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MAJOR PROBLEMS OF GROWING SESAME (*SESAMUM INDICUM* L.) IN NIGERIA

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CONTENTS

1. INTRODUCTION

1.1. Outlines and scopes of the thesis

Sesame or benniseed (*Sesamum indicum* L.) is a well established crop in parts of four provinces of the Northern States of Nigeria and is also of minor importance in some other parts of the country.

General information on the crop, its production and produce is given in Sections 1 to 3.

Growing sesame in Nigeria encounters many problems of different kinds, from which major ones have been selected for discussion in this thesis.

When one travels from Igbirra Division in Kabba Province to Tiv Division in Benue Province, it is noted with surprise that the methods of sowing sesame and the resulting plant densities differ so widely from one place to the other. Counts in farmers' fields revealed that the number of plants per ha may vary from 14,000–1,700,000. Such observations invited for further plant density and spacing studies, the results of which are presented in Section 4.

As soon as the rainy season starts, a feverish rush can be noticed to complete the sowing of various crops. The experience is that delay of sowing causes yield reduction and consequently farmers plant as soon as possible, not waiting till the rains become less erratic. This observed effect of sowing date on crop growth and its causes are important factors of growing sesame. These are dealt with in Section 5.

Harvesting of sesame takes place long before the plants and capsules have dried. This method is practiced because of the character of the capsules to open at the top when dry, which causes seed to shatter at the lightest touch. Seed loss occurs during the period of drying and threshing and it was considered a major problem of growing sesame. An evaluation of the problem and a discussion of the experiments aimed at improving the present practices of harvesting and threshing are given in Section 6.

A thesis on major problems of growing sesame in Nigeria would not be complete without mentioning the most important diseases and pests. This is done in Section 7. In 1964 a then unknown virus disease was observed for the first time at Mokwa. It was extremely harmful in 1965, when it destroyed large fields of the crop, and continued to be a major problem since 1965. A detailed discussion of the disease follows at the end of Section 7.

1.2. Botanical classification

The data compiled here have been derived from Bruce (1953), Hutchinson and Dalziel (1963), Joshi (1961), Kumar et al. (1967), Pulle (1950), Purseglove (1968) and Weiss (1971).

Sesame belongs to the division *Spermatophyta*, the sub-division *Angiospermae*, the class *Dicotyledoneae*, the order *Tubiflorae*, the family *Pedaliaceae* and the genus *Sesamum*. In addition to the *Pedaliaceae* family the order *Tubiflorae* contains twenty-three other families among which are the *Convolvulaceae*, *Solanaceae*, *Scrophulariaceae* and *Labiatae*. There are sixteen genera in the *Pedaliaceae* family and thirty-six species in the genus *Sesamum*. Most of these species are endemic in Africa.

Sesamum indicum is an erect annual herb, ½–3 metres high, taking from 80 to 180 days to mature. It possesses a typical somewhat fetid smell. It has a tap-root and a surface mat of lateral roots. The flowers are about 3–4 cm long, axillary with one flower and two extra-floral nectaries per leaf axil. The calyx is persistent and ovate-lanceolate. The stamens are didynamous and the sagittate anthers lie against the upper lip of the corolla. The ovary is many-ovuled and surrounded by a nectiferous disc; the stigma is bi- to multi-partite. The capsules are oblong, 2–5 cm in length, containing wingless 1½–4 mm long seeds with a white, yellow, grey, light brown, red-brown or black testa with a smooth or reticulate surface.

Linnaeus classified sesame in two different species, *Sesamum indicum* and *Sesamum orientale*, but De Candolle combined the two species to one and used the name *Sesamum indicum*, so referring to the country of supposed origin.

1.3. History and distribution

Sesame is a crop of great antiquity and probably one of the most ancient oilseed crops under cultivation. The oldest records of sesame are from Babylon in Sumeria where it was known in 2350 B.C. and where it played throughout its history an important role in ceremonies, in culinary uses, in the preparation of wines and as a price standard in trade (Weiss, 1971).

Both India and Ethiopia have been proposed as sesame's centre of origin, but presently the opinions are more in favour of the latter country. The fact that Africa is poor in different forms of *Sesamum indicum* but rich in species of the genus *Sesamum*, while the situation is just the opposite in India, may be explained by the more varied conditions of the latter region (Purseglove, 1968; Weiss, 1971).

The crop is now cultivated in almost all tropical and sub-tropical Asian and African countries, the southern European countries, Russia, South and Central America, and on a very small scale in the United States. The main sesame producing countries (Table 1) are India, China, Mexico and the Sudan.

The different species of the genus *Sesamum* have a wide distribution in tropical Africa, Malagasy, Arabia, India, Ceylon, tropical Australia and some of the eastern islands of the Malayan archipelago. Tropical Africa is the main centre and has thirty-two different wild species. Only two wild species have been reported to occur in Nigeria viz. *Sesamum alatum* in the northern part of the country and *Sesamum radiatum* in north and south Nigeria. The former species is called ri'din barewa (gazelle's sesame) in Hausa language and nomere baro'de

TABLE 1. Production of sesame seed in percentage of India's yield during the period 1965/66–1969/70 for principal countries (Data from Commonwealth Secretariat).

Country	Production (%)
China	86,7
Mexico	46,6
Sudan	38,2
Venezuela	19,8
Burma	18,1
Colombia	14,3
Turkey	9,3
Pakistan	8,6
Ethiopia	8,5
Uganda	7,2
Nigeria	3,9

(wild beasts' sesame) in Fulani language and possesses long, beaked capsules and brown, winged seeds. *Sesamum radiatum*, sometimes called karkashi but also ri'din barewa in Hausa, has brown-black seeds and is a common adulterant of commercial sesame. It is also grown for its leaves for use in soups.

Species of other genera of the *Pedaliaceae* family found in Nigeria are *Ceratotheca sesamoides*, *Martynia annua*, *Pedalium murex* and *Rogeria adenophylla* (HUTCHINSON and DALZIEL, 1963; DALZIEL, 1948).

1.4. CROP PRODUCTION, TRADE AND RESEARCH STATISTICS

Sesame is grown almost exclusively in countries with a small peasant type of agriculture and its cultivation is carried out without the use of much machinery.

Figure 1 indicates that the world production has not increased above the level of 1952/53. This is substantiated by Appendix I.

Individual countries as Mexico, Venezuela and Colombia have increased their production of sesame during this period, while China's production decreased.

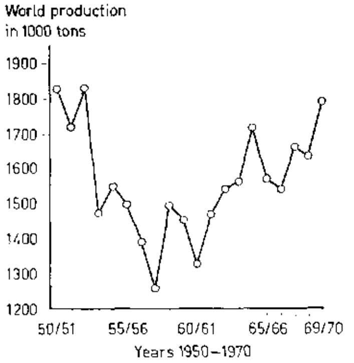


FIG. 1. World production of sesame seed in 1000 tons during the period 1950–1970.

The production decrease for Nigeria during the years 1966–1968 was caused by the political disturbances in this country.

Appendix II gives the yields per ha of sesame for various countries and shows that the yields are lowest in the Far East, followed by Africa, and that higher yields have been recorded in Central and South America, notably in Mexico and Venezuela. World average yields per ha have changed little during the last two decades and amount to about 284 kg (250 lb per acre).

Appendices III and IV show that most of the world production is for domestic use and that only approximately 10 per cent moves in international trade. Nigeria, the Sudan and some other countries are exceptional in this respect, as a good deal of their produce is exported. Imports of sesame are substantial for Italy and Japan, considerable for the U.S.A., the U.S.S.R. and Egypt, while Belgium, Hong Kong and South Yemen are importers of some size.

Trade in sesame oil is only of minor importance (Appendix V).

Prices of sesame seed fluctuate sharply with supplies and demands. An example shows this. The rise of sesame seed prices in April 1967 to a peak of £ 110 per ton (Appendix VI) was caused by fears for a world shortage of supplies; as supplies became normal, prices came down. Similarly in 1968 prices were high at the beginning, when consumers were anxious about exports, but the news of a recovery of the Sudanese crop of 1967/68 and prospects of improvements of supplies caused the quotations to fall to £ 87 per ton in December of the same year.

The fact that the production for export, the demand and the number of exporting countries of sesame seed are relatively small, makes rapid and sharp price fluctuations to be expected and these cause risks for the grower.

From the information compiled in table 2 it may be derived that research activities are aimed more at soya beans, groundnuts and sunflower than at sesame. Table 3 shows that India and Venezuela are the countries where most of the sesame research has been and is being carried out. Publications from the U.S.A. increased in number after World War II, but decreased during the late sixties, and so did the interest in the crop. Work on sesame in Japan also waned, namely after 1960. The U.S.S.R. are regular producers of some publications. Other countries publish at times their work on sesame. Monographs (JOSHI, 1961 and WEISS, 1971) and review articles (TRIBE, 1967 and EL BARADI, 1972) are published occasionally.

1.5. COMPOSITION AND USES OF SESAME

The composition of the seed, the characteristics of the oil and the composition of the protein and unsaponifiable material of the oil have been presented in Tables 4–8 for seed from different sources. Some figures have been derived from different authors to allow comparison with analysis figures of seed samples of the cultivars Yanded 55, X 30/115 and 65A-36, sown early and late in the 1970 growth season at Mokwa Agricultural Research Station; the analysis of the Mokwa seed samples was carried out at theTropical Products Institute, London.

