There is little difference in the food values of light and dark seed, but dark seed is usually more bitter when eaten whole or as meal. The bitter principle in meal produced from whole seed is easily solvent-extracted.

Sesame flour mixed with ground rice, soya bean flour and wheat flour at mass ratios of 1:2:1:1 gave 21% retention of N in children compared to 28% for cow's milk. Sesame flour alone has been shown to be beneficial to children suffering from kwashiorkor. The consumption of sesame flour is greatest in the Near and Middle East, where the crop is often grown to provide flour rather than oil.

The comsumption of sesame seed, and meal or paste is generally praised as a healthy habit. Yannai & Haas (1973), however, concluded that some care should be taken, as the sesame plant seems to have an unusual capacity for lead accumulation in the seeds. They found that Ethiopian sesame seed kernels contained lead at 1.4–2.2 mg/kg (average 1.76), and whole sesame seeds from Ethiopia 1.3–2.2 mg/kg (average 1.7). They indicate that, according to the rules of the FAO/WHO Expert Committee on Food Additives, it should be unwise for a person of weight c. 70 kg to eat more than c. 175–200 g/day.

Sesame seeds are used also quite often in sweets and bakery products, or eaten fried, roasted or pounded. In the industrial countries, it is mainly a speciality and the whole seed is used in various sweets and as a topping on breads. White seed is preferred. Trade regulations require that batches described as 'white seeds' shall not contain over 25% of coloured seeds. The mixture of dark and white seeds in trade known as 'bigarre' must contain 35% of more white seeds.

Numerous are the medical applications of sesame. In Uganda and W Africa, pounded fresh leaves are used as a poultice to ease skin conditions. This traditional use went with the slaves to America. A syrup made from the mucilaginous leaves is used in treatment of dysentry and diarrhoea in India. It was also used to make the skin soft and beautiful, and to cure rheumatism. In Sri Lanka, it is used for infections of the intestine and skin. In Japan, sesame oil was considered to promote regular bowel movements in animals. On the Island of Curaçao, a decoction of the leaves is used for washing the head as a remedy for falling hair, and as an eyewash. The seeds, milled and mixed with brown sugar, are eaten by nursing mothers to encourage their milk supply and the seeds are generally believed to 'make the blood healthy'.

Sesame oil is retained in the pharmacopoeia of many countries, mainly because of its high stability. This property makes the oil highly desirable as a vehicle for medicaments which are required to be administered subcutaneously or intramuscularly. It may also be employed in the preparation of liniments, plasters, ointments and soaps. When taken internally in a sufficient dose it is, like other fixed oils, laxative. It can also be combined with iodine.

An alcoholic or aqueous extract of the leaves has been shown to have an inhibitory effect on *Mycobacterium tuberculosis*. Sesamin had similar effect.

In several parts of the world, different uses are attributed to the plant. In Brazil, the plant is said to be useful in control of leafcutting ants. It was not clear whether the plant acted as a direct insecticide, or indirectly by poisoning the underground fungus gardens. In some countries like India and Italy, use of sesame oil in manufacture of cooking fats is compulsory. The sensitivity of the oil to a specific test (Baudouin test) makes detection of adulterants in such products as butter and olive oil possible. The oil is highly effective as a fixative in the perfume industry. Scenting oil can even be expressed from wetted seeds that have been covered with layers of scenting flowers and left covered for 12 to 18 h. A kilogram of strongly scented flowers is enough to perfume 6 litres of sesame oil. The effect of sesame oil on the stability of oils to which it is added is of some importance. Its beneficial effect on the stability of vitamin A in these mixtures is also important. Sesamin and sesamolin are active synergists in the insecticidal activity of pyrethrin and retenone, which are still safe for mammals. Sesamin, which has been found to occur in other plants than sesame, has only a fifth of the synergistic potency of sesamolin, which has so far been found only in sesame. In E Africa, it was said that the juice of the fresh plant could repel tsetse flies.

In summary, the sesame plant contains agents that are unpleasant to insects, that have a stabilizing effect against some chemical reactions, that counteract growth of certain micro-organisms and that are beneficial to epithelial tissues of man.

In Ethiopia, I saw the following uses.

1. The oil or pounded seed is added to the wot instead of butter, especially to the vegetarian type in fasting time.
2. The oil is used for frying, especially of sweets and breads. It is considered to be the best of Ethiopia (Wittmack, 1907).
3. The presscake is added to the wot.
4. The seed is mixed with other oilseeds. Those are roasted together and eaten as a snack.

5. The seed is sprinkled on breads before these are baked as a seasoning.
6. Sweets are prepared by mixing sesame seeds with slightly caramelized sugar.

Griaule (1930, Receipe 36) mentions a magical use: a person who wants to receive money should apply sesame oil to his face, watching a fire of burning chat (*Catha edulis* Endl.) branches and chanting certain magic words seven times.

Westphal (1975) indicates that Niger seed, linseed and sesame, combined with fenugreek, are sometimes crushed together for a non-alcoholic drink.

Chemical and physical properties

Sesame seeds usually weigh 2.0–3.5 mg, maximally c. 5 mg; its bulk density is 600–650 kg/m³. It has a moisture content of about 50 g/kg (Baldrati, 1950; Varma, 1958; Mazzani, 1962). The husk forms c. 10% of the weight. It occurs in different colours and sizes; the oil content is related to both. White seeds usually have the highest oil content. Baldrati (1950) reports from Eritrea that the lighter-coloured sesame seeds, cultivated by the Barria people, contained c. 530 g/kg of oil, the darker sesame from the Baza people contained c. 490 g/kg. He probably derived his data from Suzzi (1904 & 1905). But in my collection, the average of the oil contents of 12 samples from Group 1a (dark brown, Note 3) differed only 1 g/kg from the average of the oil contents of 6 samples from Group 2 (white, Note 3). The investigated 3 samples from group 1b (light brown, Note 3) averaged only 15 g/kg higher. These results do not suggest a significant difference in the oil contents of seeds of different colour within Ethiopia.

Comparison of different samples of seeds of the same colour but of different sizes shows that larger seeds tend to contain less oil than smaller seeds (Mazzani, 1962). Seeds from plants with a short growing cycle have a higher oil content than those from plants with a medium-long growing cycle (Yermanos, 1972). Rough-seeded cultivars generally have a lower oil content than smooth-seeded. This is because the rough coat forms a larger proportion in seed weight.

The oil content is usually between 44 and 54%; protein content is mostly between 19 and 25% but higher and lower values have been reported (Weiss, 1971; Yermanos, 1972). The moisture, crude fibre and ash content together seldom exceed 25% of the total weight of the seed, the remaining 75% being oil and crude protein. Weiss indicates that the protein contents he mentions in his book are based on the calculation: 'nitrogen percentage × 6.25 = percentage of crude protein'. The factor 6.25 has been used because it is in wide use for this purpose, but the factor 5.3 seems more accurate to relate sesame seed nitrogen to protein (Weiss, 1971). Ågren & Gibson (1968) used an even lower conversion factor: 5.22.

The composition of some sesame samples is given in Table 65.

The composition of sesame as commonly used in Ethiopia, according to Ågren & Gibson (1968) is given in Table 66. Those authors investigated seeds freshly harvested and about half a year old.

The place where the plant has been growing has a considerable effect on the composition of the seed (Weiss, 1971). But no clear-cut geographic pattern in the distribution

Table 65. Analysis of some sesame samples from different parts of the world. After Weiss (1971, p. 383, 384) in India and USA, and Mazzani (1962, p. 114) in Venezuela.

Origin	India						USA		Venezuela
Cultivar	White-seeded			Black-seeded			Not mentioned		Average of many cultivars
Part	W[1]	D[1]	H[1]	W[1]	D[1]	H[1]	W[1]	D[1]	Whole
Major components (g/kg)									
Moisture	54	62	42	52	61	41	54	55	56
Oil (ether extract)[2]	502	541	102	498	535	99	491	534	468
Protein (N × 6.25)	198	211	80	200	215	81	186	182	211
(N × 5.22)	165	176	67	167	180	68	155	152	176
Carbohydrates	149	147	220	147	149	159	216	176	186
Fibre	32	14	185	33	13	195	63	24	51
Ash	48	23	288	52	26	242	53	53	60
Minerals (mg/kg)									
Ca	10600	1900	97500	12100	600	121000	11600	1100	15000
P	4700	4800	5100	6200	6200	6600	6160	5920	7855
Fe	.	.	.	.	.	.	105 and 113	24	126
Na	.	.	.	.	.	.	600 and 704	.	890
K	.	.	.	.	.	.	7250 and 5213	.	5479
Mg	.	.	.	.	.	.	4116	.	4703
S	.	.	.	.	.	.	189	.	216
Si	.	.	.	.	.	.	.	.	841
Cl	.	.	.	.	.	.	85	.	120

1. W = whole, D = decorticated, H = hull.

2. Yermanos (1972) found in a world collection with more than 700 entries a range of 40.4 to 59.8% of oil, with a mean of 53.1%; data applying to decorticated seed.

Table 66. Composition of whole seeds of some Ethiopian sesame samples (Ågren & Gibson 1968).

	Seed colour				
	white (1 sample)	brown (1 sample)	unspecified		
			number of samples	mean	range
Food energy (kJ/kg)	24351	23640	3	24142	23849–24435
Moisture (g/kg)	58	55	4	41	34–54
Protein (g/kg) (5.22 × N)	167	193	6	c. 165	135–203
Fat (g/kg)	537	506	3	507	495–513
Carbohydrate (including fibre) (g/kg)	182	184	3	239	213–265
Fibre (g/kg)	252	129	3	93	48–162
Ash (g/kg)	56	62	4	57	53–60
Calcium (mg/kg)	10170	14830	4	9090	3840–13530
Phosphorus (mg/kg)	7320	5780	4	5990	5240–6770
Iron (mg/kg)	562	.	3	173	137–228
β-carotene equivalent	.	.	1	0	–
Thiamin (mg/kg)	2.2	1.4	4	4.3	3.4–5.4
Riboflavin (mg/kg)	0.2	0.5	5	c. 1.6	1.0–2.2
Niacin (mg/kg)	73	87	5	c. 58	43–72
Tryptophan (mg/kg)	2220	.	0	.	–
Ascorbic acid (mg/kg)	.	.	1	0	–

of seed oil content could be found in a world collection of sesame, grown at one locality (Yermanos, 1972). Although the protein content of undecorticated sesame seed may vary from 150 to 250 g/kg, it is usually between 190 and 230 g/kg. The seeds contain about 40 g/kg mucilage and the outer layer of the testa is rich in calcium oxalate which is responsible for the bitter taste (Weiss, 1971; Lyon, 1972). The vitamin content of sesame seed can be summarized as follows: carotene trace, thiamine c. 10 mg/kg, niacin c. 50 mg/kg, ascorbic acid c. 5 mg/kg, riboflavin c. 2.5 mg/kg, pantothenic acid c. 6 g/kg. In refined sesame oil, tocopherols were 0.5 g/kg.

Comparison of data on oil content of the seeds and that of the presscake makes it clear that, according to method of extraction, expressible oil is c. 35–40% of seed weight, leaving a cake with 6–14% oil. The colour of the oil varies from pale yellow to dark amber, according to the grain and the way of preparation. There appears also to be a correlation between the growth habit of the plant and the colour of the oil: short plants more often produce a colourless oil than tall plants (Yermanos, 1972). The oil is non-drying (Weiss, 1971) to semi-drying (Varma, 1958). It has a slight pleasant odour and a bland taste. It is slightly soluble in ethanol and miscible with ether, chloroform and light petroleum. Some of its characteristics may be found in Table 67.

Table 67. Characteristics of sesame oil (after Mazzani, 1962; Varma, 1958; Weiss, 1971 and Lyon, 1972)

Acid value	1–6
Flash point (°C)	375
Free fatty acids as oleic (g/kg)	10–30
Hehner value	c. 96
Hydroxyl value	1–10
Iodine value (Wijs)[1]	100–130
Optical activity (angular degrees in 200 mm tube)	+1–+3
Polenske value	0.1–0.5
Refractive index n_D at 25°C	1.463–1.474
at 40°C	1.464–1.476
Reichert-Meissl value	0.1–0.2
Relative density at 15.5/15.5°C	0.920–0.928
20.0/20.0°C	0.916–0.919
25.0/25.0C	0.917–0.926
Saponification value	185.8–199.0
Smoke point (°C)	165.5
Solidifying point (°C)	−3 to −4
Specific opacity 25.0/25.0°C	0.916–0.921
Thiocyanogen value	74–76
Titre (°C)	20–25
Unsaponifiable matter (g/kg)	9–23, average 12

1. Yermanos (1972) found that there is a correlation between a short growing cycle of the plant, yellow seed-coat, and large seed-size with relatively low iodine values, but that there is no correlation between the oil content of the seed and the iodine value of the oil. He found iodine values from 106 to 130 with a mean of 117.4.

Some data on the composition of the insoluble fatty acids are given in Table 68.

The glycerides of the oil are almost exclusively of a mixed type, principally oleo-di-linoleo triglyceride, linoleo-di-oleo triglyceride or triglycerides with one radical of a saturated fatty acid combined with one oleic and one linoleic radical (Weiss, 1971; Lyon, 1972).

In 21 samples of my Ethiopian collection, the oil content usually ranged from 545 g/kg to 575 g/kg, with extreme values of 526 and 587 g/kg. Grieco & Piepoli (1967) found only 498 g/kg of oil in an Eritrean sample. The method used for my investigation was hexane extraction of crushed whole seeds, followed by gas–liquid chromatography of the methylated esters. Three of the samples were compared by nuclear magnetic resonance, residual C_{17} ester method and gas–liquid chromatography. In that survey, the results were slightly different from the investigation that forms the basis of Table 68 but they fall in the ranges mentioned there or the differences were so small that they fall within the confidence limits. The only exception is given by a sample from Feddis near Harer. This sample was found to have the highest oil content (587 g/kg by GLC or 589 g/kg by NMR), the lowest oleic acid content (33.6%) and the highest linoleic acid content (50.7%) by all methods.

Table 68. Comparison of the average composition of the fatty acids of sesame oil (based on Weiss, 1971, Yermanos, 1972, Varma, 1958, and Lyon, 1972) with a sample from Eritrea (G & P, Grieco & Piepoli, 1967) and the data of 21 samples from my own collection from Ethiopia (SL). (Data as substance fraction in %.)

	Average	G&P	SL	
			Range	Mean
Saturated	14	16.6	13.2-16.8	15.1
Palmitic acid	7-12	9.7	8.4-10.3	9.4
Stearic acid	3.4-6.0	6.3	(4.1)4.5-5.8(6.1	5.2
Arachidic acid	0.4-1.2	0.6	(0.1)0.3-0.7(1.3)	0.5
Unsaturated	86	83.4	80.8-88.7	84.9
Oleic acid	32.7-53.9[1]	40.6	(36.6)39.5-43.0(43.9)	41.1
Linoleic acid	35.0-59.0[1]	42.2	(39.7)41.0-45.0(50.0)	43.3

1. Yermanos (1972) found a significant negative correlation between the oleic and linoleic acid contents, and also that a short growing cycle and yellow seed-coat are correlated to high oleic and low linoleic content.

The unsaponifiable matter of sesame oil forms with about 12 g/kg a higher proportion of the oil than normally is found in oils from oilseeds and it includes substances not found in other oils, for instance sesamin, sesamol, sesamolin and phytosterol. They form c. 80% (w/w) of the unsaponifiable matter (Varma, 1958). The unusually high resistance of normal and hydrogenated sesame oil to oxidation is mainly due to sesamol. The larger proportion of this is a compound of sesamolin. It can be liberated from this by hydrogenation to give the oil greater stability. Refined deodorized sesame oil usually contains only traces of free sesamol and is thus as stable as other similar unsaturated oils. Sesamol also gives good protection to other oils; it is one of the strongest antioxidants known. It is a phenol which, in pure state, forms colourless crystals.

Because of the presence of sesamolin and of some other unsaponifiable compounds, sesame oil is dextrorotatory.