TABLE 2. Average annual number of publications referred to in Plant Breeding Abstracts, Field Crop Abstracts and Tropical Abstracts on sesame, groundnuts, soya bean, castor and sunflower for quadrannual periods during the years 1951–1970.

Journal and Crop	Quadrannual period					
	51–54	55–58	59–62	63–66	67–70	average
Plant Breeding Abstracts:						
Sesame	15	15	16	16	13	15
Groundnut	31	29	31	34	54	36
Soyabean	59	38	61	80	123	72
Castor	13	13	13	18	24	16
Sunflower	22	25	27	44	55	35
Fields Crop Abstracts:						
Sesame	6	6	13	8	12	9
Groundnut	54	54	58	65	94	65
Soyabean	44	51	70	89	139	79
Castor	3	1	0	7	17	6
Sunflower	25	15	28	45	79	38
Tropical Abstracts:						
Sesame	–	4	8	10	12	9
Groundnut	–	36	49	85	82	63
Soya bean	–	9	17	26	45	24
Castor	–	7	14	17	11	12
Sunflower	–	1	6	10	8	6

TABLE 3. Average percentage of publications in principal countries referred to in Plant Breeding Abstracts, Field Crop Abstracts and Tropical Abstracts on sesame for quadrannual periods during the years 1951–1970.

Country	Plant Breeding Abstracts					Field Crop Abstracts					Tropical Abstracts		
	Years					Years					Years		
	51–54	55–58	59–62	63–66	67–70	51–54	55–58	59–62	63–66	67–70	59–62	63–66	67–70
India	34	22	18	35	54	12	12	18	30	33	22	24	35
Venezuela	8	17	7	17	8	20	28	12	13	13	22	23	35
U.S.A.	26	19	17	20	2	20	12	8	17	4	9	6	0
Japan	8	17	24	2	0	0	16	14	0	2	0	0	0
U.S.S.R.	8	7	11	2	8	12	0	4	0	4	0	0	0
Sudan	3	9	7	2	0	8	4	2	0	2	0	6	9
Mexico	0	2	2	3	2	0	0	4	3	0	4	0	0
Tanzania	0	0	4	1	0	0	4	8	7	0	0	6	4
Pakistan	2	0	0	0	8	0	0	0	0	7	0	0	0
U.A.R.	5	0	0	0	8	0	0	0	0	4	0	0	0
Bulgaria	0	0	6	3	2	0	0	0	3	2	0	0	0
Nigeria	3	5	0	0	3	0	0	6	4	7	4	0	9
Others	3	2	4	15	5	28	24	24	33	22	39	35	8

TABLE 4. Composition of sesame seed in percentages as published by (a) Krishnamurthy et al. (1959), (b) Ranganathan et al (1936), (c) Chatfield (1934) and (d) Zaghi and Bressani (1969) and as analysed for the cultivars Yandev 55, X30/115 and 65A-36, sown at Mokwa in 1970, early (e, f and g respectively) and late in the season (h, i and j respectively). – = not analysed.

Constituent	Samples									
	a	b	c	d	e	f	g	h	i	j
Moisture	5.47	5.08	5.8	4.0	4.5	4.5	4.6	5.0	5.0	5.0
Protein	21.23	18.33	19.3	19.9	20.9	19.8	21.6	22.5	20.8	23.4
Fat	57.34	43.26	51.0	56.4	54.8	54.6	53.1	55.6	57.0	53.1
Fibre	3.21	2.88	3.2	3.6	3.6	3.0	3.6	2.3	2.7	2.7
Calcium	1.13	–	1.0	0.73	0.67	0.53	0.83	0.68	0.51	0.86
Phosphorus	0.54	–	0.7	0.71	0.83	0.72	0.71	0.63	0.67	0.72
Oxalic acid	1.98	–	–	–	3.19	3.12	3.35	2.94	2.82	3.33
Carbohydrates	–	25.25	18.0	11.7	11.5	12.0	12.8	11.0	10.1	11.8
Ash	–	5.2	5.7	4.4	5.0	6.4	4.7	4.1	4.8	4.5

Sesame seed is a rich source of oil, protein, phosphorus and calcium. The oil content of sesame seed may vary from as low as 35 per cent to as high as 57 per cent according to ECKEY (1954). Oil contents of over 60 per cent have been reported for some Russian cultivars (ARZUMANOVA, 1958 and 1963). TSATSARONIS (1971) found oil and protein contents in Greek and East African seed samples of about 50–53 and 22–24 per cent respectively. KHATTAB and KHIDIR (1970) reported oil percentages ranging from 43.7–56.2 and protein percentages ranging from 22.3–32.9 with averages of approximately 50 and 27 respectively for 90 local cultivars, grown at two different sites in the Sudan for two years. Only the protein content was clearly affected by location and year influences. The same authors (KHIDIR and KHATTAB, 1972) investigated in a three years' study the oil development in sesame seed and observed that the oil percentage increased during the period of 11–17 days after fertilisation from less than 5 to about 40 per cent. Twenty days after fertilisation the maximum value of about 50 per cent was reached. The Iodine Value did not change after the seeds were 18 days old.

TABLE 5. Characteristics of oil from the sesame cultivars Yandev 55, X30/115 and 65A-36 sown at Mokwa early (A) and late (B) in the season of 1970, and the usual range as reported by Eckey (1954).

Characteristic	Yandev 55		X30/115		65A-36		Usual Range
	A	B	A	B	A	B	
F. Fatty Acid (%)	2.8	3.2	2.1	3.1	2.6	3.6	1 – 6
Sapon. Value	184.5	183.6	190.6	183.6	187.9	186.7	187 –193
Iodine Value	117	100	114	101	110	103	104 –116
Unsaponif. (%)	1.3	1.6	2.5	2.8	2.1	1.4	0.9 – 2.3
Refr. index, 25°C	1.4702	1.4695	1.4701	1.4699	1.4699	1.4711	1.470– 1.474
Spec. gr. 15/15°C	0.9213	0.9225	0.9210	0.9228	0.9205	0.9199	0.920– 0.926
Spec. gr. 25/25°C	0.9183	0.9180	0.9183	0.9176	0.9171	0.9164	0.916– 0.921

The oil and protein contents of the Mokwa samples were relatively high, the calcium contents rather low. Samples from the late planted crop were on an average higher in protein and oil content than those from the early planted crop, and lower in ash and crude fibre content.

The only major difference between the oils of early and late sown sesame from Mokwa appears to be the higher Iodine Value of the former, which is due to its higher linoleic and lower oleic and stearic acid content (table 6).

TABLE 6. Main constituent fatty acids of oil from the sesame cultivars Yandev 55, X30/115 and 65A-36 sown at Mokwa early (A) and late (B) in the season of 1970, and the usual range as reported by JOHNSON and RAYMOND (1964). Figures are percentages.

Constituent	Yandev 55		X30/115		65A-36		Usual Range
	A	B	A	B	A	B	
Oleic acid	34.7	40.4	36.2	38.9	33.5	42.1	45.3–49.4
Linoleic acid	50.8	42.6	48.7	44.9	52.4	42.7	37.7–41.2
Palmitic acid	9.8	9.7	10.0	9.5	9.6	9.7	7.8– 9.1
Stearic acid	4.7	7.3	5.1	6.7	4.5	5.5	3.6– 4.7

All Mokwa samples, when compared with the usual range, were low in oleic acid and high in linoleic acid. The stearic acid content was also relatively high, but more so for the late planted crop than for the early planted crop.

Sesame oil has a relatively high percentage of unsaponifiable material containing the following useful substances (ECKEY, 1954; JOSHI, 1961; JOHNSON and RAYMOND, 1964).

Substance	Content (%)	Use
Sesamolin	0.3–0.5	Specific colour reaction. Synergistic activity with pyrethrins.
Sesamin	0.7–1.0	Synergistic activity with pyrethrins.
Sesamol	traces	Antioxidant providing protection against rancidity.

TABLE 7. Sesamolin, sesamin and sesamol content of oil from the sesame cultivars Yandev 55, X30/115 and 65A-36 sown at Mokwa early (A) and late (B) in the season of 1970. Figures are percentages.

Substances	Yandev 55		X30/115		65A-36	
	A	B	A	B	A	B
Sesamolin	0.1354	0.1099	0.1260	0.1119	0.1194	0.1168
Sesamin	0.2558	0.8646	0.6520	0.9327	0.3610	0.6667
Sesamol	0.0040	0.0027	0.0040	0.0027	0.0035	0.0029

The Mokwa samples were relatively low in sesamolin, and the sesamol content of the early sown sesame was higher than that of the late sown sesame.

Sesamolin is responsible for the characteristic colour reaction of the Baudouin or Villavecchia test of sesame oil when it is shaken with concentrated hydrochloric acid to which a little cane sugar (Baudouin test) or furfural (Villavecchia test) has been added. In some countries e.g. Italy and Denmark, the addition of a little sesame oil to margarine and similar products is obligatory to enable them to be distinguished from butter and ghee by these tests, and to detect adulteration. However, more up-to-date techniques such as spectrophotometry and chromatography could more easily serve the same purpose.