The oil has a specific combustible energy between 23 and 25.1 MJ/kg it contains c. 0.368 mg/kg vitamin A, 7–10 g/kg sesamin, 0.3–1.32 g/kg phosphatids and 0.66 g/kg tocopherols. Of the tocopherols, c. 39% are α, c. 61% are γ, and there is a trace of δ.

The colour of the cake can vary from pale yellow to greyish black, depending on the colour of the seed used. Dark cakes are frequently more bitter than the lighter-coloured and the latter are preferred where there is a choice.

The composition of the cake depends not only on the seed used but also on the method of oil extraction. There is a major loss of minerals when seed is hulled and a substantial difference in the fat content of expelled and extracted cake. The composition of the oilcake is indicated in Table 69.

The data from Table 69 indicate that the seedcoat forms only a minor constituent to the weight of the seed, but that it contains almost as much of the minerals, retained

Table 69. Composition of the oilcake of sesame seed. (After Mazzani, 1962 (1), Varma, 1958 (2) and Weiss, 1971 (3).) Data in g/kg.

	Pressed				Extracted			
					ethanol		hexane	
	U[1]			D[1]	U[1]	D[1]	U[1]	D[1]
	1	2	3	3	3	3	3	3
Moisture	80	72-93	81	83	86	89	86	88
Oil	130	86-178	135	127	31	34	8	11
Protein	400	359–445	351	413	382	458	396	467[2]
Carbohydrate	220	209-252	261	294	313	334	316	345
Fibre	50	44-52	53	31	59	31	61	32
Ash	100	89-141	89	48	94	50	97	52

1. U = undecorticated; D = decorticated.
2. Lyon (1972) indicates an average protein content of oil-free meals of 570 g/kg.

in ash, as the kernel.

Weiss (1971) gives the amino acid composition of the protein of sesame seed on several occasions (Table 70).

The proteins of sesame have a higher methionine content and a lower lysine content than oilcakes of most other important oilseeds. Mixtures of sesame seed cake with

Table 70. Sesame: average crude protein content of presscake (g/kg) and amino acid composition (mass fractions (%) of crude protein). Sample 1, origin unknown; Sample 2, black cultivar from India; Sample 3, white cultivar from India. (After Weiss, 1971.)

Component	Sample		
	1	2	3
Crude protein	460	405	402
Amino acids			
Arginine	11.91	12.5	11.8
Histidine	2.21	2.1	2.4
Isoleucine	4.27	3.9	3.7
Leucine	6.92	8.9	7.4
Lysine	2.76	2.9	3.5
Methionine	2.65	3.3	3.8
Phenylalanine	4.73	6.2	6.3
Threonine	3.64	3.6	3.9
Tryptophan	1.91	.	.
Valine	5.06	3.5	3.6

cakes of other seeds or with c. 2g/kg pure lysine have been tested on man and on some animals. The results indicate that the nutritive value of protein in some of those mixtures is almost as high as that in skimmed milk. The availability of amino acids in sesame cake is, though, affected by the processing method of the seed (Lyon, 1972).

Not only the seed but also the whole plant contains much protein: dried leaves, of which up to 1400 kg/ha could be harvested, contain 200–290 g/kg and stems 40–110 g/kg (Yermanos, 1971).

2.17 Trichilla emetica Vahl ssp. emetica Fig. 16

Trichilia emetica Vahl spp. *emetica* (Synonym: T. roka Chiov.) (in Eritrea kota or gummeh, in English roka tree, in French mafura) is an evergreen tree belonging to the *Meliaceae*. It usually grows to 20 m high with a diam. at breast height of 75 cm (de Wilde, 1968).

In Ethiopia, it can be found all over the country except in the extreme N and E (de Wilde, 1968) at altitudes below 1500 m (Baldrati, 1940).

The tree can reach a considerable size, with a straight and regular stem, but it is often branched from the base and, especially under less favourable conditions, remains a small tree. In an open vegetation, branching starts low (often near the surface of the soil); in a closed vegetation, much higher. With the exception of older bark, older leaves above and seeds, all parts are hairy, or sparsely so (Baldrati, 1940; de Wilde, 1968).

The petioled leaves are usually imparipinnate, up to 42 cm long, often tufted at the end of the branchlets. Leaflets green, usually in 3–5 ± opposite pairs, petiolulate, ovate-oblong-obovate, or narrowly so, commonly 3–14 cm × 1–1.5 cm, hardly glandular punctate if at all (de Wilde, 1968).

Inflorescences with monosexual flowers, usually compact paniculate, in leaf axils of young branches or near the top of second-year branches (de Wilde, 1968).

Flowers c. 2 cm diam., greenish white, scented, on short pedicels; calyx with 5 (very) broadly ovate basally connate lobes; petals 5, free, slightly fleshy, narrowly obovate or narrowly oblong; stamens 10, 7.5–11.5 mm long, fused for half their length, forming a tube, anthers in female flower not producing pollen; ovary not developed in male flower, in female well developed, subglobular, c. 2–5 mm diam., 3-celled, 2 ovules in each cell; style c. 5 mm long, stigma subglobular to discoid, c. 2 mm diam. (de Wilde, 1968).

Fruit obovate, with distinct stipe, 15–25 mm diam., green, pale brown because of hairs, opening loculicidally with 3 valves, usually containing 3–5 seeds (de Wilde, 1968).

Seed 15–22 mm × 9–12 mm, for the largest part covered by a scarlet arillodium, with a glossy very dark brown dorsal leathery spot, plano-convex, flat on adjacent sides; cotyledons firm, fleshy, pale brown, plano-convex; radicle obovoid between the cotyledons 0.8–1.2 mm beneath the apex (de Wilde, 1968).

Of the two subspecies, only ssp. *emetica* is found in Ethiopia.

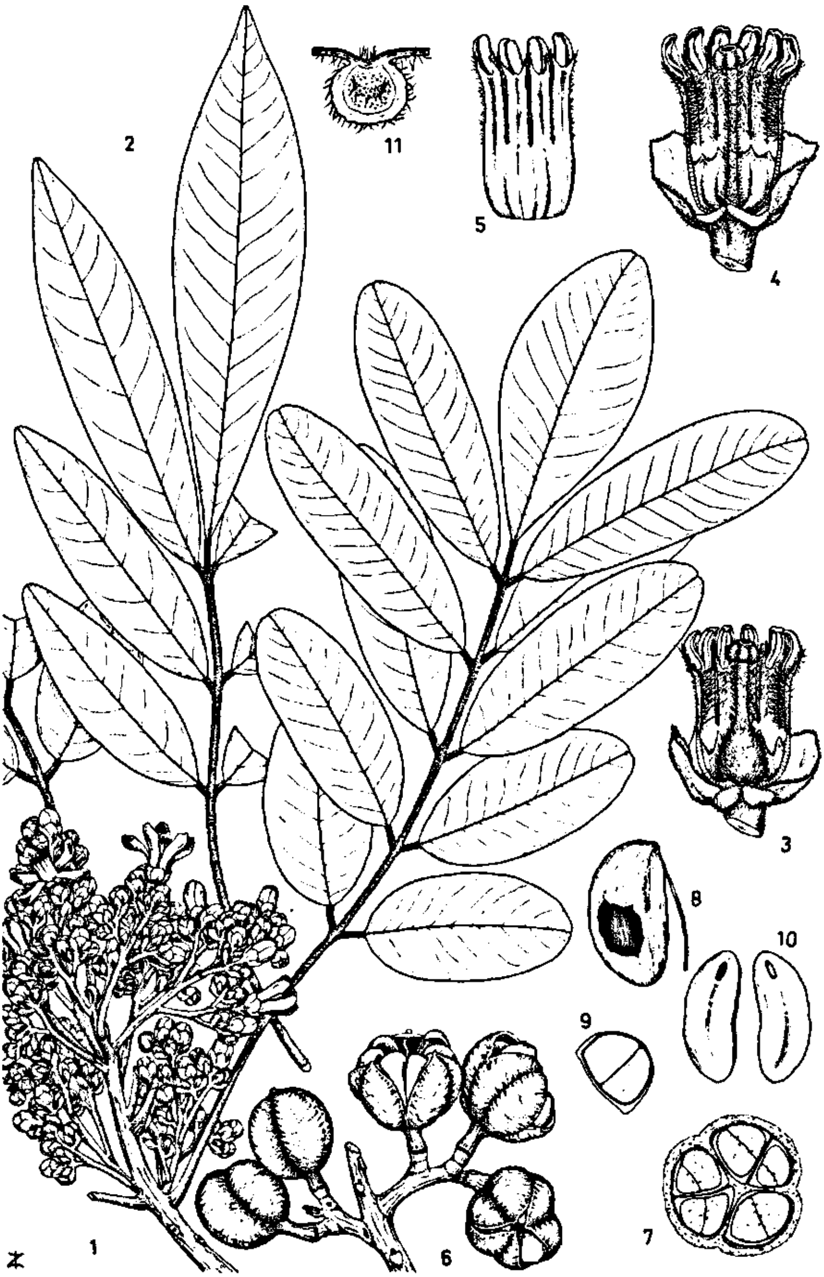


Fig. 16. *Trichilia emetica* Vahl subspec. *emetica*. 1. Flowering branch (× ½). 2. Leaf with leaflets more or less acute at apex (× ½). 3. Section of female flower, petals removed (× 3). 4. Male flower idem (× 3). 5. Part of staminal tube outside, male flower (× 3). 6. Branch with fruit (× ½). 7. Transverse section of immature fruit (× 1). 8. Seed (× 1). 9 Transverse section of seed (× 1). 10. Cotyledons (× 1). 11. Transverse section of the midrib of a leaflet. 1, 4, 5, 11, Brass 17503; 2, Angus 131; 3, Lam and Meeuse 5056; 6, 8–11, Baldrati 2067; 7, Schimper 806. (After de Wilde, 1968.)

Trichilia is found in regions with c. 500–600 mm annual rain, in protected areas or in alluvial terrain with a good permeability and fertility. It is easily propagated by seed, which germinates in three weeks, but it stands transplanting badly. Leafy cuttings from woody branches usually succeed well (Baldrati, 1940).

Growing is rather fast and a seedling can start to bear fruits after 6–7 years. There are great differences in the productivity of the trees (Baldrati, 1940). This phenomenon is probably caused by the ratio of functionally monosexual flowers. A productive well-developed tree will yield about 100 kg of fruits, equivalent to 40–45 kg of seed (Baldrati, 1940).

Wood is the most important product from this tree in Ethiopia, but the fatty character of the seed is known. I do not know of any specific Ethiopian use, though the seeds are in general use elsewhere for their oil.

The presscake contains c. 40 g of nitrogen per kilogram and is a good fertilizer (Ubbelohde, 1920).

The arrillodium contains a yellowish brown oil, the kernel a pale yellow fat. One kilogram of seeds contains the following:

arillodium	290–320 g (containing oil: c. 510 g/kg)
kernel	680–710 g (containing fat: c. 660 g/kg)
whole seed	1000 g (containing fat + oil: c. 600 g/kg)

(Suzzi, 1904 & 1905; Baldrati, 1940).

3 Review of the field-work

3.1 NUFFIC-LHW/2 in retrospect

Contact between the National Herbarium of Ethiopia at Addis Abeba and the Laboratory for Plant Taxonomy and Plant Geography at Wageningen was established by a visit by Dr H. C. D. de Wit to Dr Makonnen Kebret in 1964.

W. J. J. O. de Wilde and his wife Mrs B. E. E. de Wilde-Duyfjes spent the period 1965–1966 at Addis Abeba, assisting in the herbarium and collecting more than 5000 numbers. E. Westphal and his wife Mrs J. M. C. Westphal-Stevels arrived in Ethiopia in April 1967. They were based at the College of Agriculture in Alemaya, where they were succeeded by Dr J. J. F. E. de Wilde and his wife in 1968.

In January 1970, the financing of the cooperation was taken over by NUFFIC (Netherlands University Foundation for International Cooperation) in the form of a seven-year project on useful plants of Ethiopia, coded LHW/2. Attention shifted to cultivated plants, to plants gathered from the wild for domestic use, and to teaching. This shift is also shown by the entry into the project of the Department of Tropical Crops Science at Wageningen.

In the course of Project LHW/2, about 13500 numbers were collected, both herbarium and seed samples. In the preceding 'Flora Project' period another 10000 samples and exsiccates were collected.

The seed samples were collected mainly at numerous markets. A visit to a market included a listing of products offered, purchase of representative samples, noting the name and date of the market, the local name of the product, the use and the origin as supplied by the seller.

Field-work included surveys of gardens and fields, with occasional collection and with notes on altitude, time of the year and relative importance. Attention was given to collecting the wild flora, where time was available. Conservation was done by drying between newspapers above a butane-gas stove, or in plastic containers in FAA (ethanol with formalin and acetic acid). The altitude and road distance to the nearest major town were noted.

During the whole project, the home-base of the Dutchmen working in Ethiopia was the College of Agriculture at Alemaya, which is the Faculty of Agriculture of the University at Addis Abeba. This College, and thus the University, generously supplied housing and working facilities, counterparts (Ato Tadesse Ebba and Dr Amare Getahun, respectively), experimental fields with workers and all general assistance needed.

At Alemaya, the work consisted of running the herbarium (e.g. curating collections, identification, dispatch of overseas collections), teaching, carrying out field trials with cultivated plants, and all the further duties of a staff member of the College.

During Project LHW/2, the following Dutch collaborators were stationed at Alemaya.

Dr J. J. F. E. de Wilde	January 1970–April 1971
Ir C. J. P. Seegeler	July 1971–December 1973
Ir J. J. Bos	February 1974–July 1975
Ir P. C. M. Jansen	March 1975–July 1977

Although it was under the aegis of the earlier project, the research by the Westphals was completely in the spirit of Project LHW/2. The work in the later project by J. de Wilde and Bos, on the other hand, was more in the spirit of the earlier project.

Volumes on other groups of useful plants would have been a logical continuation but the project has, for the moment, ceased. This is thus the final volume of the series.

3.2 Ethiopian market days

It occurred to me that many people in Ethiopia, working outside their native region, were not aware at all of the days, markets were held in their working area, even though these data were of great importance to their work. It therefore seemed useful to include a list of market days that Westphal an I collected during our journeys in Ethiopia. Some of the data on markets in the Chercher region of Harergie were communicated to me by Dr H. Schneider, in 1972–1973 working at the Besidimo Leprosy Centre in that region.

As the data were often collected while passing a village, and mostly had to be gathered through an interpreter, they are fragmentary. Writing of the local place-names in Roman script was often a matter of personal interpretation, incurring uncertainties; it thus appeared to be logical to add some 'road-schemes'. For places I could not visit personally, it was sometimes difficult or impossible to indicate the exact situation. The order as presented in the schemes, therefore, should not be taken as absolute, although the regions are to be taken as exact.

Of some places, the altitude or relative distance (as noted from altimeter and Landrover hodometer) are indicated. The latter will show that there is no relation between the distances on the schemes and the actual distances. Side-roads, on the other hand, are indicated left hand or right hand, as they occur passing the described roads.

Usually the market hours in Ethiopia are around noon and early afternoon: a visit between 11:30 and 14:30 finds the market usually at its busiest.

List of market days: Mo, Monday; Tue, Tuesday; Wed, Wednesday; Thur, Thursday; Fri, Friday; Sat, Saturday; Sun, Sunday; in parenthesis, days of small markets.
(Sources: field-notes of Seegeler (SL) and Westphal (WP)).

Place	Province	Alt. (m)	Days	Source
1. Aba Guaris	Beghemder		Mo	SL
2. Abosto	Sidamo	2100	Tue, Fri	SL
3. Adaba	Bale		Tue, Sat	SL/WP
4. Addis	Gojam		Wed, Sat	SL
5. Addis Abeba	Shewa	2400	Wed, Fri, Sat, (daily)	WP
6. Addis Alem	Shewa	2410	Sat	SL
7. Addis Zemen	Beghemder		Wed	SL
8. Ades	Harergie		Sun	SL
9. Adi Arkai	Beghemder		Sat	SL
10. Adi Caieh	Eritrea		Thur	SL
11. Adi Quala	Eritrea		Sat	SL
12. Adi Show	Tigre		Fri	SL
13. Adi Ugri	Eritrea		Sat, (daily)	SL
14. Adi Wudem	Tigre		Sat	SL
15. Agaro	Kefa		Tue, Sat, (daily)	WP
(Agere Hiwot = Ambo)				
16. Agere Selam	Sidamo		Tue, Thur, Sat	WP
17. Alamata	Welo		Sat	SL/WP
18. Aleltu	Shewa		Sat	SL
19. Alelu	Shewa		Sat.	SL
20. Alemaya	Harergie	2050	Mo, Thur	SL
21. Alem Teferi	Welega	1600	Wed	SL
22. Amanuel	Gojam		Sat	SL
23. Ambalage	Tigre		Fri	SL
24. Ambo	Shewa		Sat	SL/WP
25. Ambuye	Kefa		Wed	WP
26. Amedeber	Beghemder		Sat	SL
27. Ano	Welega	1970	Thur	SL
28. Arada	Sidamo		Sat	SL
29. Arb	Shewa	1400	Fri	SL
30. Arba Minch	Gemu Gofa		Tue, Thur, Sat	WP
31. Arbereketti	Harergie		Sat	SL
32. Asbe Teferi	Harergie	1500	Thur	SL
			Wed	WP
33. Asella	Arussi		Tue, Sat	WP
34. Asguri	Shewa		Tue, Sat	SL
35. Asosa	Welega		Mo, Fri	WP
36. Assebot	Harergie	1100	Thur	SL
37. Assendabo	Kefa	1840	Thur, Sat	SL
38. Ataye	Shewa	1300	Thur	SL
39. Atigebru	Beghemder		Sat	SL
40. Awagelan	Welega	1910	Wed	SL
41. Awale	Harergie		Mo, Thur	SL

42. Awasa	Sidamo	1860	Mo, Thur every 5 days	SL WP
43. Awash Tabia	Harergie		Mo	SL/WP
44. Axum	Tigre		Sat	SL
45. Aytank	Illubabor	550	Sun	SL
46. Azegoy	Shewa	2475	Sun	SL
47. Azezo	Beghemder		Thur	SL
48. Babicho	Shewa	2320	Thur	SL
49. Bahar Dar	Gojam		Sat	SL/WP
50. Bai Nebri	Tigre		Tue	SL
51. Bako	Shewa	1680	Tue, Fri	SL/WP
52. Balo	Shewa		no market	SL
53. Bati	Welo		Mo	WP
54. Bedele	Illubabor		Sat, Tue	SL/WP
55. Bedeno	Harergie		Mo, Thur	SL
56. Bedesa	Harergie		Sat	SL/WP
57. Belbeleiti	Harergie		Thur	SL
58. Bekejama	Welega	2100	Thur	SL
59. Bekoji	Arussi		Tue, Sat	WP
60. Berhe Mariam	Shewa		no market	SL
61. Bichena	Gojam		Sat	SL
62. Bido	Illubabor	2170	Fri	SL
63. Bitmara	Tigre		Sat	SL
64. Biyo	Harergie		Mo	SL
65. Bonga	Kefa	1750	Sat, (Mo)	SL/WP
66. Bordede	Haregie		Sun	SL
67. Bore	Sidamo	2800	Tue, Sat	SL/WP
68. Boroda	Harergie	2350	Mo, Sat	SL
69. Boya	Tigre		no market	SL
70. Buditi	Sidamo		Tue, Thur	WP
71. Bure	Gojam		Sat	SL
72. Burka	Harergie		Mo, Thur	SL
73. Buro	Illubabor	1650	Thur	SL
74. Butajira	Shewa		Fri	WP
75. Chacha	Shewa	2550	Tue	SL
76. Chafa	Shewa	1300	Wed	SL
77. Chagi	Shewa	2600	Fri	SL
78. Chamo	Welega	1590	Thur	SL
79. Charaka-Kormeda	Gojam		Sat	SL
80. Chelenko	Harergie	2175	Mo. Thur	SL
81. Chena	Kefa	2180	Mo, Thur	SL
82. Chenka	Welega	1580	Fri	SL
83. Dabat	Beghemder		Sat	SL
84. Daleti	Welega	1850	Wed	SL
85. Dangla	Gojam		Sat	SL
86. Dawe	Harergie		Wed	SL
87. Debarak	Beghemder		Wed	SL
88. Debesa	Harergie	2100	Mo	SL
89. Debre Birhan	Shewa	2550	Sat	SL/WP
90. Debre Markos	Gojam		Sat	WP
91. Debre Sina	Shewa	2500	Mo, Thur	SL

92. Debre Tabor	Beghemder		Mo	SL
93. Debre Zeit	Shewa		Tue, Sat	WP
94. Deder	Harergie	2300	Sat	SL/WP
95. Dedo	Kefa		Sat	WP
96. Defno	Welega	1750	Wed	SL
97. Dege Bonaya	Welega		Sun, Tue	SL
98. Demba	Kefa	1800	Thur	SL
99. Dembecha	Gojam		Mo, Wed	SL
100. Dembi	Illubabor	1940	Mo, Wed	SL/WP
101. Dembidolo	Welega	1900	Mo	SL
102. Dera	Arussi		Tue, Sat	WP
103. Dessie	Welo		Mo	SL
104. Dibe Wahir	Beghemder		no market	SL
105. Didessa Valley, Shankale market	Welega		Tue	WP
106. Dilela	Shewa		Tue	SL
107. Dilla	Sidamo		daily	WP
108. Dinsha	Bale		Tue, Sat	SL
109. Dire Dawa	Harergie	1150	Sat, (daily)	SL/WP
110. Doba	Harergie		Tue	SL
111. Dodolo	Arussi		Mo, Thur	SL/WP
112. Dogu	Harergie		Mo, Thur	SL
113. Elias	Gojam		Mo	SL
114. Enda Medhane Alem	Tigre		Fri	WP
115. Enda Selassie	Tigre		Sat	SL
116. Erer Gota	Harergie		Fri	WP
117. Ethaya	Arussi		Thur	WP
(Fachase = Dege Bonaya)				
118. Fareddu	Harergie		Sat	SL
119. *Feddis*	Harergie		Mo, (Thur)	SL
120. Ferekessa	Harergie		Thur	SL
121. Fiche	Shewa	2600	Mo	SL
122. Finote Selam	Gojam		Sat	SL
123. *Fontanina*	Welo		*no market*	SL
124. Furda	Harergie		Sat	SL
125. Gambela	Illubabor	600	Mo, Sat, (daily)	SL
126. Ganami	Harergie		Sat	SL
127. Gergertu	Harergie		Mo	SL
128. Ghedo	Shewa		Sat, (Tue, Thur)	SL
			Wed	WP
129. Ghelemso	Harergie		Tue, Fri	SL/WP
130. Ghenemin	Harergie		Sat	SL
131. Gherero	Bale?, Arussi?		Wed, (Sun)	SL
132. Ghimbi	Welega		Sat, (daily)	SL/WP
133. Ghion	Shewa		(Mo), Wed, (Sun)	SL/WP
134. *Gichi*	Illubabor	2080	Mo	SL
135. Gidole	Gemu Gofa		Tue, Thur, Sat	WP
136. Ginchi	Shewa	2300	Thur	SL
137. Goba	Bale	2745	Wed, Sat	SL
138. Gobiye	Welo		Thur	SL
139. Goje	Shewa		Thur	SL
140. Golin	Harergie		Thur	SL

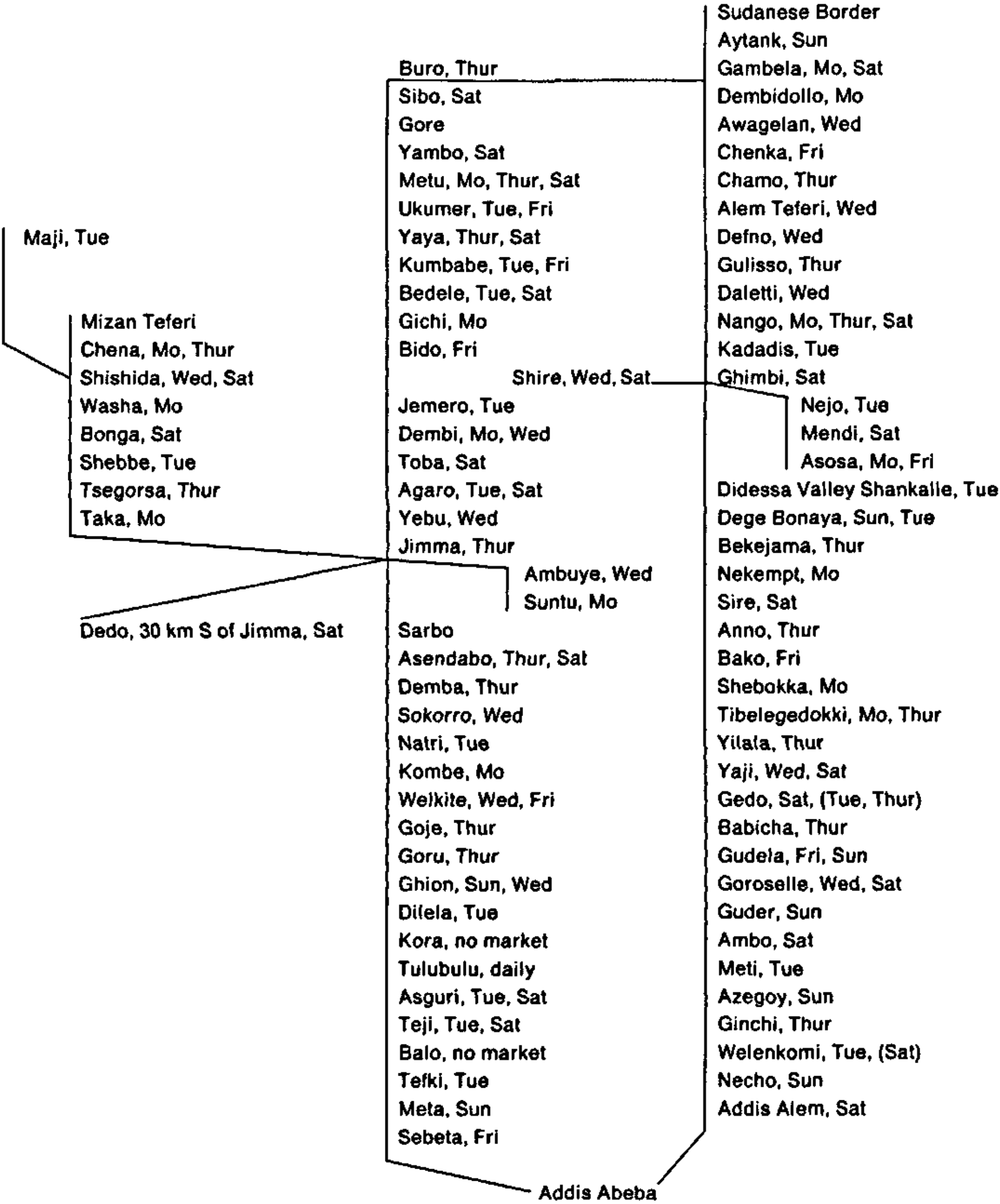
141. Gonder	Beghemder	1970	Sat, (daily)	SL/WP
142. Goro	Bale		Mo, Thur	SL
143. Goro Giber	Welo		Sat	SL
144. Goromselle	Shewa	2390	Wed, Sat	SL
145. Goru	Shewa		Thur	SL
146. Grawa	Harergie		Tue, Sat	SL
147. Gude Beret	Shewa	2760	Mo	SL
148. Gudela	Shewa	2420	Fri, Sun	SL
149. Guder	Shewa	2070	Sun, (daily)	SL
150. Guliso	Welega	1700	Thur	SL
151. Gumda	Sidamo		Fri	SL
152. Gurghessa	Welo		Tue	SL
153. Habe	Bale		Wed	WP
154. Habela	Sidamo	2100	every 5 days	SL
(Hagere Hiwot = Ambo)				
(Hagere Selam = Agere Selam)				
155. Haik	Welo		Tue	SL
156. Hamaressa	Harergie		Sat	WP
157. Hamusit	Beghemder		Thur	SL
158. Harakello	Sidamo	1900	Mo, Thur	SL
159. Harawacha	Harergie		Sat	SL/WP
160. Harema	Beghemder		Sat	SL
161. Harer	Harergie	1850	Sat, (daily)	SL/WP
162. Hidna	Sidamo	2700	Mo, Fri	SL
163. Hirna	Harergie	1780	Sat	SL/WP
164. Hosaina	Shewa	2325	Tue, Thur, Sat	WP
165. Hundene	Harergie		daily	SL
166. Market, 22 km E of Hosaina	Shewa		Fri	WP
167. Infranz	Beghemder		Thur	SL
168. Injibar	Gojam		Tue (early)	SL
169. Jaja	Harergie		Tue	SL
170. Jara	Shewa		no market	SL
171. Jejersa (Gegersa)	Harergie		Mo, Thur	SL
(Jejertu = Gegertu)				
172. Jemero	Illubabor	2200	Tue	SL
173. Jewuha	Shewa	1050	Thur	SL
174. Jiga	Gojam		Thur	SL
175. Jijiga	Harergie		(Tue), Sat	SL
			Thur	WP
176. Jimaj	Shewa	1300	Fri	SL
177. Jimma	Kefa	1675	Thur, (daily)	SL/WP
178. Market 34 km N of Jimma (?Yebu)	Kefa		Wed	WP
179. Kabit (Silti)	Shewa		Thur	WP
180. Kadadis	Welega		Tue	SL
181. Kamise	Shewa	1325	Thur	SL
182. Kanado	Sidamo	2040	every 5 days	SL
183. Karakore	Shewa	1550	Tue	SL
184. Karamakalle	Harergie		Tue	SL
185. Karamile	Harergie	2250	Mo	SL
186. Karra	Harergie		Mo	SL
187. Kebre Megist	Sidamo		Tue, Sat, (Wed)	SL/WP

188. Kembolcha	Welo	1700	Wed, Sat	SL
189. Kembolcha	Harergie		Mo, Thur	SL
190. Kersa	Harergie		Sat	SL
191. Kobbo	Harergie	2075	Mo, Sat	SL
192. Kobbo	Welo		Mo	SL/WP
193. Kofale	Arussi		Wed, Sat	SL
			Fri, Sat	WP
194. Kolito	Shewa		Thur	WP
195. Kombe	Shewa		Mo	SL
196. Konso	Gemu Gofa		Mo, Thur (late)	WP
197. Kora	Shewa		no market	SL
198. Kora	Harergie		Mo	SL
199. Koramina	Harergie		Mo, Thur	SL
200. Kosso	Beghemder		Thur	SL
201. Kulubi	Harergie	2350	Sat	SL/WP
202. Kumbabe	Illubabor	2060	Tue, Fri	SL
203. Kuna Zigabala	Welo		Thur	SL
204. Kuni	Harergie		Mo	SL
205. Kurbita	Gojam		Tue	SL
206. Kurfachelle	Harergie		Fri	SL
207. Kuyera (Shashemane)	Shewa		Sun	SL
208. Kwanni	Tigre		Thur	SL
209. Lafto	Harergie		Mo, Fri	SL
210. Lahu	Sidamo		every 5 days	SL
211. Lalibela	Welo	1975	(Mo)	WP
212. Langano ('Lake')	Shewa		Tue	WP
213. Lange	Harergie		(Mo), Thur	SL
214. Lengedadi	Shewa		Thur	SL
215. L(N)ekem(p)t(i)	Welega	1980	Mo	SL
			Thur, (daily)	WP
216. Libsoa	Welo		Wed	SL
(Limo = Suntu)				
217. Madara	Harergie		Tue, Sat	SL
218. Maichew	Tigre		Mo	SL
			Tue	WP
219. Maikaya	Tigre		no market	SL
220. Maisemri	Tigri		Sat	SL
221. Maji	Kefa		Tue	WP
222. Makareba	Eritrea		no market	SL
223. Maksenyit	Beghemder		Tue	SL
224. Mankuse	Gojam		Thur	SL
225. Marawi	Gojam		Sat	SL
226. Masala	Harergie		Tue	SL
227. Matagesha	Harergie	2225	no market	SL
228. Mechara	Harergie		Tue, Sat	SL
229. Mekdela	Welo		Sat	SL
230. Mekele	Tigre	2280	Mo	SL/WP
231. Meleke	Sidamo		Thur	SL
232. Mendi	Welega		Sat	WP
233. Mersa	Welo		Sat	SL
234. Meseway	Eritrea		Mo	SL