The highly appreciated resistance to oxidative rancidity of sesame oil, specially after hydrogenation, is due to the presence of sesamol, a component of sesamolin which is liberated from it by hydrolysis by dilute mineral acids, by bleaching of the oil with acid-type bleaching earths, and by hydrogenation. LEROY et al. (1970) proposed to add traces of sesame oil to butter for its antioxidative effect.

TABLE 8. Amino acid composition of meal from the sesame cultivars X30/115, sown early (A) and Yandev 55, sown late (B) in the season of 1970 at Mokwa. Figures are in g/16 g N.

Amino acid	A	B	Amino acid	A	B
Aspartic acid	8.0	8.3	Methionine	2.1	2.5
Threonine	4.1	3.5	Isoleucine	3.9	3.5
Serine	4.5	4.4	Leucine	6.3	6.0
Glutamic acid	18.7	18.5	Tyrosine	3.4	3.7
Proline	3.1	2.6	Phenylalanine	4.3	3.9
Glycine	4.9	4.8	Lysine	2.8	2.6
Alanine	4.6	4.7	Histidine	2.2	2.4
Valine	4.6	4.5	Arginine	16.4	16.6

Sesame meal protein is short in lysine, but rich in methionine, and is therefore good for supplementing groundnut, soya bean and other vegetable proteins which lack sufficient methionine (DAGHIR et al., 1967). Sesame protein is digestible for over 90 per cent (COLLISTER, 1955).

The composition of the Mokwa samples as shown in Table 8 agrees well with published figures. However the protein of X 30/115 contained rather more threonine and proline and less methionine than would have been expected and this would tend to decrease its nutritive value to some extent.

The oil extracted from sesame seed is used in salad oils, in cooking oils, for shortenings and margarine, as a substitute for olive oil, as a carrier for medicines, in paints and toilet soaps, as a fixative for perfumes and as an illuminant. Sesame oil, because of its constituents sesamolin and sesamin, is being used as a synergist for insecticides such as pyrethrum and rotenone. The cake, obtained after oil extraction, is used for animal feed, as supplementary food for humans and as a fertilizer.

The whole seeds are used in the bakery trade on bread and rolls, mainly in the United States, in confections, sweetmeat, soups and bird food. Ground seeds are used in cakes, pastries and malted milk (ECKEY, 1954; KIRTIKAR et al., 1935; MARKELEY, 1950; JOSHI, 1961; WEISS, 1971).

The sesame plant is used as a medicinal herb, while in the past crystalline salt was obtained from burned stalks for use as a condiment.

In the sesame growing areas of Nigeria the seeds are most commonly used in soups which are prepared in different ways and are known under different names (Hausa: Miya; Eggon: Azo; Ibo: Ofe; Idoma: Obobo; Jukun: Bodo; Kuteb: Utow; Tiv: Iyuwe). To prepare the soup, ground and cooked sesame is supplemented with palm oil, salt, pepper, fish, chicken, vegetables etc. Not only sesame seed but also sesame leaves are used for the preparation of soup. Sesame oil is expressed and used only on a small domestic scale. Sesame seed is eaten raw, or fried in the form of cakes, or fried, pounded and mixed with sorghum and millet to a pastry, or fried and ground and mixed with water to give a sustaining drink. The sesame plants after harvesting are used as fuel where firewood is scarce, and the ash is commonly used for local soap production by adding it to palm oil and boiling the mixture (Tiv: Chahulmtse). Ash from burnt sesame plants and sesame oil are both used in native medicines. Sesame seed may play a role in religious ceremonies and wedding parties (DALZIEL, 1948; VAN RHEENEN, 1972, Unpublished data from questionnaires).

2. SESAME PRODUCTION IN NIGERIA

This chapter deals with the distribution, agronomic characters and cultivation practices of the main sesame growing areas in its first two sections, and the collected data on local productions, trade, export and prices of sesame seed are given in section 2.3.

2.1. Distribution and agronomic characteristics of production areas

2.1.1. *Geography*

There are four different areas in Nigeria in four different States where sesame production is of importance (fig. 2):

A. Igbirra Division of Kabba Province in Kwara State.
B.1. Tiv Division of Benue Province in Benue-Plateau State.
B.2. Beli area, bordering Benue Province in South-West Adamawa Province of North-Eastern State.
C. Doma District of Benue Province in Benue-Plateau State.
D. Kwali area in North-East Kabba Province and South-East Niger Province of Kwara State and North-Western State respectively.

Sesame is known under different names in different languages as the list below shows.

Language	Name of sesame	Language	Name of sesame
Akpa	Enjinu	Idoma	Ocha, Igogo, Oncha
		Igbirra	Igorigo
Bagarmi	Karru, Gon, Gun	Jukun	Doo, Ado, Do
Bassa	Vaga	Kanbari	Isuan
Dukanci	Shak	Kanuri	Marrashi
Eggon	Enom	Koto	Gogo
Ganagana	Aso	Koros of Zuba	Anuhu
Fulani	Malasiri, Nomere Marasiri	Kuteb	Dukun, Sukun, Isen, Isin
Gade	Ago-go	Nupe	Eso, Esso
Gwarin Genge	Nuhu, Anufu	Tiv	Ishwa
Gwarin Yamma	Nufu, Nufun	Utonkon	Esa
Hausa	Ridi, Lidi, Karkashi, Nome, Nomi	Yergem	Ichin
Ibo	Igogo	Yoruba	Yamati, Yanmoti

All sesame producing areas of importance are situated between the latitudes 6° and 10°, have a distinct rainy season and dry season as is common in Nigeria, and are part of the so called Middle Belt, a not clearly defined part of the Northern States for which PULLAN (1962) found as common feature that the dry season duration was four or five months in 50 per cent or more of the years.

2.1.2. *Climate and vegetation*

The distribution of the rain in Nigeria is of the 'twin-peak' type in the South and the 'one-peak' type in the North.

It appears that the 'twin-peak' rainfall distribution becomes less pronounced from the South to the North of the Middle Belt, the South showing for 100 per cent of the years a 'twin-peak' distribution and the North only for 40 per cent of the years, if by definition a 'twin-peak' regime has a fall of two or more inches between the first peak and the lowest monthly rainfall between the two peak months (HIGGINS, 1961; PULLAN, 1962). The rains in the sesame growing areas start in March or April and end in October, the duration of the wet season being 210–240 days (WALTER, 1967).

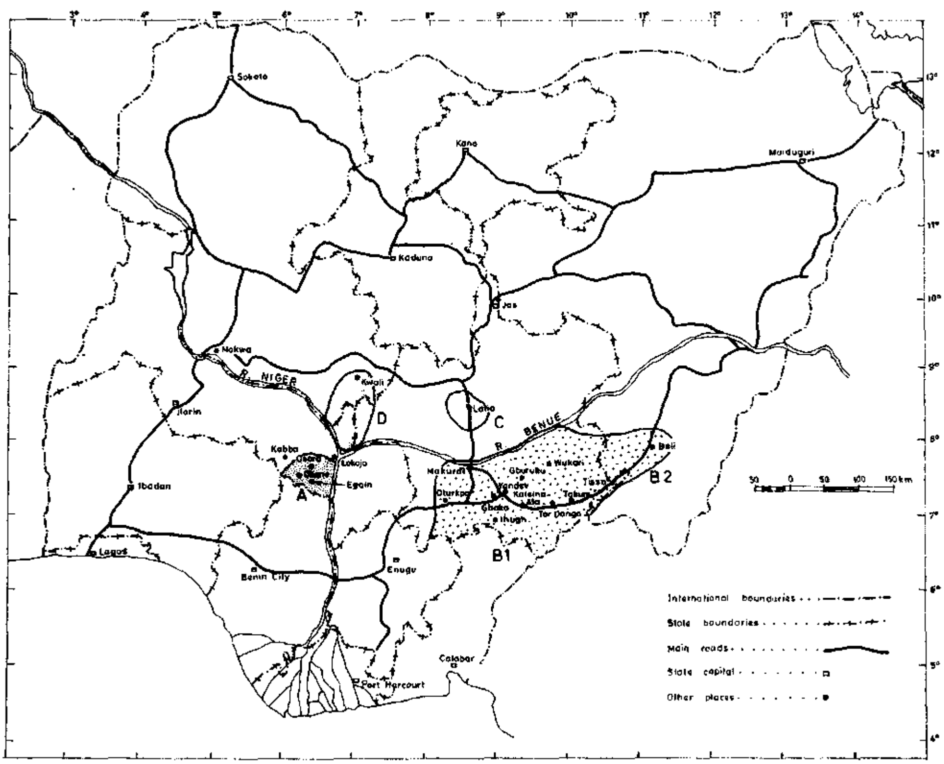


FIG. 2. Map of the Northern States of Nigeria with main sesame production areas A, B1, B2, C and D.

The main sesame production areas are in the Southern Guinea Vegetation Zone of the Nigerian Savannah Region, characterised by rather open savannah woodland with trees of 12–15 m, rarely up to 27–30 m height, with short boles and broad leaves. Tall grasses of 1,5–3 m occur between the open tree vegetation (KEAY, 1953).