235. Meshinti	Gojam		Thur	SL
236. Meta	Shewa		Sun	SL
237. Metahara	Shewa	900	Thur	SL
238. Meti	Shewa	2450	Tue	SL
239. Metu	Illubabor	1750	Mo, Thur, Sat	SL
240. Michita	Harergie		Mo	SL
241. Mieso	Harergie		Tue	WP
242. Morojo	Sidamo		no market	SL
243. Mulu	Harergie		Sat	SL
244. Nango	Welega	1860	Mo, Thur, Sat	SL
245. Natri	Kefa	2000	Tue	SL
246. Nazareth	Shewa		Thur	WP
247. Necho	Shewa	2270	Sun	SL
248. Neghele	Sidamo	1710	Thur, (daily)	SL
249. Nejo	Welega		Tue	WP
(Nekem(p)t(i) = Lekem(p)t(i))				
250. Quiha	Tigre		Thur	SL
251. Rama	Tigre		Sat	SL
252. Robi	Bale	2475	Thur	SL
253. Robi	Shewa	1150	Tue, Thur	SL
254. Robit	Shewa	1375	Wed	SL
255. Robit	Welo		Wed	SL
256. Sagure	Arussi		Mo, Thur	WP
257. Sarbo (? = Serbo)	Kefa	1825	Mo	SL
258. Sebeta	Shewa		Fri	SL
259. Selak Leka	Tigre		Sat	SL
260. Senbeta	Shewa	1300	Mo	SL/WP
261. Sendafe	Shewa	2350	Wed	SL
262. Serbo (? =Sarbo)	Kefa		Tue	WP
263. Seringa	Welo		Thur	SL
264. Shano	Shewa	2650	Sat	SL
265. Shashemane	Shewa		Sat	SL
			Tue, Thur	WP
266. Shebe	Kefa		Tue, Sat	SL/WP
267. Sheboka	Sheba	1740	Mo	SL
268. Shire	Welega		Wed, Sat	WP
269. Shishida	Kefa	2000	Wed, Sat	SL
270. Sibo	Illubabor	1780	Sat	SL
(Silti = Kabit)				
271. Sire	Arussi		Mo	SL
272. Sire	Welega		Sat	SL
273. Sodo	Sidamo		Wed, Sat	WP
274. Market 20 km S of Sodo	Sidamo		Wed	WP
275. Soka	Harergie		Mo	SL
276. Sokoru	Kefa	1940	Wed	SL
277. Sudan Sefer	Welo		Thur	SL
278. Suntu (Limo)	Kefa		Mo	WP
279. Taka	Kefa	1850	Mo	SL
280. Teda	Beghemder		Mo	SL
281. Tefki	Shewa		Tue	SL
282. Teji	Shewa		Tue, Sat	SL

283. Teliki	Gojam		Tue (early)	SL
284. Tibellegedoki	Shewa	1750	Mo, Thur	SL
285. Toba	Illubabor	1750	Sat	SL
286. Tsegorsa	Kefa	1980	Thur	SL
287. Tulla	Sidamo	2050	Tue, Fri	SL
288. Tullo	Harergie		Wed	SL
289. Tulubulu	Shewa		daily	SL
290. Ukumer	Illubabor		Tue, Fri	SL
291. Unkurat	? Tigre		Sat	SL
292. Wadera	Sidamo	2010	Tue, Sat	SL
293. Waja	Welo		Tue	SL
294. Washa	Kefa		Mo	SL
295. Waychu	Harergie	1750	Sun	SL
296. Weldiya	Welo		Tue	SL
			Tue, Thur, ?Sat	WP
297. Welenkomi	Shewa	2200	Tue, (Sat)	SL
298. Welkite	Shewa	1950	Wed, Fri	SL/WP
299. Wenago	Sidamo		Mo, Thur	WP
300. Wendo	Sidamo	2100	every 5 days	SL/WP
301. Wesha	Bale		Sun, Thur	SL
302. Wochale	Welo		Sat	SL
303. Wonji	Shewa	1550	Sat	WP
304. Worata	Beghemder		Sat	SL
305. Wore Heimanu (Tenta)	Welo		Sat	SL
306. Wore Ilu	Welo		Thur	SL
307. Woshi (? = Washa)	Kefa		Sat	WP
308. Wotet Abay	Gojam		Thur	SL
309. Wotter	Harergie		Tue	SL
310. Yaji	Shewa	1800	Wed, Sat	SL
311. Yambo	Illubabor		Sat	WP
312. Yaya	Illubabor	1690	Thur, Sat	SL
313. Yebu	Kefa		?Wed	SL
314. Yedigba	Beghemder		no market	SL
315. Yilala	Shewa	1840	Thur	SL
316. Yirga Chaffe	Sidamo		Tue, Sat	WP
317. Yirgalem	Sidamo		Mo, Thur	SL/WP
318. Three markets on road Yirgalem –Dila	Sidamo		Mo	WP
319. Yitemen	Gojam		no market	SL
320. Zegeta	Harergie	2300	no market	SL
321. Zengo	Shewa	2600	Thur	SL

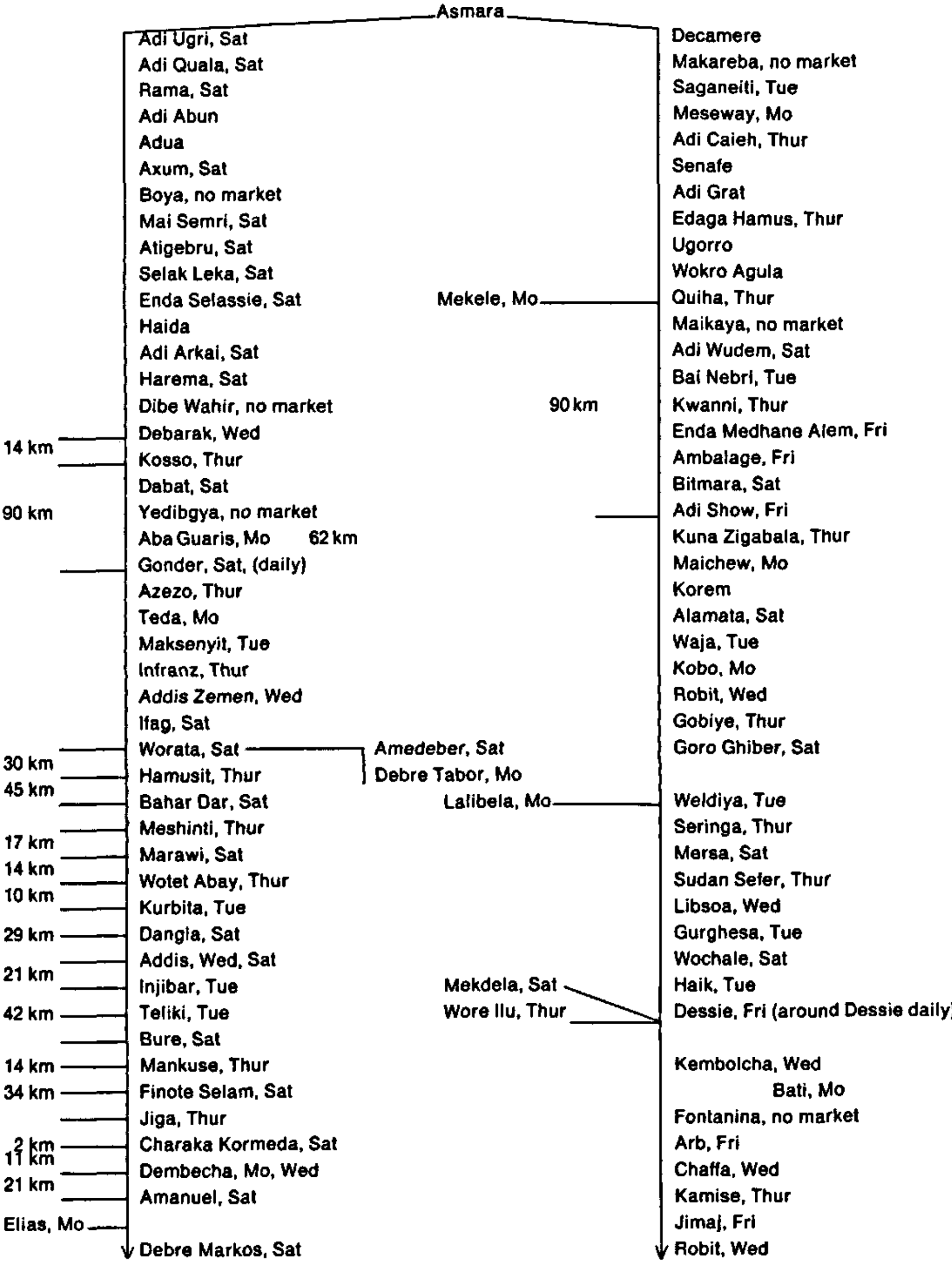
Road scheme of the markets W of Addis Abeba

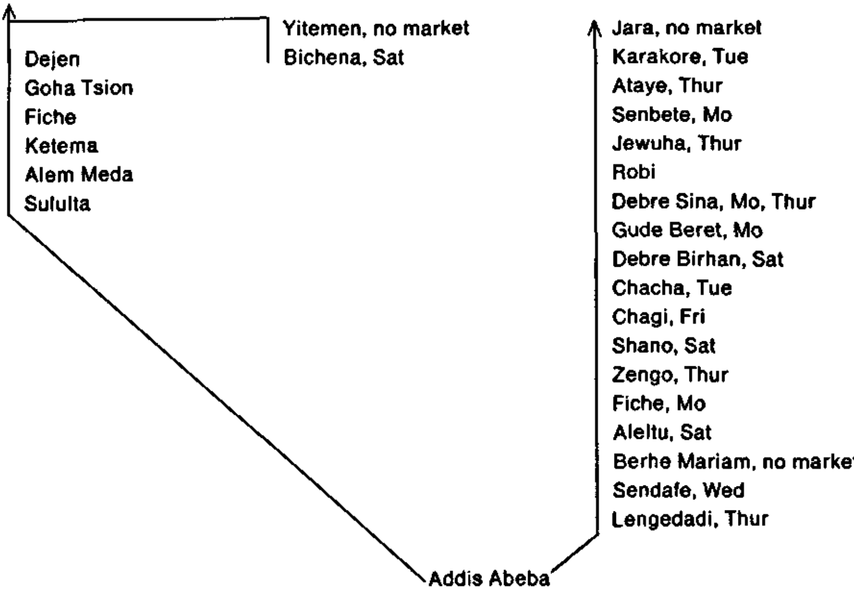


Road scheme of the markets S of Addis Abeba

- Addis Abeba, Wed, Fri, Sat
  - Alem Gena
  - Melka Kunture
  - Butajira, Fri
  - Silti (Kabit), Thur
  - Hosaina, Tue, Thur, Sat
  - (22 km E)
  - ?, Fri
- Akaki
- Debre Zeit, Tue, Sat
  - Nazareth, Thur
  - Melkassa
  - Dera, Tue, Sat
    - Sire, Mo
  - Ethaya, Thur
  - Kulumsa
  - Asella, Tue, Sat
  - Sagure, Mo, Thur
  - Bekoji, Tue, Sat
- Mojo
- Alem Tena
- Maki
- Zway
- Adami Tulu
- Langano, Tue
- Neghelle
- Shashemane, Tue, Thur, Sat
  - Kolito, Thur
  - Shone
  - Buditi, Tue, Thur
  - Soddo, Wed, Sat
  - ?, 20 km from Soddo, Wed
  - Chencha
  - Arba Minch, Tue, Thur, Sat
  - Gardulla
  - Gidole, Tue, Thur, Sat
  - Konso, Mo, Thur
  - Kuyera, Sun
  - Kofale, Wed, Sat
  - Dodolo, Mo, Sat
  - Gherero, Wed, (Sun)
  - Adaba, Tue
  - Wesha, Sun, Thur
  - Dinsha, Tue, Sat
  - Robi, Thur
    - Goro, Mo, Thur
  - Gobba, Wed, Sat
  - Habbe, Wed (75 km from Robi)
- Alelu, Mo, Thur
- Awasa, Mo, Thur
- Tulla, Tue, Fri
- Habela, every 5 days
- Lahu, every 5 days
- Morojo, no market
- Abosto, Tue, Fri
- Kanado, every 5 days
- Yirgalem, Mo, Thur
- Wendo, every 5 days
  - Dilla, daily
  - Wenago, Mo, Thur
  - Yirga Chaffe, Tue, Sat
- Agere Sekam, Tue, Thur, Sat
- Arada, Sat
- Bore, Tue
- Hidna, Mo, Fri
- Gumda, Fri
- Meleke, Thur
- Kebre Mengist, Tue Sat
- Wadera, Tue, Sat
- Harakello, Mo, Thur
- Neghelle, daily

Road scheme of markets N of Addis Abeba




Yitemen, no market
Bichena, Sat
Dejen
Goha Tsion
Fiche
Ketema
Alem Meda
Sululta
Jara, no market
Karakore, Tue
Ataye, Thur
Senbete, Mo
Jewuha, Thur
Robi
Debre Sina, Mo, Thur
Gude Beret, Mo
Debre Birhan, Sat
Chacha, Tue
Chagi, Fri
Shano, Sat
Zengo, Thur
Fiche, Mo
Aleltu, Sat
Berhe Mariam, no market
Sendafe, Wed
Lengedadi, Thur
Addis Abeba

Road scheme of the markets E of Addis Abeba

Other markets in the Chercher region
Ades, Sun
Arberekette, Sat
Biyo, Mo
Fareddu, Sat
Ferekessa, Thur
Genemin, Sat
Jejersa, Mo, Thur
Koramina, Mo, Thur
Madara, Tue, Sat
Michita, Mo
Tullo, Wed

Addis Abeba, Wed, Fri, Sat
Akaki
Debre Zeit, Tue, Sat
Mojo
Holetta, Sat
Nazareth, Thur
Welenchite
Melka
Metahara, Thur
Awash Tabia, Mo
Arba
Kora, Mo
Assebot, Thur
Mieso, Tue
Mulu, Sat
Bordede, Sun
Afdem
Bichet
Erer Gota, Fri
Urso
Dire Dawa, Sat, (daily)
Awalle, Mo, Thur
Kembolcha, Mo, Thur

Wonji, Sat

Mechara, Sat
Belbeleiti, Thur
Ghelemso, Tue, Fri
Waichu, Sun
Karra, Mo
Bedeisa, Sat
Kuni, Mo
Asbe Teferi, Thur
Debesa, Mo
Matagesha, no market
Hirna, Sat
2 h by foot Dobba, Tue
Zegeta, no market
Boroda, Mo, Sat
Karamile, Mo
Kobbo, Mo, Sat
Chelenko, Mo, Thur
Kulubi, Sat
Lange, Thur
Kersa, Sat
Dengago
Adelle
Alemaya, Mo, Thur
Hamaressa, Sat
Harer, Sat, (daily)
Babile
Jijiga, (Tue), Sat

Golin, Thur
Masala, Tue
Jaja, Tue
Jejertu, Mo
Karamakalle, Tue
Harawacha, Sat
Sokka, Mo
Deder, Sat

Wotter, Tue
Lafto, Mo, Fri
Dogu, Mo, Thur
Grawa, Tue, Sat
Kurfachelle, Fri
Dawe, Wed
Bedeno, Mo, Thur
Ganami, Sat
Burka, Mo, Thur
Furda, Sat

Feddis, (Mo), Thur

4 A tabulated list of Ethiopian plants, their oil-bearing parts and oil contents

Fats are a normal constituent of most forms of life. In plants, particularly in the tropics, fat is usually concentrated in the seed. In some plant families, most species have high oil contents (e.g. *Compositae, Cruciferae, Cucurbitaceae*), while others usually have seeds poor in fat (e.g. *Gramineae, Leguminosae*).

However the fat in the seeds of 'low-fat families' often plays a major role in the diet of man or animal, because the seeds are main components in food or feed. The oils bear the lipid-soluble vitamins.

A considerable number of entries refer to plants reported both to occur in Ethiopia and also to produce fats or oils, although outside Ethiopia. Possibly these plants are used locally or to a limited extent, unknown to me. The list draws attention to their possible importance. *Melia* and *Zea mays* are striking examples of this latter group.

Table 71 lists many species occurring in Ethiopia. They are arranged alphabetically by their generic and specific names. The nomenclature is based mainly on Cufodontis' Enumeratio Plantarum Aethiopiae (Facsimile of 1974), which was also used to check the presence of a species in Ethiopia. The few species which are not found in Cufodontis, were seen by me in Ethiopia.

Each entry is accompanied by the name of the family to which the species belongs. Where available to me, local names are given. The following codes for the language from which they are derived is used:

A = Amarinya	K = Kaffinya	T = Tigrinya or Tigray
G = Gallinya (Orominya)	S = Somalinya	

The last three colums indicate the oil-bearing part, the oil contents, and the literature sources, respectively. With some species the column 'oil contents' is marked 'n.n.', which stands for 'not noted'. In such cases the indicated references give information about the oil but do not clearly indicate the amount present.

In several cases, a few references are marked by an asterisk; these refer to publications on the taxonomy or to the occurrence of the species in Ethiopia.

Table 71. Enumeration of plants present in Ethiopia reported to contain oil.

Scientific name	Family	Vernacular names	Part with oil	Oil (g/kg)	Sources
Abelmoschus esculentus (L.) Moench	Malvaceae	bahamia (S)	seed	200–250	Mensier 1957
Abrus precatorius L.	Leguminosae	suawa, luhlo (T)	seed	30	Mensier 1957, Derbesy & Busson 1968; *Aykroyd & Doughty 1964
Abutilon bidentatum Rich.	Malvaceae	oyo (G); tsada-eide (Eritrea); balumbal (S)	seed	150	Barclay & Earle 1974; *de Lotto & Nastasi 1955
Acacia cyanophylla Lindl.	Leguminosae		seed	130	Barclay & Earle 1974
Acacia farnesiana (L.) Willd.	Leguminosae		seed	30	Barclay & Earle 1974; *Whyte et al. 1953
Acacia nilotica (L.) Del.	Leguminosae	chia (T); afilo (Saho); marah, galol, dghir (S)	seed	110	Barclay & Earle 1974
Achyranthes aspera L.	Amaranthaceae	attuch, talang, telendj (A); muchollo, dodut (T)	seed + pericarp	40	Barclay & Earle 1974
Adansonia digitata L.	Bombacaceae	bamba (A); baobab, dima, hömmer (T)	seed kernel	130 300–330	Derbesy & Busson 1968, Ferré 1941, Mensier 1957; *Suzzi 1904/5, Bruno 1906, Jannone 1940, Amare 1974
Albizzia lebbek (L.) Benth.	Leguminosae	sassa (A)	seed	50	Farooq & Varshney 1954, Barclay & Earle 1974
Alisma plantago-aquatica L.	Alismataceae		seed + pericarp	40	Barclay & Earle 1974
Allium cepa L.	Liliaceae	shenkurt, shugurt (A, T); kulubi dimtu (G)	seed	n.n.	Mensier 1957
Alternanthera sessilis (L.) R. Br.	Amaranthaceae		seed	110	Barclay & Earle 1974
Amaranthus caudatus L.	Amaranthaceae	chifogot, lalisho (A); zelal-enomariam (T); katilla, iyaso, jolili (G); rasu reinok (S)	seed	50– 80	Mensier 1957, Sauer 1967
Amaranthus retroflexus L.	Amaranthaceae	rasu-demer (S)	seed	70	Barclay & Earle 1974
Amaranthus tricolor L.	Amaranthaceae		seed	60	Mensier 1957
Ammi majus L.	Umbelliferae	goi-gennem, kuerta-adegi (T)	fruit	130–190	Barclay & Earle 1974

Scientific name	Family	Vernacular names	Part with oil	Oil (g/kg)	Sources
Anagallis arvensis L.	Primulaceae		seed	210	Barclay & Earle 1974
Anethum foeniculum L. (syn. *Foeniculum vulgare* Miller)	Umbelliferae	ensilal, silan (T); kamun (A); kamona (G)	fruit	100	Mensier 1957
			fruit	220	Barclay & Earle 1974; *Jansen 1981
Anethum graveolens L.	Umbelliferae	ensilal, selan (A); kamuni (G); sedan shewa, salanbeta (T)	fruit	170	Mensier 1957; *Jansen 1981
Annona cherimola Miller	Annonaceae	gishta (A, G)	seed	70–80	Mensier 1957
			pulp	10	Mensier 1957
Annona muricata L.	Annonaceae	ambasha, ambasho (A, G)	seed	250	Mensier 1957, Kabele Ngiefu et al. 1976b; *Massa 1934
Annona reticulata L.	Annonaceae	yebare-leb (A)	seed	400	Ubbelohde 1920, Mensier 1957; *Massa 1934
Annona senegalensis Pers.	Annonaceae		seed	280	Kabele Ngiefu et al. 1976b
Annona squamosa L.	Annonaceae	komate (A); cononcona (S)	seed	450	Ubbelohde 1920, Mensier 1957; *Massa 1934
Apium graveolens L.	Umbelliferae		fruit	170	Ubbelohde 1920
			fruit	360	Mensier 1957, Barclay & Earle 1974
Arachis hypogaea L.	Leguminosae	lewz, loze (A); ocholloni (G)	seed	430–480	Williams 1950; *Bigi 1949, this publication
Argemone mexicana L.	Papaveraceae	medafe tilian, fifo (T)	seed	350	Mensier 1957
Argylobium uniflorum (Decne) Jaub. & Spach	Leguminosae		seed	50	Barclay & Earle 1974
Asparagus officinalis L.	Liliaceae		seed	150	Ubbelohde 1920, Mensier 1957
Astragalus boeticus L.	Leguminosae		seed	10	Barclay & Earle 1974
Avena sativa L.	Gramineae	ssa-a (T); gerbu (Jamjam)	caryopsis	50	Ubbelohde 1920, Mensier 1957, Martens et al. 1979

Scientific name	Family	Vernacular names	Part with oil	Oil (g/kg)	Sources
Balanites aegyptiaca (L.) Del.	Zygophyllaceae	djeme, mutcha, shifferrau (A); badana, bedena (G); qok, quassa, magoh (T)	kernel	380–400	Suzzi 1904/5, Sorges 1924, Chantegrel et al. 1963, Heintz et al. 1965
			kernel	410–580	Williams 1950; *Bruno 1906, Ciccarone 1940, Jannone 1940, Cufodontis 1957, de Lotto & Nastasi 1955, Amare 1974
Barbarea vulgaris R. Br.	Cruciferae		seed	200	Mensier 1957
Barringtonia racemosa (L.) Roxb.	Lecythidaceae	de-quasa (S)	seed	140	Ubbelohde 1920, Mensier 1957
Bellardia trixago (L.) All.	Scrophulariaceae		seed	320	Barclay & Earle 1974
Beta vulgaris L.	Chenopodiaceae	key-ser (A)	seed	70	Ubbelohde 1920
			fruit	70	Mensier 1957
			fruit + calyx	50	Barclay & Earle 1974
Bidens biternata (Lour.) Merr. & Sherff	Compositae		achene	150	Barclay & Earle 1974
Biserrula pelecinus L.	Leguminosae		seed	20	Barclay & Earle 1974
Boscia octandra Hochst.	Capparidaceae	hamta, zehet (T)	seed	10	Mensier 1957
Brachiaria ramosa (L.) Stapf	Gramineae		caryopsis	50	Barclay & Earle 1974
Brassica spp.	Cruciferae	gwemenzer, krumba, senafich (A); adri, hamli (T); rafu (G)	seed	390–450	Williams 1950
Brucea antidysenterica J. F. Miller	Simaroubaceae	shoitan buna, wuaginis, kakero (A); abalo, datatu, tamija (G); melita (T); hadawi (S)	seed	220	Mensier 1957; *Jansen 1981
Butyrospermum paradoxum (Gaertn. f.) Hepper (syn. *Butyrospermum parkii* Kotschy)	Sapotaceae		seed	340–440	Williams 1950
			kernel	450–550	Mensier 1957, Jart 1959
Caesalpinia bonduc (L.) Roxb.	Leguminosae	kurunguriu (S)	seed	200–250	Mensier 1957
Caesalpinia decapetala (Roth) Alst.	Leguminosae	kajima (G)	seed	90	Mensier 1957

Scientific name	Family	Vernacular names	Part with oil	Oil (g/kg)	Sources
Cajanus cajan (L.) Millsp.	Leguminosae	yewof-ater (A); ohota, farengota (K); salboko-ghet (S)	seed	10– 20	Ubbelohde 1920, Mensier 1957; *Whyte et al. 1953, Aykroyd & Doughty 1964, Westphal 1974, Thrower 1978
Calendula arvensis L.	Compositae		achene	400	White et al. 1971, Barclay & Earle 1974
Calophyllum inophyllum L.	Guttiferae		seed	500–550	Ubbelohde 1920, Mensier 1957, Polonski 1957
			kernel	c. 700	Williams 1950
Calotropis procera (Ait.) Dry.	Asclepiadaceae	ginda (A, T); tobeya, yehara-zaf (A); denda, torufi (T)	seed	370	Barclay & Earle 1974; *Ferrara 1926, Jannone 1940, Pierucci 1940
Camellia sinensis (L.) O. Kuntze	Theaceae	shay (A); sha (S)	seed	240–450	Ubbelohde 1920
			kernel	500–700	Mensier 1949, 1957; *Ciccarone 1940, Massa 1941
Canarium schweinfurthii Engl.	Burseraceae		kernel	700	Mensier 1957
Canavalia ensiformis (L.) DC.	Leguminosae	der-daguer, saar-sar (S)	seed	30	Barclay & Earle 1974; *Brizioli 1930, Whyte et al. 1953, Aykroyd & Doughty 1964, Westphal 1974
Canavalia rosea (Sw.) DC. (syn. *Canavalia maritima* Thou.)	Leguminosae		seed	20	Mensier 1957
Cannabis sativa L.	Cannabinaceae		fruit	330–350	Williams 1950
Capparis tomentosa Lam.	Capparidaceae	gamaro, konter (A); huntuli (A, G); andal (T)	seed	300	Mensier 1957
Capsella bursa-pastoris (L.) Medic.	Cruciferae	hamli-grat (T)	seed	260	Mensier 1957, Barclay & Earle 1974; *Franchetti 1958
Capsicum annuum L.	Solanaceae	berbere, mitmita, karia (A); filfil (S)	fruit (dry)	12–222	Jansen 1981; *Jansen 1981

Scientific name	Family	Vernacular names	Part with oil	Oil (g/kg)	Sources
Cardiospermum halicacabum L.	Sapindaceae		seed	260–350	Covello 1951, Mensier 1957, Barclay & Earle 1974
			seed + pericarp	190	Barclay & Earle 1974
Carica papaya L.	Caricaceae	papayeh, babayeh (A)	seed	250–270	Mensier 1957, Kabele Ngiefu 1976a; *Massa 1934, de Lotto 1951
Carthamus lanatus L.	Compositae	dender-beita, af-enesti, sekender (T)	achene	170–210	Mensier 1957, Barclay & Earle 1974
Carthamus tinctorius L.	Compositae	suf (A, T); sufi (G); shuf (T); astur (S)	achene	250–300	Williams 1950; *this publication, p. 87
Carum carvi L.	Umbelliferae		fruit	150	Mensier 1957
Cassia arereh Del.	Leguminosae	chitolobei, hambe-hambo (T); shi-lobai (A)	seed	50– 60	Mensier 1957
Cassia fistula L.	Leguminosae		seed	20	Mensier 1957
Cassia occidentalis L.	Leguminosae	senamaki (A); ghed-demer (S)	seed	30– 40	Barclay & Earle 1974; *Whyte et al. 1953, Aykroyd & Doughty 1964, Serratio Valenti 1971
Cassia tora L.	Leguminosae	sonó (Beni Amer)	seed	40	Mensier 1957, Barclay & Earle 1974; *Brizioli 1930, Whyte et al. 1953, Aykroyd & Doughty 1964
Ceiba pentandra (L.) Gaertn.	Bombacaceae	kapok (general)	seed	200–250	Williams 1950, Mensier 1957; *Rass. *econ. Colonie* 1933
Celosia argentea L.	Amaranthaceae		seed	90	Ubbelohde 1920, Barclay & Earle 1974
Cephalocroton cordofanus Hochst.	Euphorbiaceae	chimba (S)	seed	400–450	Mensier 1957
Chenopodium murale L.	Chenopodiaceae	hamli-gewo, hamat-mado (T); ayu-guri (S)	seed	90	Barclay & Earle 1974
Chenopodium opulifolium Schrad.	Chenopodiaceae	hamli-hubo (T); darandaro (Konso); adala, bukana (G)	seed	90	Barclay & Earle 1974; *de Lotto & Nastasi 1955

Scientific name	Family	Vernacular names	Part with oil	Oil (g/kg)	Sources
Chorozophora plicata (Vahl) Juss.	Euphorbiaceae		seed	350–400	Mensier 1957
Chrysanthemum coronarium L.	Compositae		achene	50– 90	Barclay & Earle 1974
Cicer arietinum L.	Leguminosae	shimbera (A, G); ater caich (T); seberé (Eritrea)	seed	50	Ubbelohde 1920, Mensier 1957; *de Lotto & Nastasi 1955, Westphal 1974
Cichorium intybus L.	Compositae		achene	250	White et al. 1971, Barclay & Earle 1974
Cinnamomum zeylanicum Garc. ex Bl.	Lauraceae	karafa (A); karafu (G); krefteh (T)	seed	300–350	Mensier 1957
Citrullus colocynthis (L.) Schrad.	Cucurbitaceae	anguille-baita (T); ya-medur-ombay (A); garedamer (S)	seed	170–230	Ubbelohde 1920, Mensier 1957, Barclay & Earle 1974; *Amare 1974, Oyolu 1977
Citrullus lanatus (Thunb.) Matsumura & Nakai	Cucurbitaceae	cara, gareh, unun (S)	seed	200–400	Kabele Ngiefu et al. 1976b
			kernel	500	Ubbelohde 1920, Mensier 1957; *Amare 1974, Thrower 1978
Citrus aurantium L.	Rutaceae	bahro, bahr lomi (A)	seed	200–280	Ubbelohde 1920, Mensier 1957, Braddock & Kesterton 1973
			kernel	c. 550	Williams 1950; *Massa 1934, Jannone 1940, Castellani 1948, de Lotto 1951, de Lotto & Nastasi 1955
Citrus limon (L.) Burm. f.	Rutaceae	turungo (A); lomi (G); narage (Hamasen)	seed	300–350	Ubbelohde 1920, Franquelli & Mariani 1959, Braddock & Kesterton 1973; *Massa 1934, de Lotto 1951
Citrus medica L.	Rutaceae	turungu (A); trungui (T)	seed	n.n.	Ubbelohde 1920; Braddock & Kesterton 1973; *as preceding one
Cleome arabica Juslen	Capparidaceae		seed	210	Barclay & Earle 1974
Cleome diandra Burch.	Capparidaceae		seed	280	Barclay & Earle 1974
Cleome gynandropsis L. (syn. *Gynandropsis gynandra* (L.) Briq.)	Capparidaceae	gargama, bökhbeha (T); aiya, darjo, gowlollo (S)	seed	180–250	Mensier 1957, Cruse 1973, Barclay & Earle 1974; *Amare 1974, Cufodontis 1974