2.1.3. *Soils*

According to HIGGINS (1961), HIGGINS and MOULD (1962) and KLINKENBERG and HIGGINS (1968) most of the soils of the sesame production areas are to be classified as Ferruginous Tropical Soils. The legend of the soil map of Africa by D'HOORE (1964) is used as a basis for their classification. The pH-water ranges from 6.0–6.4 in the topsoil and amounts to 5.5 in the lower horizons. The soil group is characterized by the almost total absence of poorly drained depression soils. Marked differentiation of horizons occurs. The E horizon is frequently leached and always a textural or structural B horizon is found. Typical is the separation of free iron oxides, which may be leached out of the profile but most commonly are deposited in the profile in the form of mottles or concretions and even an actual hard iron pan has often been formed at about 1 meter depth. There may be some reserves of weatherable minerals. Kaolinite is the main component of the clay fraction, but small quantities of illite may also be present.

The kation exchange capacity is moderately low at 20–40 meq per 100 g clay. The exchange complex of the B horizon is more than 40 per cent saturated. Soil colours vary from greyish brown to yellowish red and the depth to rock is usually less than 2,5 m. The soils have mostly developed on rocks of the Basement Complex such as granite and gneiss, but they are also found on sedimentary material. In sesame growing areas of less importance such as parts of Kabba Province – also around Mokwa – Ferrisols have developed over Turonian sandstones. These soils are red, very deep and they often have a textural B horizon with clay skins. They are normally well drained and are free from concretions. The Ferruginous Tropical Soils and Ferrisols of KLINKENBERG and HIGGINS (1968) would have been classified as Ultic Haplustalfs and Typic Tropustults respectively by the 7th Approximation (U.S.D.A., 1960 and 1967). The production of sesame is mostly on upland plains, while depressions and valleys with poorer drained soils are generally avoided.

2.2. CULTIVATION PRACTICES

There is no large scale mechanized system of growing sesame in Nigeria but only a small peasant type. Differences exist in respect of crop rotation, seed bed preparation, sowing date, sowing method, cultivations after sowing and harvesting methods as will be discussed briefly.

2.2.1. *Crop rotation and fertilizer application*

Often sesame is grown as the third or fourth and last crop in the rotation, frequently after yams or sorghum, but also following maize, groundnuts, cotton, millet or beans; exceptionally it takes the second place in the rotation, while in Kwali area sesame is sometimes an opening crop.

The results from a questionnaire on sesame production conducted in the main sesame growing areas show that no fertilizers are applied to sesame and personal observations carried out in these areas confirm that fertilizer applications are most uncommon.

2.2.2. *Seed for sowing*

Farmers usually keep their own seed for sowing and store it in sealed pots or sacks in their houses or rumbus. From a multiplication scheme at Yandev, seed of the recommended cultivar Yandev 55 has been distributed to farmers in the various areas. Sesame on local farms has the same type of growth and characteristics as Yandev 55 and it may be safely assumed that most farmers grow this cultivar.

2.2.3. *Seed bed preparation, and time and method of sowing*

After clearing and burning of grasses and crop residues, heaps or ridges from previous crops are levelled to have the field ready for planting (Tiv and Beli area), or low, fairly wide ridges are made with a hoe (Doma and Kwali area). In Igbirra Division very large ridges are made.

There are two different periods of sowing sesame. In Igbirra Division, Tiv Division and Beli area it is sown after the end of the dry season and with the onset of the rains and the crop is called early sesame. In Doma District and Kwali area it is sown two or three months before the rainy season ends, and the crop is called late sesame.

Two different methods of sowing may be distinguished, which could be called the 'Igbirra method' and the 'Tiv method' after the main areas where the methods are applied.

The farmers in Igbirra Division of Kabba Province sow on the widely spaced, large ridges by making holes with the toe, dropping a pinch of seed in the holes, and closing these again with the foot. Interplanting of melons which creep in the furrows in between the ridges, is not uncommon.

The farmers in Tiv Division, Beli area, Doma District and Kwali area broadcast the seed either over the whole flat field, or on the low, fairly wide ridges. The amount of seed used for sowing is estimated to vary between 2.2–17 kg per ha with averages of 4.5–9 kg per ha. After sowing, the seed may be covered by hoeing or 'raking' with leafed branches, but often no such operation follows the sowing.

2.2.4. *Cultivations and weeding after sowing*

Generally no cultivation is practiced other than once or twice hoe weeding. Hand-pulling of weeds is done, but sesame fields show often abundant weed growth.

2.2.5. *Thinning and plant densities*

In Igbirra Division plants used to be left without thinning. The number of plants per hole is usually high, the spacing is very wide and the number of plants per acre is relatively low. In 1970 in five different farms near Osara and Okene the distance between ridges and between plants on the ridges was measured at three randomly chosen places and also the number of plants per stand was counted. The average distance between the ridges was 417 cm, the spacing between the plants on the ridges was 145 cm and the average number of plants per stand amounted to 16. The estimated number of stands per ha was 1,654 and the number of plants per ha 26,464.

In the other sesame growing areas thinning is often not done. The number of plants per ha varies but is often high.

In the same year plant numbers per square foot were counted in five different farms in each of four different areas. The plants were counted at three randomly chosen places per farm. The estimated average number of plants per ha is tabulated below. The open space between ridges has been neglected under (a) and has been accounted for under (b). The number of plants per square foot varied greatly; minimum was 1 and maximum 45.

	Estimated number of plants per ha	
Area	(a)	(b)
Tiv Division	1,471,095	619,534
Beli area	1,306,046	908,969
Doma district	2,109,766	703,255
Kwali area	1,377,806	459,269

The close spacing for both sowing methods causes many plants to remain small with few and tiny branches and not many capsules.

2.2.6. *Harvesting*

At the time many leaves have dropped off and most of the remaining ones have turned yellow, and when the lowest capsules on the stem are about to split open, sesame is ready to be harvested. The plants are uprooted or cut with cutlasses or sickles and either left in the windrow for one or two days or immediately bundled and tied. The plant bundles are placed in shocks or put to racks and stay there till they are sufficiently dry for threshing.

2.2.7. *Threshing*

When the capsules are dry, have opened and release the seed easily at the lightest touch, the plant bundles are taken out of the shocks or off from the racks and are turned over to mats or any type of cloth available as tapaulin, or sacks. The plants are then beaten gently with sticks and the seed is collected, winnowed and bagged.

2.3. Sesame purchases, prices and export

The farmers' produce is bought by Buying Stations of the Marketing Board and the price paid per ton is fixed and gazetted beforehand. Table 9 shows purchases of the Marketing Board and prices paid during the period 1950/51–1970/71, (Adeyinka, Federal Office of Statistics, personal communications, 1972). Table 10 shows the distribution of the export of sesame seed from Nigeria during the period 1960–1970 (McNerney, Commonwealth Secretariat, personal communication, 1972).

Table 9. Purchases of sesame by the Marketing Board in tons and producer prices paid in pounds (£N) per ton during 1950/51–1970/71.

Season	Purchase	Price £ s d
1950/51	9,001	20: = : =
1951/52	10,235	32: = : =
1952/53	13,501	36: = : =
1953/54	13,434	36: = : =
1954/55	15,689	36: = : =
1955/56	18,256	36: = : =
1956/57	15,759	36: = : =
1957/58	16,197	38: = : =
1958/59	16,232	40: = : =
1959/60	20,387	40: = : =
1960/61	27,089	45: 18: =
1961/62	20,436	45: 18: =
1962/63	20,886	45: 18: =
1963/64	19,932	45: 18: =
1964/65	22,726	46: 18: =
1965/66	22,743	46: 18: =
1966/67	15,200	46: 18: =
1967/68	13,258	46: 18: =
1968/69	13,013	48: = : =
1969/70	17,459	42: 2: 6
1970/71	5,714	42: 18: =

Table 10. Distribution of exports of sesame seed in 1000 tons from Nigeria during 1960–1970.

Importing country	Year										
	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970
Italy	5	7	7	10	3	13	13	3	13	15	11
Japan	7	5	2	3	3	3	3	–	–	–	–
Venezuela	10	6	12	2	9	–	3	–	–	–	–
Denmark	–	–	–	–	1	–	2	1	1	–	1
Portugal	–	–	–	–	2	3	3	–	–	1	–
Spain	2	–	–	–	–	–	–	–	–	–	–
Others	3	3	3	–	–	2	1	–	–	–	–
Total	27	21	24	15	18	21	25	4	14	16	12

Table 10 shows that Italy is Nigeria's main buyer of sesame seed. The reliability of the present market is open for speculation.

3. EXPERIMENTAL STATIONS

The main experimental stations for sesame, representing the sesame growing areas, and their location and average annual rainfall are listed in Table 11 (Data from Nigerian Meteorological Service).The rainfall at Beli is not recorded.

TABLE 11. Main experimental stations for sesame producing areas and their latitude, longitude, altitude in m and average annual rainfall in mm.

Experimental station	Represented area	Latitude	Longitude	Altitude	Annual rainfall
Osara	Igbirra Division	07° 41′N	06° 25′E	241	1389
Yandev	Tiv Division	07° 23′N	09° 01′E	122	1331
Wukari	Tiv Division	07° 52′N	09° 47′E	152	1242
Beli	Beli area	07° 53′N	10° 58′E	274	–
Lafia	Doma District	08° 30′N	08° 30′E	183	1280
Kwali	Kwali area	08° 53′N	07° 00′E	237	1275
Mokwa	General	09° 18′N	05° 04′E	152	1054

3.1. MOKWA AGRICULTURAL RESEARCH STATION

The experimental station at Mokwa, situated in the North-Western State of Nigeria, in Niger Province, has been the centre of sesame research since 1959.