Scientific name	Family	Vernacular names	Part with oil	Oil (g/kg)	Sources
Cleome viscosa L.	Capparidaceae	behhbehha, behleha (T)	seed	30	Ubbelohde 1920, Mensier 1957
			seed	230	Barclay & Earle 1974
Cocos nucifera L.	Palmae	gawz (?)	fresh endosperm	350	Ubbelohde 1920
			coprah	650	Ubbelohde 1920, Woodroof 1979; *Massa 1934
Coffea arabica L.	Rubiaceae	buna (A, G, T)	seed	120–160	Ubbelohde 1920, Mensier 1957
Colutea istria Mill.	Leguminosae	gwaye, gewayeta, kokhata (T)	seed	20	Barclay & Earle 1974; *Senni 1909, Amare 1974
Conium maculatum L.	Umbelliferae	chof-chof (G)	fruit	120–180	Barclay & Earle 1974
Convolvulus arvensis L.	Convolvulaceae	gama-haresti, ja-gurberi-gammi (T)	seed	90	Mensier 1957, Barclay & Earle 1974
Conyza bonariensis (L.) *Cronq.*	Compositae		achene	240	Barclay & Earle 1974
Corchorus aestuans L.	Tiliaceae		seed	130	Barclay & Earle 1974
Corchorus olitorius L.	Tiliaceae		seed	100–150	Mensier 1957
Cordeauxia edulis Hemsl.	Leguminosae	fruit: yeb, yeheb (S) shrub: gud, guda (S)	seed	100–120	Marassi 1939, Brilli & Mulas 1939, Bally 1966; *Brilli & Mulas 1939, Marassi 1939, Roti-Michelozzi 1957, Aykroyd & Doughty 1964, Bally 1966, Kazmi 1979, Miège 1978, 1979, this publication, p. 110.
Coriandrum sativum L.	Umbelliferae	dimbelal (A); shukar (G); zagda (T)	fruit	50	Ubbelohde 1920
			fruit	150–250	Mensier 1957
			fruit	120	Barclay & Earle 1974; *Jansen 1981
Crambe abyssinica Hochst. ex R. E. Fries	Cruciferae	fujul (Mieso)	seed		This publication, p. 82.
Crotalaria laburnifolia L.	Leguminosae	gelélo, darga (S)	seed	40	Barclay & Earle 1974; *Aykroyd & Doughty 1964
Crotalaria pallida Ait. (syn. *Crotalaria mucronata* Desv.)	Leguminosae		seed	30	Barclay & Earle 1974; *White et al. 1953, de Lotto & Nastasi 1955

Scientific name	Family	Vernacular names	Part with oil	Oil (g/kg)	Sources
Crotalaria saltiana Andr.	Leguminosae	gobol-deye (S)	seed	20	Barclay & Earle 1974; *de Lotto & Nastasi 1955
Croton macrostachyus Hochst.	Euphorbiaceae	besana (A); makanisa, bakanisa (G); ambuk (T)	seed	190	Mensier 1957; *Jansen 1981
Croton megalocarpum Hutch.	Eurphorbiaceae		seed	280–340	Mensier 1957
Cryptostegia grandiflora R. Br.	Asclepiadaceae		seed	100	Mensier 1957
Cucumis melo L.	Cucurbitaceae	unun (Danakil); corongi (S); rhotah (Eritrea)		400	Ubbelohde 1920
			seed	300–400	Mensier 1957; *Thrower 1978, this publication, p. 112.
			seed		
Cucumis sativus L.	Cucurbitaceae	dösala-döbba (T)	seed	250–300	Mensier 1957; *Massa 1934
Cucurbita maxima Duch.	Cucurbitaceae	duba (A, T); adubi (G); hamham (T)	kernel	350–400	Mensier 1957
Cucurbita pepo L.	Cucurbitaceae	baharkel, yequara-arag (A); duba, wushish (A, T)	seed	360	Ubbelohde 1920
			kernel	500	Mensier 1957; *Kline et al. 1969, Ashagari 1973, this publication, p. 112.
Cuminum cyminum L.	Umbelliferae	ensilal, kamun (A); kamun, hawaja (G); kemano (T)	fruit	100	Mensier 1957
			fruit	400	Jansen 1981 (also *)
Cynara scolymus L.	Compositae	karshuf (G)	achene	400–450	Mensier 1957
Cyperus articulatus L.	Cyperaceae	kolafo, garbab (S)	corm	160–170	Mensier 1957
Cyperus esculentus L.	Cyperaceae	go-ondo (S)	corm	170–280	Ubbelohde 1920, Mensier 1957, Wojnarowicz 1964, Osman & Gad 1972, Kabele Ngiefu et al. 1976a, Chelkowski & Leonczuk 1978; *Amare 1974
Datura ferox L.	Solanaceae		seed	180	Barclay & Earle 1974
Datura inoxia Mill.	Solanaceae	barambal (S)	seed	120–170	Barclay & Earle 1974
Datura metel L.	Solanaceae	atafaris (A); ashenger (G); messerbah (T)	seed	n.n.	Suzzi 1904/5, Mensier 1957; *Schweinfurth 1891, Bruno 1906
Datura stramonium L.	Solanaceae	as preceding	seed	180–290	Ubbelohde 1920, Mensier 1957, Barclay & Earle 1974; *Siegenthaler ?1963

Scientific name	Family	Vernacular names	Part with oil	Oil (g/kg)	Sources
Daucus carota L.	Umbelliferae	karot (A, G); kuerta (T)	fruit	130	Ubbelohde 1920, Mensier 1957
				190–270	Barclay & Earle 1974
Digitalis ferruginea L.	Scrophulariaceae		seed	280	Barclay & Earle 1974
Digitaria longiflora (Retz.) Pers.	Gramineae	yebi-oki (S)	caryopsis	50	Ubbelohde 1920
Diplotaxis erucoides (L.) DC.	Cruciferae	aitha-gunarama (T)	seed	320–360	Barclay & Earle 1974
Dodonaea viscosa (L.) Jacq.	Sapindaceae	tadacha, kitkita (A); kirtita (G); tasos (T)	seed	70–190	Mensier 1957, Barclay & Earle 1974
Duranta repens L.	Verbenaceae	kombolcha (A, G)	seed	10	Barclay & Earle 1974
Echinochloa crus-galli (L.) Beauv.	Gramineae	afsisso (T); assandawa (A, T); ossugul (S)	caryopsis	70	Barclay & Earle 1974
Echium plantagineum L.	Boraginaceae		seed	n.n.	White et al. 1971
Eclipta prostrata (L.) L.	Compositae	ghed-agindi (S)	achene	130	Barclay & Earle 1974
Eleusine coracan (L.) Asch. & Gräbn.	Gramineae	dagussa, tocuso (A); daguja (G)	caryopsis	c. 20	Mahadevappa & Raina 1978
Elymus farctus (Viv.) Runemark & Melderis (syn. *Agropyron junceum* (L.) Beauv.)	Gramineae		caryopsis	30	Barclay & Earle 1974
Entada gigas (L.) Fawcett & Rendle	Leguminosae		seed	50	Derbesy & Busson 1968
			seed	300	Mensier 1957
Epilobium hirsutum L.	Onagraceae	ya- lamchou (A)	seed	310	Barclay & Earle 1974
Eruca sativa Hill	Cruciferae		seed	240–350	Mensier 1957, White et al. 1971, Barcaly & Earle 1974; *Thrower 1978
Erucaria hispanica (L.) Druce	Cruciferae		seed	320	Barclay & Earle 1974
Erythrina crista-galli L.	Leguminosae		seed	150	Mensier 1957
			seed	170	Barclay & Earle 1974
Euphorbia abyssinica Gmel.	Euphorbiaceae	kolkwal (A, T); qalanqal (T); hadami (G)	seed	300–350	Mensier 1957
Euphorbia lathyris L.	Euphorbiaceae		kernel	350–500	Mensier 1957
			seed	480	Kleiman et al. 1965
Euphorbia peplus L.	Euphorbiaceae		seed	n.n.	Mensier 1957

Scientific name	Family	Vernacular names	Part with oil	Oil (g/kg)	Sources
Ferula communis L.	Umbelliferae	dog (A); deok (T)	fruit	90	Barclay & Earle 1974; *Amare 1974
Ficus carica L.	Moraceae		achene	300	Mensier 1957
Flacourtia indica (Burm. f.) Merrill	Flacourtiaceae	menedem (A); huda, hudaferda (G)	seed	120	Barclay & Earle 1974
Fragaria vesca L.	Rosaceae		nutlet	200	Ubbelohde 1920, Mensier 1957; *Massa 1934
Funtumia elastica (Preuss) Stapf	Apocynaceae		seed	280–330	Mensier 1957
			kernel	500–580	Mensier 1957
Glycine max (L.) Merr.	Leguminosae		seed	120–190	Oléagineux 1957; *this publication, p. 114.
Gossypium spp.	Malvaceae	tiftirre (A)	seed	c. 200	Williams 1950
			kernel	c. 400	Williams 1950; *this publication, p. 116.
Grewia tenax (Forsk.) Fiori	Tiliaceae	kach (A); asha, ado, eka, merayo, eka (G); heda (T)	seed	230	Barclay & Earle 1974
Grewia villosa Willd.	Tiliaceae	agobdi, ogomde, udu-kabedu (G); hawene, khafule (T)	seed	10	Mensier 1957
Guizotia abyssinica (L. f.) Cassini	Compositae	nug (A); nugi, nuga (G); neuk (T)	achene	400–450	this publication, p. 122.
Halocnemum strobilaceum (Pall.) M. Bieb.	Chenopodiaceae		seed	130	Barclay & Earle 1974
Helianthus annuus L.	Compositae	ferenj suf (A)	achene	220–320	Mensier 1957
			kernel	410–550	Mensier 1957; *this publication, p. 146.
Hibiscus cannabinus L.	Malvaceae	sugot, ahor-harrish (T)	seed	150–250	Mensier 1957; *Bruno 1906
Hibiscus sabdariffa L.	Malvaceae	karkade (A, T)	seed	n.n.	Mensier 1957
Hibiscus tiliaceus L.	Malvaceae		seed	60	Barclay & Earle 1974
Hordeum vulgare L.	Gramineae	gebs (A); gerbu, garbu (G); segam (T)	caryopsis	20	Ubbelohde 1920, Mensier 1957; *Welch 1978
Hyphaene benadirensis Becc.	Palmae	acat-bar, locob (S); dum (Eritrea)	kernel	n.n.	Boll. econ. Eritrea 1929; *Branca 1960

Scientific name	Family	Vernacular names	Part with oil	Oil (g/kg)	Sources
Hyphaene thebaica (L.) Martius	Palmae	dum (general)	kernel	80– 90	Mensier 1957
Hyptis spicigera Lam.	Labiatae		fruit	200–400	Mensier 1957
Iberis umbellata L.	Cruciferae		seed	n.n.	White et al. 1971; *Franchetti 1958
Indigofera hirsuta L.	Leguminosae		seed	20	Barclay & Earle 1974; *Brizioli 1930, Whyte et al. 1953
Indigofera linifolia (L. f.) Retz.	Leguminosae		seed	30	Barclay & Earle 1974
Ipomoea eriocarpa R. Br.	Convolvulaceae		seed	100	Barclay & Earle 1974
Ipomoea nil (L.) Roth	Convolvulaceae		seed	110–140	Ubbelohde 1920, Barclay & Earle 1974
			seed	150	Mensier 1957
Ipomoea pes-tigridis L.	Convolvulaceae		seed	100	Barclay & Earle 1974
Jatropha curcas L.	Euphorbiaceae	andelmeluc (S); abelmeluk (T)	seed	310–400	Williams 1950
			kernel	500–610	Mensier 1957, Williams 1950; *this publication, p. 149.
Jatropha lobata (Forsk.) Muell.-Arg.	Euphorbiaceae		seed	200–250	Mensier 1957
Lablab niger Medic. (syn. *Dolichos lablab* L.)	Leguminosae	amora-gwaya (A)	seed	20	Ubbelohde 1920, Mensier 1957; *Westphal 1974
Lactuca serriola L.	Compositae		achene	350–450	Mensier 1957, Barclay & Earle 1974
Lagenaria siceraria (Molina) Standley	Cucurbitaceae	buke, dabakula (G); kil (A); ham-ham, shenkenab (T); bohor, gareh (S)	kernel	500–550	Mensier 1957
Lawsonia inermis L.	Lythraceae	elam (T); elan, ghedur, henun (S)	seed	60–100	Ubbelohde 1920, Agarwal et al. 1959
Lens culinaris Medic.	Leguminosae	ades, missir (A); missera, missing (G); misser, bersem (T)	seed	10– 20	Mensier 1957; *Westphal 1974
Leonotis nepetifolia (L.) R. Br.	Labiatae		fruit	250–300	Mensier 1957
			fruit	380	Barclay & Earle 1974, White et al. 1971, Bagby et al. 1964
Lepidium sativum L.	Cruciferae	feto (A); shimfo (G)	seed	250	Mensier 1957; *Jansen 1981

Scientific name	Family	Vernacular names	Part with oil	Oil (g/kg)	Sources
Linaria flaviflora (Boiss.) Cuf.	Scrophulariaceae		seed	370	Ubbelohde 1920
Linum strictum L.	Linaceae		seed	330	Barclay & Earle 1974
Linum usitatissimum L.	Linaceae	telba (A); konter (G); entatie (T); mutu (K)	seed	280–440	Mensier 1957; *this publication, p. 151.
Lotus corniculatus L.	Leguminosae		seed	60– 70	Ubbelohde 1920, Mensier 1957; *Whyte et al. 1953
Luffa cylindrica (L.) Roemer	Cucurbitaceae	madodoki (S)	kernel	450	Mensier 1957, Kabele Ngiefu et al. 1976
Lupinus albus L.	Leguminosae	gebto, gibdo (A, T)	seed	60	Ubbelohde 1920, Mensier 1957; *Gladstones 1970, 1974, Westphal 1974
Lycopersicon esculentum Miller	Solanaceae	timatim (A); timatimi (G); nyanyo (S)	seed	c. 200	Williams 1950; *Ciccarone 1940, de Lotto 1951, Ashagari 1973
Maesa lanceolata Forsk.	Myrsinaceae	kelawa (A); abaye (G); saoria (T)	dry fruit	260	This publication, p. 197.
Magnolia hypoleuca Sieb. & Zucc. (syn. *M. obovata* Thunb.)	Magnoliaceae		seed	180	Mensier 1957
Malus sylvestris Miller var. domestica (Borkhausen) Mansfeld	Rosaceae	appel (A)	seed	200	Ubbelohde 1920, Mensier 1957; *Massa 1934, de Lotto 1951
Malva parviflora L.	Malvaceae	lut, lit (A); lekti, angeffteha (T)	seed	180	Mensier 1957
			seed	150	Barclay & Earle 1974
Malva verticillata L.	Malvaceae	adguar, lut (A); liti (G)	seed	180	Barclay & Earle 1974
Malvastrum coromandelianum (L.) Garcke	Malvaceae		seed	140	Barclay & Earle 1974
Mangifera indica L.	Anacardiaceae		seed	60	Ubbelohde 1920
			kernel	150	Mensier 1957; *Massa 1934, de Lotto 1951, de Lotto & Nastasi 1955
Manihot aipi Pohl.	Euphorbiaceae	mohogo (s)	seed	200–250	Mensier 1957

Scientific name	Family	Vernacular names	Part with oil	Oil (g/kg)	Sources
Manihot esculenta Crantz	Euphorbiaceae	mohogo, batata, mananga (S)	kernel	230	Ubbelohde 1920
			kernel	470	Mensier 1957
			tuber (flour)	25	Hudson & Ogunsua 1974
Manihot glaziovii Muell. Arg	Euphorbiaceae		seed	100	Ubbelohde 1920
			kernel	400	Mensier 1957
Maytenus senegalensis (Lam.) Exell	Celastraceae	kombolcha (G); atatt (A) argudi (T)	seed	500	Mensier 1957
Medicago lupulina L.	Leguminosae		seed	50	Barclay & Earle 1974; *Whyte et al. 1953
Medicago orbicularis (L.) Allioni	Leguminosae		seed	30– 40	Barclay & Earle 1974
Medicago sativa L.	Leguminosae	siddisa (G)	seed	70–110	Mensier 1957
Melia azadirachta L. (syn. *Azadirachta indica* A. Juss.)	Meliaceae		kernel	350–450	Mensier 1957; *Bois et Forêts 1963
Melia azedarach L.	Meliaceae	geed-hindi, meri-meri (S)	seed	400–440	Ubbelohde 1920, Mensier 1957, Barclay & Earle 1974; *Bruno 1906, Radwanski 1977, Kazmi 1980, Bois et Forêts 1963
Melilotus neapolitana Ten.	Leguminosae		seed	20	Barclay & Earle 1974
Melilotus officinalis (L.) Pall.	Leguminosae		seed	80	Mensier 1957
Mentha pulegium L.	Labiatae	samhall-beita (T)	fruit	270	Barclay & Earle 1974
Mirabilis jalapa L.	Nyctaginaceae	harmele kobera (A); harmal dima (G)	seed + pericarp	50	Barclay & Earle 1974
Momordica charantia L.	Cucurbitaceae		seed	350	Mensier 1957
			seed	320	Barclay & Earle 1974
Moringa oleifera Lam.	Moringaceae	mrongo (S)	kernel	370	Mensier 1957, Ferrao et al. 1970; *Amare 1974
Moringa peregrina (Forsk.) Fiori	Moringaceae	mokor (S)	kernel	500	Mensier 1957