3.1.1. *Brief history*

The great demand for oilseeds in Europe after World War II made the West African Oilseeds Mission to investigate in 1947 possibilities for the production of groundnuts and other oil seeds and on its recommendations of two different sites the Nigerian Government selected Mokwa. Plans were completed in 1948 to farm 32,000 acres and the Colonial Development Corporation was invited to take part in the project together with the Nigerian Government. On its approval a limited liability company was formed named Niger Agricultural Project Limited with equal shares for both participants. Clearing from bush, attracting settlers, building settlement villages and cropping of groundnuts and sorghum started soon, but social, technical and economical problems caused the Colonial Development Corporation to withdraw from the venture in 1954 and the Nigerian Government to hand over the project to the Northern Regional Government, which was to carry on and broaden the set-up of the scheme by initiating experimental work on an Agricultural Research Station (BALDWIN, 1957).

The Agricultural Research Station became part of the Institute for Agricultural Research at Samaru and was incorporated in the Ahmadu Bello University at Zaria in 1962. Settlers' villages became living places for staff and workers and work continued on oilseed crops like groundnuts, soya beans, castor and sesame, while also maize, cotton and other crops were taken up in the research programme.

3.1.2. *Experimental farm*

The experimental farm, called Dangakpe, covers a partly cropped area of approximately 486 ha.

The layout of the farm is of the broad-based ridge terrace type. Terraces are separated by roads and grass strips. Each terrace consists of a field of approximately 0.8–1.6 ha and the fields are ridge-cultivated for soil conservation purposes with the ridges following the contour of the land, but with such a deviation that the slope of the furrows is 0.1 per cent for drainage. The field outlets for excess water are in the shape of a fish tail to spread water evenly.

The soil of the experimental farm can be classified as ferrisol (2.1.3.). An example of a sample place at Dangakpe is reproduced from KLINKENBERG and HIGGINS (1968) in table 12.

TABLE 12. Profile description and analytical data of a soil sample place at Dangakpe, reproduced from KLINKENBERG and HIGGINS (1968).

	Profile description
0– 3 in (0– 8 cm)	Reddish brown, 5 YR 5/3; loamy sand; dry soft; many fine grass roots; clear and smooth boundary.
3– 24 in (8– 61 cm)	Yellowish red, 5 YR 4/8; sandy clay loam; few medium dusky red, fine grained sandstones; dry and hard; common fine gras roots; gradual and smooth boundary.
24– 55 in (61–140 cm)	Dark red, 2.5 YR 3/6; sandy clay; moist firm; few grass roots; gradual and smooth boundary.
55–111 in (140–282 cm)	Dark red, 2.5 YR 3/6; sandy clay; moist and firm; few fine grass roots.

Analytical data

Depth					
	in	0–3	3–24	24–55	55–111
	cm	0–8	8–61	61–140	140–282
Part. size distr.:					
2.0–0.2 mm (per cent)		34	30	30	24
0.2–0.02 mm (per cent)		52	36	32	38
0.02–0.002 mm (per cent)		8	8	2	2
< 0.002 mm (per cent)		6	26	36	36
pH-water		4.7	4.9	4.9	4.8
C.E.C. (meq/100 g soil)		3.00	4.30	7.70	9.30
Extractable cations:					
Na (meq/100 g soil)		0.02	0.03	0.03	0.02
K (meq/100 g soil)		0.03	0.04	0.04	0.04
Ca (meq/100 g soil) Mg (meq/100 g soil)		1.32	1.60	2.64	2.64
Total (meq/100 g soil)		1.37	1.67	2.71	2.70
Saturation (per cent)		47	40	35	29
C (per cent)		0.49	0.23	0.25	0.23
N (per cent)					
Total P (p.p.m.)		98	130	120	100

The soils are formed on cretaceous sediments of coarse sandstone of Turonian-Maestrichtian age (HIGGINS, HOPE and CLAYTON, 1957). The ferrisols provide a good physical growing medium but their chemical properties are poor due to long periods of subjection to an annual rainfall of over 1000 mm causing leaching away of a large quantity of plant nutrients. The drainage properties are good. Colloidal contents of the surface horizons are very low and therefore in addition to having a low nutrient retention capacity the soil tends to form a surface cap through the action of beating rain on the structureless sand fraction.

3.1.3. *Farm management practices*

After the cropping season is completed, the land is cleared from plant residues and weeds, or from a fallow crop like pigeon pea (*Cajanus caian*) either by removal or by burning. The burning is believed to assist in killing weed seeds and to reduce termite populations and prevent their expansion.

At the end of the dry season, around February, the ridges of the previous season are ripped open with a heavy ('Mammoeth') chisel-plough. This somewhat awkward operation has several advantages. The opening of the soil enables the first rain to penetrate rapidly and to the proper place. As a result of this good penetration the preparation of the field can start immediately and sowing will follow without delay. This is considered an advantage for a good number of crops. Finally during the dry season there is a slack period of work and the operation can be carried out without rush.

With the first rains N and K fertilizers are applied. Superphosphate is applied by machine into the ridge at the time of ridging. The ridging implement is run through the old ridges cropped the previous year. Small bunds or 'crossties' are placed in the furrows at some interval by hand. This prevents runoff (LAWES, 1966).

Sowing for most experiments is done by hand, using the moving string method with spacing pegs on guide ridges at required distance. For sesame this is usually 15 cm (6 inches). Sometimes the ridge tops are levelled just before sowing to obtain even germination, but if a long dry spell follows after planting, plants succumb sooner than on unlevelled ridges. For sesame a pinch of about twenty-five seeds between finger and thumb is sown at a depth of about 2,5 cm. The large number of seedlings after germination is able to break and lift the soil if capped after some days of drought. A uniform depth of sowing is important for even growth, especially if the subsequent rains are sparse.

Initially sesame grows slowly and is very sensitive to adverse conditions. Weeding during the early stages of growth is important.

Thinning is usually done when the plants are about 7–10 cm tall, but it can well be done much earlier; one or two plants are left per stand.

When the leaves turn yellow and drop and when the lowest capsules on the stem are about to dehisce, the plants are cut, bundled and tied to poles or hung over frames as described in 5.

Threshing of sesame follows the conventional methods (2.2.7.).

3.1.4. *Climate*

Fig. 3 shows the following climatic elements and their average values obtained from Mokwa Meteorological Station.

clematic element	average value
(a) Monthly rainfall in mm	89
(b) Daily tank evaporation in mm	13.1
(c) Daily Penman's evapotranspiration in mm	13.3
(d) Daily maximum temperature in °C	33.5
(e) Daily minimum temperature in °C	20.7
(f) Daily earth temperature at 1 ft in °C	30.4
(g) Daily earth temperature at 4 ft in °C	30.6
(h) Duration of daylight in hours	12.12
(i) Daily sunshine hours	7.30

3.2. OTHER EXPERIMENTAL STATIONS

Most of the soils at Osara Farm Centre are sandy or sandy clay soils characterised by the presence of appreciable amounts of iron concretions, normally found over ironpan. The depth to pan varies but is normally within 1 m. In the centre of the farm is an area with many rock outcrops and very shallow soils. Deep soils occur but are rare.

The soils at Wukari usually have a light coloured sandy surface horizon over a mottled reddish yellow sandy loam or sandy clay loam. Lateritic ironpan is found at depths of 1–1.5 m, The pan gradually merges into deep weathered sandstone or granite rock.

The main soil at Kwali Farm Centre is a deep, yellowish red sandy loam with a well defined, compact, concretionary layer, normally well below 30 cm. This is underlain by a very deep zone of rotten rock. This soil occupies most of the upper and middle slopes. On the highest sites shallower soils occur and on lower middle slopes the ironpan comes to the surface. Between this pan and the fadama proper are brownish soils.

No detailed soil survey information is available for Yandev, Beli and Lafia; the soils at Beli are probably similar to those at Wukari (KLINKENBERG, personal communications).

Average rainfall figures per month recorded over a number of years are shown in Table 13 (Nigerian Meteorological Service).

No other meteorological data are available except on maximum and minimum temperatures for Yandev and Kwali, and on evaporation for Yandev.

Cultivation, sowing, harvesting and threshing practices are similar to those at Mokwa. Only a little more handwork and less tractor work is carried out.

TABLE 13. Rainfall per month in mm as averages over more years.

Month	Experimental Station				
	Osara	Yandev	Wukari	Lafia	Kwali
January	0.25	6.35	0.15	2.54	0.25
February	5.84	11.94	5.84	5.08	8.13
March	44.70	35.31	26.92	26.42	25.91
April	154.18	113.28	89.66	78.49	81.79
May	187.20	179.32	168.40	155.96	140.46
June	211.33	189.74	180.01	164.85	237.74
July	202.69	143.76	143.51	202.95	130.81
August	200.15	146.56	151.38	240.03	217.68
September	229.62	275.08	277.62	252.22	250.19
October	124.71	207.52	181.36	141.73	161.80
November	17.02	17.53	13.21	8.13	21.34
December	10.92	5.33	2.29	0.76	0.00
Total	1388.61	1331.72	1240.35	1279.16	1276.10

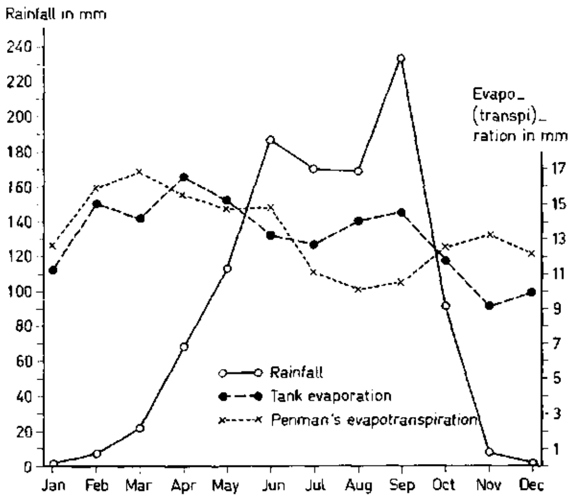


FIG. 3. a. Monthly rainfall (average of 18 years).
b. Daily tank evaporation (average of 5 years).
c. Daily Penman's evapotranspiration (average of 5 years).

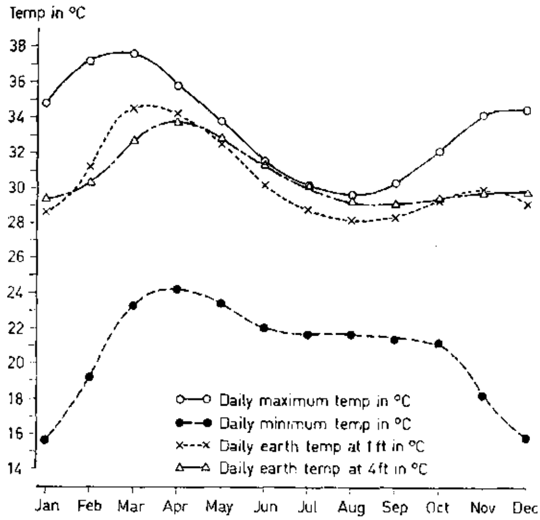


FIG. 3. d. Daily maximum temperature (average of 16 years).
e. Daily minimum temperature (average of 16 years).
f. Daily earth temperature at 1 ft (average of 15 years).
g. Daily earth temperature at 4 ft (average of 15 years).

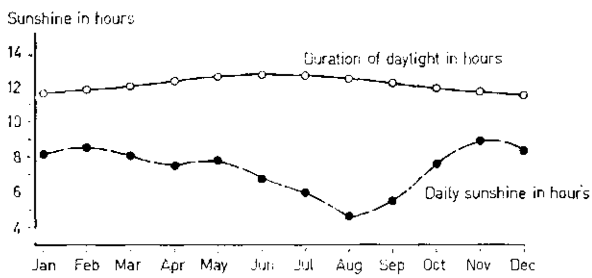


FIG. 3. h. Duration of daylight in hours.
i. Daily sunshine hours (average of 6 years).

4. PLANT DENSITY AND SPACING

Sowing methods and spacings or plant densities vary in the different sesame growing areas of Nigeria as discussed in 2.2. and differ from the recommendations made by the Extension Service of the Ministry of Agriculture, the Extension Research Liaison Section of the Institute for Agricultural Research at Samaru, and from the earlier recommendations made by the Agricultural Research Station at Mokwa, which suggested that stands should be spaced 15 cm (6 inches) apart on 91 cm (3 ft) ridges and thinned to two plants, or that after broadcasting at a seed rate of 9 kg per ha (8 lb per acre) on a flat seed bed, completely free from weeds, thinning should be to 15–23 cm (6–9 inches) between the plants, when these are about 15 cm long (Extension Service, 1960; Extension Research Liaison Section, 1968; STEELE, 1960). These recommendations were provisional and more information was needed on the influence of plant density and spacing on yield. In this chapter relevant literature has been reviewed and results of spacing trials carried out since 1960 are discussed.

4.1. LITERATURE REVIEW

The variation in spacing and plant densities is considerable. WEISS (1971) shows in a table the seed rates for broadcasting sesame used in eighteen different countries. The amounts vary from 2–15 kg per ha with averages ranging from about 5–8 kg per ha. Assuming a 1000-seeds weight of 2.5 g and a germination percentage of 75, an amount of 5 kg seed would potentially produce 1,500,000 plants.

High seed rates may compensate for – often substantial – losses of seed and plants during the period from sowing till harvesting. MAZZANI (1966) recorded in Venezuela plant losses of 22–26 per cent during the period from 80–100 days after sowing, and in Tanzania plant losses of 25–34 per cent occurred between emergence and harvest (WEISS, 1971).

Table 14 shows optimal, recommended or practiced spacings for different countries to give a further idea of the variation mentioned.

Results of spacing and plant density experiments are available from different sesame growing countries:

East Africa: In Uganda row-planting gave better yields and better weed control than broadcasting and for unbranched cultivars 23–30 cm row widths were recommended. The branched cultivars showed a high stand tolerance and relatively small yield differences occurred between densities of 25,000 and 500,000 plants per ha and row widths of 32 and 66 cm. Closer row width encouraged more even growth and uniform ripening (NYE, 1940; TRIBE, 1964).

In a publication of the Commonwealth Bureau of Plant Breeding and

TABLE 14. Spacings and plants densities in different countries.

Author	Country	Spacing (cm)	Number of plants in '000 per ha
Weiss (1971)	China	150 × 150	4.4
Weiss (1971)	Colombia	70 × 15	95.2
Weiss (1971)	Ecuador	70 × 10	142.9
Baluch (1966)	India	61 × 30	54.6
Joshi (1961)	India	30 × 30	111.1
Seshadri (1955)	India	28 × 28	127.6
Singh (1963)	India	46 × 20	108.7
Kostrinsky (1959)	Israel	45 × 20	111.1
Lavronov (1950)	Russia	80 × 55	22.7
Khidir (1972)	Sudan	81 × 15	82.3
Tanganyika (1966)	Tanzania	71 × 28	50.3
Money-Kyrle (1957)	Turkey	58 × 30	57.5
Tribe (1967)	Uganda	61 × 8	215.3
Uganda (1964)	Uganda	61 × 8	215.3
Martin (1955)	U.S.A.	84 × 8	156.6
Collister (1955)	U.S.A.	90 × 5	215.2
Arroyo (1967)	Venezuela	60 × –	56.0*
Cano (1950)	Venezuela	76 × 20	64.4

* at harvest

Genetics (LEAKEY, 1970) Auckland reports on spacing x cultivar trials in Uganda with the local cultivar and the introductions Morada and Venezuela 51. Spacings between the rows were 17.8, 35.5 and 71 cm and within the rows 7.5, 17.8 and 28 cm. The best yields were obtained from 17.8 × 17.8 and 35.5 × 7.5 cm spacings.

GERAKIS and TSANGARAKIS (1969) in the Sudan kept the inter-row spacing unchanged at 50 cm and varied the intra-row spacing from 25.0 to 16.7, 12.5 and 10.0 cm, so arriving at 80,000, 120,000, 160,000 and 200,000 plants per ha respectively. Fertilizer applications were nil, or 50 kg per ha sulphate of ammonia plus 22 kg per ha triple superphosphate. The results showed no interaction between spacing and fertilizer treatments, and the yields for the lowest to the highest plant densities were 330, 380, 360 and 320 kg per ha respectively.

In Tanganyika three different inter-row spacings of 18, 36 and 71 cm respectively and three different intra-row spacings of 8, 18 and 28 cm respectively were tested in all nine possible combinations, using three different sesame cultivars: Local, Inamar and Acarigua, which show in that order a decrease in branching. The results showed that the local cultivar gave the highest yield at the widest spacing, the cultivar Inamar did so at the closer spacing of 36 × 18 cm and Acarigua yielded best at the still closer spacing of 18 × 18 cm; highest yields for the three cultivars were 389, 138 and 121 kg per ha respectively. At the closest intra-row spacing there was a marked tendency to stunted growth (Tanganyika, 1966).

India: NARAIN and SRIVASTAVA (1962) testing three different inter-row spacings of 31, 46 and 61 cm and three intra-row spacings of 15, 31 and 46 cm in all possible combinations over a period of three years found no statistically significant yield differences, but the highest yields were obtained at the 31 cm inter-row spacing and 15 cm intra-row spacing.

Middle and South America: MAZZANI and COBO (1958) investigated in Venezuela in two experiments the effect of inter- and intra-row distance on yield for the unbranched sesame cultivar Aceitera, using inter-row distances of 30, 50 and 70 cm and intra-row distances of 5, 10 and 20 cm respectively. The average yield increase due to reducing the inter-row spacing from 70 to 30 cm amounted to 39 and 9 per cent respectively for the two experiments, and reducing the intra-row spacing from 20 to 5 cm resulted in a yield increase of 28 and 21 per cent respectively. The plant densities varied from 71,400–667,000 plants per ha.