Scientific name	Family	Vernacular names	Part with oil	Oil (g/kg)	Sources
Morus alba L.	Moraceae		whole fruit	40	Ubbelohde 1920
			seed	250–350	Mensier 1957
Mucuna pruriens (L.) DC.	Leguminosae		seed	60	Nair et al. 1954; *Westphal 1974
Musa paradisiaca L.	Musaceae	muz (A)	fruit	< 10	Mensier 1957
Myrsine africana L.	Myrsinaceae	kachamo (A, G); saso (T); rearamole (S)	seed	200	Barclay & Earle 1974; *Jansen 1981
Myrtus communis L.	Myrtaceae	ades (A); addisa, koddo (G)	seed	120–150	Mensier 1957
			seed	10– 60	Barclay & Early 1974
Nasturtium officinale R. Br.	Cruciferae	gungumeh-mai (T)	seed	250	Mensier 1957; *Schweinfurth 1891
Nerium oleander L.	Apocynaceae	machallow (G)	seed	150–200	Mensier 1957
Nicandra physalodes (L.) Gaertn.	Solanaceae	gheraksha, kesh-kesh (Eritrea)	seed	270	Barclay & Earle 1974
			seed	200	Mensier 1957
Nicotiana rustica L.	Solanaceae	galla-tambo (G); tombaco (T)	seed	330–430	Mensier 1957
Nicotiana tabacum L.	Solanaceae	tembaho (A); timbo, balatimbo (G)	seed	300–450	Ubbelohde 1920, Mensier 1957, Barclay & Earle 1974; *de Lotto 1951, Cufodontis 1957
Nigella sativa L.	Ranunculaceae	tikur azmud (A); abasuda, gurati (G); awosede (T)	seed	400	Suzzi 1904/5
				300–350	Mensier 1957; *Jansen 1981
Ocimum basilicum L.	Labiatae	basobila (A); sesak (T); kassé, kefo (G); rehan (S)	seed	190	Mensier 1957, Barclay & Earle 1974; *Jansen 1981
Ocimum canum Sims	Labiatae	sahmar (T); mirra-arthraleh (S)	fruit	100–120	Mensier 1957
Ocimum kilimandscharicum Guerke	Labiatae		fruit	150	Mensier 1957
Ocimum urticifolium Roth	Labiatae	basobila (A); abbu-neddia (T); angeabí (G)	fruit	n.n.	Mensier 1957
Oncoba spinosa Forsk.	Flacourtiaceae	akoko (A); gilbo (G); hegot (T)	seed	350–380	Mensier 1957
Oryza sativa L.	Gramineae	ruez (A)	germ	80–160	Ubbelohde 1920, Oléagineux 1962; *Luh 1980

Scientific name	Family	Vernacular names	Part with oil	Oil (g/kg)	Sources
Osteospermum muricatum E. Meyer ex DC.	Compositae		achene	n.n.	Willingham & White 1973
Panicum miliaceum L.	Gramineae		caryopsis	30– 70	Mensier 1957
			bran	180	Ubbelohde 1920
Panicum turgidum Forsk.	Gramineae	dungarre (S)	caryopsis	40	Barclay & Earle 1974
Papaver somniferum L.	Papaveraceae	genbicha (A); shankore (G); bahr-tef (Bonga)	seed	450–500	Williams 1950; *Massa 1942, Gericke 1948
Pappea capensis-Eckl. & Zeyh. var. capensis	Sapindaceae	bika (A, G)	seed	450–500	Mensier 1957
			kernel	700–750	Mensier 1957
Pappea capensis Eckl. & Zeyh. var. radlkoferi Schinz	Sapindaceae	bika (A, G); abagama, araugagut (T); adadak (S)	seed	470–570	Mensier 1957
Parkinsonia aculeata L.	Leguminosae		seed	10– 20	Mensier 1957
Passiflora edulis Sims	Passifloraceae		seed	180–230	Mensier 1957
Persea americana Mill.	Lauraceae	tha-saré (G)	seed	n.n.	Ubbelohde 1920
			fruit	50–100	Ubbelohde 1920, Vergriete 1949, Mensier 1957; *Massa 1934, Williams 1977
Phacelia tanacetifolia Benth.	Hydrophyllaceae		seed	30	Mensier 1957
Phalaris paradoxa L.	Gramineae		caryopsis	90	Barclay & Earle 1974
Phaseolus coccineus L.	Leguminosae		seed	100–200	Mensier 1957; *Westphal 1974
Phaseolus lunatus L.	Leguminosae	atera bakerra (A), lojo, fasoelea make (G)	seed	100–200	Mensier 1957; *Westphal 1974
Phaseolus mungo L.	Leguminosae	dir-agrar, salboco (S)	seed	100–200	Mensier 1957; *Westphal 1974, Whyte 1953
Phaseolus vulgaris L.	Leguminosae	adanguare (A); ashanguare (G); adagora (T)	seed	100–200	Mensier 1957; *Whyte et al. 1953, Westphal 1974
Phoenix dactylifera L.	Palmae	timira, tamar (G); timir (S)	kernel	80–100	Ubbelohde 1920
			kernel	60– 80	Mensier 1957; *Baccarini 1909, Massa 1934, Branca 1936, Pierucci 1940

Scientific name	Family	Vernacular names	Part with oil	Oil (g/kg)	Sources
Pistacia lentiscus L.	Anacardiaceae	jirersa (G); murkut, heis (S)	kernel	500	Mensier 1957
			seed	500–600	Ubbelohde 1920
			seed + pericarp	130	Barclay & Earle 1974
Pisum sativum L.	Leguminosae	ater (A, T); atari, dangule (G)	seed	100–200	Mensier 1957
				100	Barclay & Earle 1974;*Westphal 1974
Plantago albicans L.	Plantaginaceae		seed	60	Barclay & Earle 1974
Plantago lanceolata L.	Plantaginaceae	götöb (A); mendelo (T)	seed	50– 80	Barclay & Earle 1974
				80– 90	Mensier 1957
Plantago major L.	Plantaginaceae	medelo (T); sirign (G)	seed	160	Barclay & Earle 1974
				100	Mensier 1957
Polygala butyracea Heckel	Polygalaceae		seed	400	Ubbelohde 1920
			seed	320–420	Williams 1950, Mensier 1957
Polypogon monspeliensis (L.) Desf.	Gramineae	waila-siddeh (S)	caryopsis	60	Barclay & Earle 1974
Prosopis juliflora (Sw.) DC.	Leguminosae	lebi (S)	seed	30	Barclay & Earle 1974
Prunus armeniaca L.	Rosaceae	cacá (Eritrea)	kernel	400–450	Ubbelohde 1920
(syn. *Armeniaca vulgaris* Lam.)			kerne'	400–500	Mensier 1957
Prunus dulcis (Mill.) Webb (syn. *Amygdalus communis* L.)	Rosaceae		fresh kernel	400	Ubbelohde 1920
			dry kernel	530	Rocchetti 1948, Mensier 1957; *Jannone 1940, de Lotto & Nastasi 1955
Prunus persica (L.) Batsch (syn. *Persica vulgaris* Mill.)	Rosaceae	kohk (A); kuchi (G)	kernel	300–450	Ubbelohde 1920, Mensier 1957; *Massa 1934, Jannone 1940, de Lotto 1951
Psidium guajava L.	Myrtaceae	zeitun (A); zeituna (G)	leaves	60	Ubbelohde 1920
			seed	95	Idiem' Opute 1978
			seed	150	Mensier 1957; *Massa 1934
Psoralea corylifolia L.	Leguminosae	ghet-biot, balambal (S)	seed	200	Ubbelohde 1920, Mensier 1957
Pulicaria undulata (L.) C. A. Meyer	Compositae	enambatta, hobba (T)	achene	90	Barclay & Earle 1974

Scientific name	Family	Vernacular names	Part with oil	Oil (g/kg)	Sources
Punica granatum L.	Punicaceae	roman, *ruman* (A); rumana (Kefa)	seed	70	Ubbelohde 1920
				190	Umarov 1969; *Massa 1934
Raphanus raphanistrum L.	Cruciferae		seed	250–400	Mensier 1957
Raphanus sativus L.	Cruciferae	fujul (G)	seed	450–500	Mensier 1957
Rapistrum rugosum (L.) All.	Cruciferae		seed	360	Barclay & Earle 1974
Reseda luteola L.	Resedaceae		seed	220–340	Ubbelohde 1920, Barclay & Earle 1974
Rhynchosia minima (L.) DC.	Leguminosae		seed	10	Barclay & Earle 1974
Ricinus communis L.	Euphorbiaceae	gulo (A); kobo (G); guleh, bulleh (T)	seed	460–500	Williams 1950; *this publication, p. 204.
Rosa species	Rosaceae	gaga (A, T); gora (G); *koloshim*, sege-reda (T)	*achene*	100	Ubbelohde 1920, Mensier 1957, Rutkowsky et al. 1965
Rubia tinctorum L.	Rubiaceae		seed	120	Barclay & Earle 1974
Ruta chalepensis L.	Rutaceae	tenadam, saina-adam (A, T); gulla, talladam (A); dsharta (G)	seed	330	Barclay & Earle 1974; *Jansen 1981
Salvadora persica L.	Salvadoraceae	garsa (A); adai (S, T)	seed	400–450	Mensier 1957
Salvia nilotica Juss. ex Jacq.	Labiatae	basobilla (A); shokoksa (G); entatie-wollakha (T)	nutlet	275	Suzzi 1905; *this publication, p. 243.
Salvia schimperi Benth.	Labiatae	debarak (A); abadera (T)	seed	280	Suzzi 1904; *this publication, p. 239.
Sauromatum venosum (Ait.) Kunth	Araceae	hamaserau, hambughaita (T)	seed	300	Barclay & Earle 1974
Schinus molle L.	Anacardiaceae	libanata, berberé-zellim (T)	seed + pericarp	80	Barclay & Earle 1974
Scirpus articulatus L.	Cyperaceae		seed + pericarp	30	Barclay & Earle 1974
Scleranthus annuus L.	Caryophyllaceae	zegner-demmu, zoggeri-dummo (T)	seed	90	Barclay & Earle 1974
Sclerocarpus africanus Jacq.	Compositae		achene	420	Barclay & Earle 1974
Sclerocarya birrea (Rich.) Hochst.	Anacardiaceae	kumal, gomales (A); abogul, abungul (T)	kernel	550	Mensier 1957

Scientific name	Family	Vernacular names	Part with oil	Oil (g/kg)	Sources
Scorpiurus muricata L.	Leguminosae	erwé (T)	seed	30	Barclay & Earle 1974
Secale cereale L.	Gramineae	damash, senaf-kollo (A)	caryopsis	20	Mensier 1957
			germ	> 100	Mensier 1957
Sesamum indicum L.	Pedaliaceae	selit (A); zedi (G); angada (T)	seed	480–540	Williams 1950; *this publication, p. 248.
Sesbania sesban (L.) Merrill	Leguminosae	balambal-biot,ghed-bio (S)	seed	90	Barclay & Earle 1974
Setaria italica L.	Gramineae		caryopsis	30– 60	Mensier 1957
Setaria verticillata (L.) P. Beauv.	Gramineae	marabol (S); be-getti-feddani (T)	caryopsis	70	Barclay & Earle 1974
Setaria viridis (L.) P. Beauv.	Gramineae		caryopsis	40	Barclay & Earle 1974
Sida acuta Burm. f.	Malvaceae		seed	170	Barclay & Earle 1974
Sida acuta Burm. f. var. carpinifolia (L. f.) Schum.	Malvaceae		seed	50– 70	Mensier 1957
Sida cordifolia L.	Malvaceae		seed	40	Mensier 1957
Sida rhombifolia L.	Malvaceae	daaro-medri, dechedaro, kerura-thiel (Eritrea)	seed	140–170	Mensier 1957
Sinapis alba L.	Cruciferae	senafich (A, T)	seed	250–350	Mensier 1957
Sinapis arvensis L.	Cruciferae	ghidde-belu (T)	seed	300–400	Mensier 1957
Sisymbrium erysimoides Desf.	Cruciferae	gungumeh, kartanesto (T)	seed	300	Barclay & Earle 1974; *Franchetti 1958
Sisymbrium irio L.	Cruciferae	demmet (T)	seed	n.n.	Mensier 1957
Solanum arundo Mattei	Solanaceae	alundo, arundo (S)	seed	120	Paoli 1938
Solanum incanum L.	Solanaceae	embway (A); angulleh (T); addur, mor (S)	seed	110	Barclay & Earle 1974
Solanum melongena L.	Solanaceae	brinjan (S)	seed	100	Mensier 1957
Solanum nigrum L.	Solanaceae	tikur-aut (A); achọ (K)	seed	310	Mensier 1957, Barclay & Earle 1974
Solanum pseudocapsicum L.	Solanaceae		seed	n.n.	Mensier 1957
Solanum tuberosum L.	Solanaceae	dinnich (A); dinicha-shewa (G); doko (K)	tuber	1	Mensier 1957
Sorghum cernuum (Ard.) Host.	Gramineae		caryopsis	30	Ubbelohde 1920

Scientific name	Family	Vernacular names	Part with oil	Oil (g/kg)	Sources
Sorghum species	Gramineae	mashinga, bishinga (G), mashilla (A)	caryopsis	10– 40	Mensier 1957
Spergula arvensis L.	Caryophyllaceae		seed	140–150	Barclay & Earle 1974
Stellaria media (L.) Cyr.	Caryophyllaceae		seed	60	Barclay & Earle 1974
Sterculia africana (Lour.) Fiori	Sterculiaceae	karrare, darrab (S)	kernel	300	Mensier 1957
Sterculia setigera Del.	Sterculiaceae	darille (T)	seed	300–350	Mensier 1957
Tamarindus indica L.	Leguminosae	homar (A, T); roka (G)	seed	200	Ubbelohde 1920, Mensier 1957
			seed	70	Pitke et al. 1977; *Jansen 1981
Tecoma stans (L.) Juss.	Bignoniaceae		seed	200	Mensier 1957
Telfairia pedata (Smith ex Sims) Hooker	Cucurbitaceae		pulp	70	Ubbelohde 1920
			seed	300–400	Mensier 1957
			kernel	550–650	Mensier 1957
Tephrosia purpurea (L.) Pers.	Leguminosae	birssenai (T)	seed	90	Barclay & Earle 1974
Terminalia catappa L.	Combretaceae	bidan (S)	seed	470–570	Ubbelohde 1920, Mensier 1957, Kabele Ngiefu et al. 1976a; *Branca 1960, Cufodontis 1974
Terminalia chebula Retz.	Combretaceae		kernel	350–400	Mensier 1957
Teucrium polium L.	Labiatae	gedad, waronasha (S)	fruit	150	Barclay & Earle 1974
Thlaspi arvense L.	Cruciferae		seed	200–330	Ubbelohde 1920, Barclay & Earle 1974; *Franchetti 1958
Torilis arvensis (Huds.) Link	Umbelliferae	dannah-anshoa (T)	fruit	230	Barclay & Earle 1974
Trachyspermum copticum (L.) Link	Umbelliferae	asmuth (T); nech azmud (A); azmud adi, kamuni, insilata (G)	fruit	200–250	Mensier 1957;*Jansen 1981
Trema orientalis (L.) Blume (syn. *Trema guineensis* (Schum. & Thonn.) Ficalho	Ulmaceae	hudufarda (K); balambal-dured (S)	seed	250–300	Mensier 1957
Tribulus terrestris L.	Zygophyllaceae	akak-ima (A); kakite-harmat, kuakito (T); kurumshit (G)	seed	290–380	Barclay & Earle 1974