MAZZANI and COBO (1956) also investigated in two experiments the effect of inter- and intra-row spacing on yield for two branched cultivars, using row distances of 50, 70 and 90 cm and intra-row distances of 10, 20 and 30 cm. For the cultivar Morada the effect of the inter-row spacing differences was not reflected in the yield figures and the intra-row spacing effect was only small. For the cultivar Inamar the spacing, especially between the rows, was somewhat more pronounced in its effect. Plant populations varied from 37,000–200,000 plants per hectare and the higher densities gave higher yields.

WHITEHEAD (1967) found in trials in Jamaica, testing plant spacings of 61.0 × 30.5, 61.0 × 15.2, 30.5 × 30.5, 30.5 × 15.2 and 30.5 × 7.6 cm (corresponding plant densities: 53,820, 107,640, 107,640, 215,280 and 430,560 plants per ha respectively) and using unbranched sesame cultivars, that the closest spacing gave the best yield, 61.0 × 15.2 cm was next, followed by 30.5 × 15.2 and 30.5 × 30.5 cm, and the lowest yield was from the widest spacing; yields were 73, 94, 82, 88 and 100 per cent respectively of that of the closest spacing.

OLIVE and CANO (1954) found in experiments in El Salvador that an inter-row distance of 30 cm gave better yields than one of 60 or 90 cm, but varying the intra-row spacing from 10 to 20 and 30 cm had little effect on the yield.

In Colombia it was observed that the local cultivar needed a little wider inter-row spacing of 60–80 cm to produce about the same as the newer less branched cultivars sown at an inter-row spacing of 40–60 cm; intra-row spacing was about 10–20 cm.

In Ecuador branched cultivars were frequently sown in 90 cm and unbranched cultivars in 60 cm rows.

In Brazil the local, tall, branched cultivar was formerly planted at a spacing of 175 × 88 cm, but a spacing of 90 × 40 cm was found to give the highest yields. Newer unbranched cultivars were recommended to be planted in a spacing of 60–70 × 10 cm.

In Argentina at standard row widths of 75–100 cm a population of 300,000–400,000 plants per ha is considered optimal (WEISS, 1971).

Middle East: MONEY-KYRLE (1957) tested in Turkey inter-row spacings of 50 and 58 cm and intra-row spacings of 20 and 30 cm in all four possible combinations on the flat and on ridges. Ridge-planting was better than flat planting, but yield differences due to spacing differences were only small. KOSTRINSKY (1959) found that at an inter-row spacing of 75 cm yields were 22 per cent higher than at 100 cm in 1958, but in 1959 yields were 34 per cent lower.

U.S.A.: RUSSELL et al. (1967) drilled the seed at a rate of 1.1 kg per ha in rows 102 cm apart and no thinning was done later.

COLLISTER (1955) compared solid drilling of about 5.6 kg per ha with drilling of approximately 1.1 kg seed per ha in rows 91 cm apart and found row drilling to yield about 59 per cent more than solid drilling. The results of his spacing trial over a three years period with the essentially non-branched cultivar Kansas 8, using a fixed row distance of 91 cm and intra-row distances varying from 2.5–30.5 cm, showed no significant yield differences and the 23 cm spacing yielded best. Inter-row spacings of 46–76 cm were recommended in the U.S.A. by KINMAN (1955) and U.S.D.A. (1958) and it was observed that weed growth was suppressed at this rather close spacing.

CULP (1963) did cultivar trials in the Mississippi Delta during two years using row spacings of 50 and 100 cm; the closer spacing yielded on an average 36 per cent more than the wider row spacing.

From the above references it is concluded that sesame and especially the branched cultivars can adapt very well to the space available. The unbranched cultivars may be planted at a closer spacing than the branched ones. Plant densities of about 400,000 plants per ha for unbranched cultivars and 200,000 plants per ha for branched cultivars will probably be not too far off from the optimum and these figures correspond with a land availability of 250 and 500 cm^2 per plant respectively.

4.2. SPACING EXPERIMENTS IN NIGERIA

STONEBRIDGE (1962) compared in six experiments the Igbirra, Tiv and 'experimental farm' method of sowing – the latter with a spacing of 23 cm on ridges 91 cm apart and the Tiv method with thinning to a spacing of 23 × 23 cm. He concluded that, from a yield point of view, the Igbirra method was inferior to the other two methods, while the yields from the Tiv method and the experimental farm method showed no statistically significant difference.

During 1961 two spacing experiments were carried out, one at Mokwa and one at Yandev, in which the row distance was fixed at 38 cm and the spacing within the row was varied from 8 to 15, 23 and 30 cm. Spacing effects on yield were for both experiments not significant (STONEBRIDGE; results not published).

In 1962 a trial was carried out at Mokwa in which the effect of six different spacing combinations on yield were investigated (STONEBRIDGE; results not published). The yields for the different treatments were as follows.

Spacing combination (cm)	Yield (kg per ha)
15 × 15	592
23 × 23	577
30 × 30	565
30 × 46	565
46 × 46	558
61 × 61	457
S.E.D.	28

The 61 × 61 cm spacing was obviously too wide; yield differences between the other spacing combinations were not significant, but the closest spacing gave the best yield.

A further series of spacing - plant density experiments was carried out at Mokwa during the years 1965–1967. Details are shown below.

Experiment	Year	Layout*	Replications	Plot size (m^2)	Average yield (kg per ha)	Spacings
1	1965	L.S.	6	54	372	3
2	1966	R.B.	6	30	559	10
3	1967	R.B.	6	27	490	8

* L.S. = Latin Square. R.B. = Randomized Block.

Fertilizer applications were at a rate of 250 kg sulphate of ammonia per ha and 125 kg superphosphate per ha. Planting for all experiments was in the month of August. Yandev 55 and some other branched and unbranched cultivars were tested. Table 15 shows results for Yandev 55.

Table 16 shows results for the unbranched entries and yields are expressed as a percentage of those of Yandev 55 planted at the same spacing or density.

The cultivar Dulce produces small plants, has three capsules per leaf axil and short internodes; the other cultivars are somewhat taller, but for the other characters similar; 65B-14 possesses long capsules.

From the results it is concluded that Yandev 55 is very space tolerant; even at a density of over two million plants per ha the yield was not too badly suppressed.

The most significant yield increase was obtained from reducing the 91 cm inter-row spacing rather than from altering the intra-row spacing. The data suggest that an inter-row spacing of 30 cm and an intra-row spacing of 10–15 cm, corresponding with densities of about 222,000–333,000 plants per ha, are for Yandev 55 near optimal. Flat planting gave slightly better results than ridge planting. The unbranched cultivars, sown in close spacing, yielded less than Yandev 55 at its best spacing.

TABLE 15. Yield of cultivar Yandev 55 in kg per ha as affected by inter- and intra-row spacing at Mokwa during 1965–1967.

Year	Spacing in cm		Plants per ha		Yield
	inter-row	intra-row	number	per cent**	
	91*	15	66,786	93	487
1965	91	15	66,196	92	539
	30	15	202,944	94	647
				S.E.D.	36
	91*	15	67,753	94	427
	91*	10	97,090	90	517
	91*	x	331,597	30	465
	30	15	207,572	96	760
1966	30	10	315,344	98	800
	30	x	106,427	32	527
	15	15	414,922	97	820
	15	10	566,811	88	758
	15	x	2,349,608	35	578
	x	x	1,455,110	17	621
				S.E.D.	43
	91*	15	58,753	82	374
	91	15	56,559	79	428
	30	15	170,281	79	604
1967	30	10	203,441	63	572
	30	5	277,747	43	475
	23	15	221,235	77	549
	23	10	266,819	62	512
	23	5	373,677	45	482
				S.E.D.	21

* Sowing on ridges.
** Plants per ha at harvest in per cent of possible number.
x = Drilling at seed rates of 3.7, 11.2 and 22.5 kg per ha for 91, 30 and 15 cm inter-row spacing respectively; broadcasting at seed rate of 28.1 kg per ha
Percentage of plants per ha based on 1000 seeds weight of 2.5 g and germination percentage of 75.

TABLE 16. Yields of unbranched cultivars in percentage of the yield of Yandev 55, sown at the same spacing or density, at Mokwa during 1965–1967.

Year	Cultivar	Spacing in cm		Plants per ha		Yield
		inter-row	intra-row	number	percent**	
	Dulce	91*	15	69,183	96	25
1965	Dulce	91	15	68,966	96	34
	Dulce	30	15	209,888	97	40
1966	Dulce	15	x	3,026,737	45	29
	Dulce	x	x	2,160,913	26	43
	65B-12	23	15	281,436	65	107
1967	65B-14	23	15	279,662	65	62
	65B-176	23	15	278,448	65	23

* Sowing on ridges. ** Plants per ha at harvest in per cent of possible number.
x = Drilling at seed rate of 22.5 and broadcasting at 28.1 kg per ha. Percentage of plants per ha based on 1000 seeds weight of 2.5 g and germination percentage of 75.

A further series of spacing trials, which will be discussed in the next chapters, was carried out during 1971. The experiments were of two types: One where planting was on ridges 91 cm apart, and one where planting was on the flat.