Scientific name	Family	Vernacular names	Part with oil.	Oil (g/kg)	Sources
Trichilia emetica Vahl (as *Trichilia jubensis* Chiov.)	Meliaceae	goro-mas (S)	fruit	600	Branca 1960
			seed	490–610	Branca 1960
			arillodium	510–860	Branca 1960
Trichilia emetica Vahl (as *Trichilia roka* (Forsk.) Chiov.)	Meliaceae	kota, gummch (T); jachi (S)	whole seed	400–600	Mensier 1957
			kernel	450–650	Mensier 1957
			arillodium	300–520	Mensier 1957; *de Wilde 1968; this publication, p. 282.
Trichodesma zeylanicum (Burm.) R. Brown	Boraginaceae		seed	250–300	Mensier 1957
Trifolium arvense L.	Leguminosae		seed	60	Barclay & Earle 1974
Trifolium campestris Schreb.	Leguminosae	wodima (A); sidissa (G); hasa, maget (T)	seed	60– 70	Mensier 1957
Trifolium fragiferum L.	Leguminosae		seed	70	Barclay & Earle 1974
Trifolium pratense L.	Leguminosae		seed	90	Ubbelohde 1920, Barclay & Earle 1974
			seed	140–150	Mensier 1957
Trifolium resupinatum L.	Leguminosae		seed	70	Barclay & Earle 1974
Trigonella foenum-graecum L.	Leguminosae	abish (A); ulbata, sunko (G); abacha, abakte (T)	seed	60	Ubbelohde 1920; *Westphal 1974
Triticum aestivum L.	Gramineae	adja (A, G); kamado (G); sermai (T); sinde (A)	germ	120	Ubbelohde 1920, Mensier 1957; *de Lotto & Nastasi 1955
Triumfetta rhomboidea Jacq.	Tiliaceae	duba (Eritrea); os-aran (S)	seed	170	Mensier 1957, Barclay & Earle 1974
Tropaeolum majus L.	Tropaeolaceae		seed	n.n.	Mensier 1957; *Jannone 1940
Typha angustifolia L.	Typhaceae	kombat, aronkway (A); alala, alalmedu (S)	seed	n.n.	Mensier 1957
Typha latifolia L.	Typhaceae	aronkway (A)	seed	180	Mensier 1957
Urtica dioica L.	Urticaceae		seed	230–380	Barclay & Earle 1974

Scientific name	Family	Vernacular names	Part with oil	Oil (g/kg)	Sources
Vaccaria hispanica (Mill.) Rauschert (syn. *Vaccaria pyramidata* Medic.)	Caryophyllaceae	bahar kemam (A)	seed	20– 30	Barclay & Earle 1974
Verbascum thapsus L.	Scrophulariaceae		seed	270	Barclay & Earle 1974
Vernonia species	Compositae		seed	n.n.	White et al. 1971
Vicia faba L.	Leguminosae	bakela (A, G); baldenga, ater-bahari (T)	seed	10– 20	Mensier 1957; *de Lotto & Nastasi 1955, Westphal 1974
Vicia sativa L.	Leguminosae	gwaya (A); sabbarch-quast (T)	seed	10– 20	Mensier 1957
Vigna unguiculata (L.) Walp. cv. group biflora Westphal	Leguminosae	atera-bechene (A) atera-babili (G)	seed	10– 20	Mensier 1957; *Westphal 1974
Vitis vinifera L.	Vitaceae	wein (A, T), enaba (G)	fresh seed	150–190	Ubbelohde 1920, Chotiner & Gain 1967
			seed		
			black cvs	60	Williams 1950
			white cvs	up to 200	Williams 1950; *Massa 1934, Ciccarone 1940, de Lotto & Nastasi 1955
Withania somnifera (L.) Dunal	Solanaceae	gizewa (A); agol, atmai (T); gatita, gurune (S)	seed	180–200	Barclay & Earle 1974
Xanthium pungens Wallroth	Compositae		achene	400	Barclay & Earle 1974
Ximenia americana L.	Olacaceae	enkoi (A); melhetta, mellau (T); huda (G); mandarut (S)	seed	650	Suzzi 1911, Mensier 1957
			kernel	630–660	Williams 1950; *Suzzi 1904/5, 1911, Amare 1974
Zea mays L.	Gramineae	bokolo (A, G, T)	caryopsis	30– 55	Williams 1950
			germ	300–360	Ubbelohde 1920, Williams 1950; *de Lotto & Nastasi 1955

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Glossary

acetyl value: mass of potassium hydroxide (mg) required to neutralize the acetic acid obtained when actylated oil is saponified divided by mass of acetylated oil (g); it is a measure for the presence of hydroxyl groups in the oil.
acid value: mass of potassium hydroxide (mg) required to neutralize the free fatty acids in oil divided by mass of oil (g). It may also be expressed in terms of the percentage of free fatty acids present, calculated as the predominant free fatty acid. It is usually then calculated as mass of oleic acid equivalent.
acidity = acid value.
albuminoid = crude protein.
arachidic acid: $CH_3.(CH_2)_{18}.COOH$, eicosanoic acid, an essential fatty acid.
ash: mass fraction of a sample remaining after incineration.
bleaching: removal of colour from neutralized oil by adsorption onto an agent (as activated carbon) and filtration. Bleached oil is known commercially as 'common edible grade'. It is refined but not odourless.
carbohydrates (as tabulated): sum or sugar and starch.
colour: colour of oil is mostly assessed on the Lovibond scale. In an instrument with a standardized light source and a standard set of coloured glasses, the colour of the glasses is matched against the oil. The glasses used are the standard of reference.
crude fat = crude oil.
crude oil (1): oil as obtained by expression or extraction. (2): crushed seed is extracted with light petroleum (flash point 40–60 °C). The extract should be free from suspended matter. After evaporation of the solvent, the oil is dried at 100 °C and weighed. Mass fraction of oil in the original sample is reported as crude oil.
crude protein: quantity of nitrogen multiplied by a factor specific for the species to which the seed belongs. If the factor is unknown, 6.25 is commonly used. The presence of ammoniacal and nitrate nitrogen should be tested for and the amount, if any, be deducted from total nitrogen. Crude protein is commonly expressed as a mass fraction.
dega (traditional Ethiopian name): cooler highlands.
deodorization: common edible-grade oil (see bleaching) is treated with superheated steam in a closed vessel (a deodorizer) to remove odour and taste.
drying oil: oil that is easily oxidized on contact with the air to form a thin elastic film. Such oils are widely used in paints.
erucic acid: $CH_3.(CH_2)_7.CH = CH.(CH_2)_{11}.COOH$, *cis*-13-docosenoic acid.
essential fatty acid: a fatty acid that must be part of the regular diet. Insufficient intake

leads to nutritional deficiency.

essential oil = volatile oil.

extraction flour: the solids remaining after extraction of soil free from any solvent and well ground. It looks like oilcake flour but its composition is different.

fat: lipid that is solid at ordinary temperatures.

fatty acid: an organic substance characterized by a carboxyl group. In vegetable oils, the carboxyl group usually forms part of a chain of 16 or 18 carbon atoms.

fibre: component estimated by the following procedure. From a weighed sample (m_1), oil is extracted and proteins, starches and sugars are removed with dilute sulphuric acid. A dried ash-free filter paper is weighted (m_2) and the residue washed onto it. After drying again, the filter paper with residue is weighed (m_3). After incineration at dull-red heat, the ash is weighed (m_4). Mass fraction of fibre can be calculated as $(m_3 - m_2 - m_4)/m_1$.

field capacity: the amount of water held in the soil after the excess or gravitational water has drained away.

fixed oil = vegetable oil.

foots: matter settling from suspension in oil.

hydration (of oil): adding water to remove water-soluble impurities.

hydrogenation: process by which some of the unsaturated fatty acids in the glycerides of an oil are combined with hydrogen under the influence of a catalyst. The process is used to convert liquid oils to solid fats (e.g. margarine).

hydroxyl value: mass of potassium hydroxide (mg) required to neutralize the acetic acid that can combine with an oil on acetylation divided by the mass of that oil (g). It is a measure of the presence of hydroxyl groups in the oil.

Iodine index = iodine number = iodine value.

Iodine value: mass of iodine (g) or equivalent amount of other halogen absorbed by an oil under specified conditions divided by mass of oil (hg). It is a measure of the number of double bonds present and is thus an indication for the unsaturation of the oil.

kolla (traditional Ethiopian name): hot lowlands.

lauric acid: $CH_3.(CH_3)_{10}.COOH$, dodecanoic acid.

linoleic acid: $CH_3.(CH_2)_4.CH = CH.CH_2.CH = CH.(CH_2)_7.COOH$, *cis*-9, *cis*-12-octadecadienoic acid, an essential fatty acid. It imparts drying properties on oils.

Linolenic acid: octadecatrienoic acid. By its unsaturation, it oxidizes readily, contributing to the drying properties of an oil. Several isomers are known. The most common isomer is $\triangle 9$, 12, 15-octadecatrienoic acid: $CH_3.CH_2.CH = CH.CH_2.CH = CH.CH_2.CH = CH.(CH_2)_7.COOH$. Another isomer, $\triangle 6$, 9, 12- octadecatrienoic is essential to man:

$CH_3.(CH_2)_4.CH = CH.CH_2.CH = CH.CH_2.CH = CH.(CH_2)_4.COOH$.

lipid = oil.

maleic anhydride value: fraction of maleic anhydride, calculated as iodine, that reacts with an oil under prescribed conditions. It may be used as an estimate of conjugated double-bonds.

Maumené test (after E. J. Maumené, 19th Century French chemist): test of the rise in temperature after adding concentrated sulphuric acid to a fatty oil under specified conditions. It indicates the degree of unsaturation of an oil.

melting point: temperature at which a material melts. Oils have no sharp melting point but rather a melting range. Various methods are available to estimate the temperature at which a definite degree of melting occurs. The melting point largely depends on the way in which an oil has been allowed to solidify.

mineral matter = ash.

moisture: mass fraction lost when a sample is dried at 100°C or 105°C.

myristic acid: $CH_3.(CH_2)_{12}.COOH$, tetradecanoic acid.

neutralization: removing free (fatty) acids from an oil with an aqueous solution of alkali.

non-drying oil: oil that remains liquid at ordinary temperatures and does not form solid films upon contact with the air. Such oils react very slowly, if at all, with oxygen. They include many important edible oils.

non-saponifiable matter = unsaponifiable matter.

oil (1): a mixture of triglycerides of fatty acids and some minor components. Synonym: lipid. (2) = crude oil.

oilcake, presscake: the solid residue after expression of oil.

oilcake flour: ground oilcake.

oilmeal = oilcake flour.

oleic acid: $CH_3.(CH_2)_7.CH = CH.(CH_2)_7.COOH$, *cis*-9-octadecenoic acid.

optical activity: the tendency of a material to alter the plane of polarized light. Optical activity of oils is usually recorded with a polarimeter through a pathlength of 200 mm. For oils, it is usually attributable to unsaponifiable components or non-lipid impurities. It can, therefore, be used to identify certain oils or to assess purity.

palmitic acid: $CH_3.(CH_2)_{14}.COOH$, hexadecanoic acid.

Polenske value or *Polenske number* (after E. Polenske, 20th Century German chemist): value that indicates the content in oil of the volatile water-insoluble fatty acids.

presscake = oilcake.

processed oil: product prepared from oil, e.g. stearin, olein, margarine.

refined oil: product prepared from crude oil by various processes including neutralization, bleaching and deodorization.

refractive index (n_D): ratio of the speed of light in vacuo to that in the material under study. At a given temperature, it is characteristic for an oil but varies with temperature.

Reichert-Meissl value (R-M value) (after K. Reichert and E. Meissl, 19th Century German chemists): value that indicates the content of the volatile water-soluble fatty acids.

relative density: ratio between mass in air of a given volume of oil at a given temperature, and of that same volume of water measured at 15.5°C.

ricinoleic acid: $CH_3.(CH_2)_5.CHOH.CH_2.CH = CH.(CH_2)_7COOH$, 12-hydroxy-*cis*-9-octadecenoic acid.

saponification equivalent: mass of oil (g) saponified by 56.1 mg potassium hydroxide. Use analogous to saponification value.

saponification value: mass of potassium hydroxide (mg) required to saponify an oil divided by mass of the oil (g). It is a measure of the average molecular weight of the fatty acids in an oil and is characteristic.

saturated fatty acid: fatty acid without double-bonds in the carbon chain of the molecule. Such a fatty acid reacts less easily with oxygen than one with double-bonds and increases the stability of the oil.

semi-drying oil: oil reacting only slowly with oxygen of the air to form a rather soft coat. Many such oils are edible.

smoke point (1): temperature at which a thin continuous stream of bluish smoke escapes from an oil after it has been heated in a standard manner. It is used in evaluating cooking fats, for which it usually is c. 225°C.

(2) (for lamp oil): maximum flame height (mm) at which the oil will burn without smoking.

solidification point: temperature at which a material turns solid. When oils or fatty acids are allowed to cool, the temperature falls until crystals of solid fat have begun to separate. It then rises slightly because of latent heat (enthalpy of phase change). Under standard conditions of testing the peak of the rise in temperature is often reproducible for a given sort of oil and is thus characteristic.

solidifying point = solidification point.

solvent extraction: process in which crushed seed is mixed with a solvent to remove oil. After separation, the solvent is evaporated to leave the oil.

specific gravity = relative density.

specific opacity: pathlength dividied by transmittance. It is an indication of the purity of an oil.

starch: polysaccharides hydrolysable in dilute acid. After washing out soluble sugars, starch is dissolved with hydrochloric acid. The solution is cleared by rinsing, addition of phosphotungstic acid and filtering. The clear filtrate is examined in a polarimeter with a tube of 200 mm. The optical rotation indicates the concentration of the resulting monosaccharides.

stearic acid: $CH_3.(CH_2)_{16}.COOH$, octadecanoic acid.

sugar: carbohydrate soluble in water. They are washed out of oilmeals and estimated by a standard method.

technical oil: oil altered by chemical reaction (e.g. sulphonation) for certain technical uses.

thiocyanogen value: mass of thiocyanogen (g), calculated as iodine, absorbed by an oil under prescribed conditions. Thiocyanogen is absorbed less completely than is iodine. It is possible to calculate the composition of a mixture of linolenic, linoleic, oleic and saturated fatty acids from the thiocyanogen value and the iodine value, if the amount of linolenic acid is known.

titre: solidification point of the mixed fatty acids prepared from an oil. It is measured if the solificiation point of an oil is indefinite or unreproducible. If the oil is used for making soap, the titre is assumed to bear a direct relation to the hardness of the soap.

unsaponifiable matter: residue after saponification of an oil with caustic alkali, extraction with a solvent, and drying at 80 °C. Its composition is usually highly characteristic.

unsaturated fatty acid: fatty acid with at least one double-bond in the carbon chain of the molecule. The more of such double-bonds, the easier the substance oxidizes, thus making the oil more drying and more subject to rancidity.

vegetable oil: oil derived from a plant.

viscosity: resistance of a fluid to flow. It is measured in a viscometer and is relevant mainly for lubricating oils. It is seldom measured in cooking oils.

volatile oil: oil that evaporates rapidly. Such oils are usually scented and their main component is not glycerides of fatty acids.

weina dega (traditional Ethiopian name): highlands with a moderate climate.

Wijs method: standard method of estimating iodine value.

winterization: separation of easily crystallizing components from oils by cooling and filtering. It is done after neutralization, decoloration and deodorization.

wot (Ethiopian term): stew.

Index of vernacular names

Index of scientific names

Synonyms are in italics. Names of Table 71 have not been included. Some names lack the indication of their authors. Those names were found that way in the literature and I did not trace their origin.