4.2.1. *Spacing trials – 1971 series, ridge planting*

4.2.1.1. Materials and methods

The cultivar used was Yandev 55. Sowing was both early and late in two different experiments. Fertilizer applications were at rates of 250 kg nitrochalk and 125 kg superphosphate per ha. The experimental layout was a Randomized Block with nine spacing treatments and six replications. The ridges were lightly opened with cultivator tines, sowing was done by drilling, after which the seed was covered with soil. Thinning to the required spacing was done as early as possible. The plot size was twelve ridges 91 cm apart and 3 m long. Insecticidal (Vetox 20) and fungicidal (Dithane) spraying was once or twice per week. A germination test in petri-dishes was carried out on five times fifty seeds before planting. The spacing treatments were: Drilling at a seed rate of 9 kg per ha and no thinning afterwards (x), and drilling followed by thinning to 2.5, 5.1, 7.6, 10.2, 12.7, 15.2, 20.3 and 25.4 cm (1, 2, 3, 4, 5, 6, 8 and 10 inches) spacing. Plant counts were carried out at harvest. Calculations of plants per ha in per cent were based on possible numbers of plants per ha, and for drilling and broadcasting on a 1000 seeds weight of 2.5 g. In the late planted experiments the number of capsules on stem and branches of thirty plants per spacing treatment was counted at harvest and capsule lengths were measured of forty capsules taken at random. Also 1000 seeds weights were determined.

4.2.1.2. Results

The germination tests showed percentages of 92.0 and 72.8 for the early and late planted experiment respectively.

The experimental results are summarised in Table 17 and Fig. 4.

4.2.1.3. Discussion and conclusions

The growth of the early planted experiment was disappointing from the early start. A dry spell some weeks after planting caused delay of thinning. hence weakness of stem and severe lodging; yields were low. Plants per ha in per cent showed a trend of increase with a decrease of plant density. The treatment of drilling the seed at a rate of 9 kg per ha without subsequent thinning gave the lowest yield.

The late planted trial developed and yielded better. In Fig. 5a the spacing is plotted against the yield. It is noticed that the points, with the exception of those at 2.5, 10.2 and 15.2 cm, are about on a straight line, with regression of yield in kg per ha (Y) on spacing in cm (x) of

(a) $Y = 404.1 - 3.2x \ (t = 15.8^{***})$

At spacings below 5.1 cm (2.5 cm and drilling) yields were depressed because of 'over-crowding' of the plants for space. The expression: Crowding for space,

TABLE 17. Yield in kg per ha and 1000 seeds weight in g as affected by intra-row spacing on ridges at Mokwa during 1971.

Spacing (cm)	(in)	Early sowing plants per ha number	per cent	1000- seeds	yield	Late sowing plants per ha number	per cent	1000- seeds	yield
x	x	273,390	8	1969	69	560,722	21	2183	281
2.5	1	133,474	31	1726	96	207,390	48	2072	361
5.1	2	136,704	64	1755	117	155,721	72	2283	391
7.6	3	105,489	74	1645	109	108,837	76	2183	379
10.2	4	68,531	64	1639	78	95,263	89	2257	391
12.7	5	67,454	78	1825	89	74,916	87	2201	359
15.2	6	58,605	82	1752	98	66,139	92	2186	297
20.3	8	48,169	90	1631	90	47,900	89	2125	340
25.4	10	36,886	86	1679	69	39,253	91	2168	324
S.E.D.			5		20		3		31

x = Drilling at seed rate of 9 kg per ha.

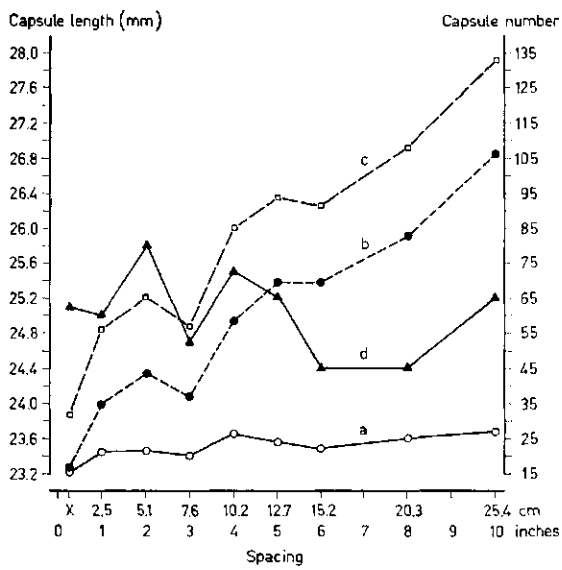


FIG. 4. Number of capsules per plant on stem (a), branches (b) and total (c) and length of capsules (d) as affected by intra-row spacing on ridges at Mokwa during 1971, late season.

is from DE WIT (1960) who developed models to describe competition between plants of different species and extended these to single crops in spacing trials.

He arrived at the following formulas:

(b) $A = k_{10}z_1(k_{10}z_1 + z_0)^{-1}$

(c) $O = k_{10}z_1(k_{10}z_1 + z_0)^{-1}M$

(d) $O_s = \beta(\beta + s)^{-1}\Omega$

in which:

A = area effectively available for the crop

k_{10} = relative crowding coefficient of crop with respect to open space

z_1 = relative space allotted to the crop

z_0 = relative space left open

O = yield

M = yield at arbitrary value of $z_1 = 1$

O_s = yield at a space per seed of s

s = space per seed

β = $(k_{10}-1)m$, in which m is an arbitrary value of the space per seed

Ω = extrapolated yield at an infinite seed density

Application of the above formulas to the results of the late planted trial is instructive. If it is assumed that $z_1 = 1$ at a spacing of 5.1 cm, the relative crowding coefficient k_{10}, calculated for and then averaged over spacings 7.6, 12.7, 20.3 and 25.4 cm, amounts to 17.7. The relation between the relative plant density z_1 and the yield O is shown in Fig. 5b. If the effective plant density A is plotted against the yield O, the relation between these appears to be linear (Fig. 5c). Similarly a straight line can be fitted to the points obtained by plotting the inverse of the yield O_s^{-1} in 10^{-5} ha kg^{-1} against the space per plant s at 5,1, 7.6, 12.7, 20.3 and 25.4 cm spacing, the regression formula being:

(e) $O_s^{-1} = 243.6 + 2.5s \; (t = 23.7^{***})$

According to formula (a) the yield at infinite plant density is 404.1 kg per ha. Formula (e) arrives at a corresponding value of = 410.5 kg per ha. These values are at the same time extrapolated yield maxima. However the formulas assume a continued linear relationship between spacing and yield (a) and spacing and inverse of yield (e) even at very close spacing which does not hold true as Figures 5a and 5d clearly show. The maximum yield therefore is obtained at a spacing where the effect of 'over-crowding' cancels the yield increasing effect of closer spacing, which took place between 2.5 and 5.1 cm spacing.

The reproductive rate of one plant, grown with no limitation of available land, equals $\beta\Omega$, which amounted to 36.3 g.

The number of capsules on the stem increased slightly with an increasing distance between the plants. The capsule length showed no clear spacing effect, but the number of capsules on the branches increased considerably with wider spacing. The 1000 seeds weights showed no clear spacing effect.

4.2.2. *Spacing trials – 1971 series, flat planting*

4.2.2.1. Materials and methods

The materials and methods used were the same as those described in 4.2.1.1. with the following differences:

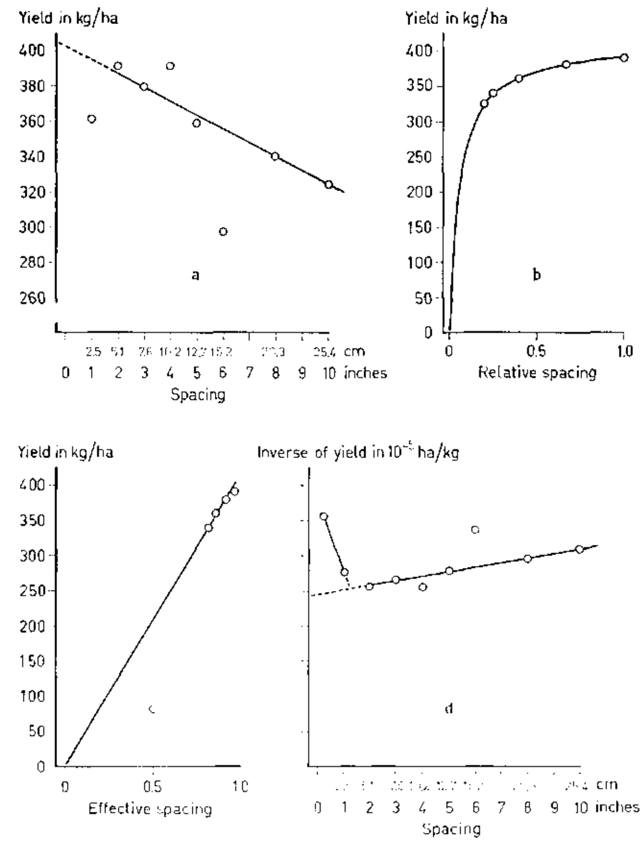


FIG. 5. 1971 Late planted spacing trial on ridges
a. Relation between spacing and yield.
b. Relation between relative space allotted to the crop (z_1), assuming that $z_1 = 1$ at a spacing of 5.1 cm, and yield.
c. Relation between area effectively available for the crop (A), assuming that $z_1 = 1$ at a spacing of 5.1 cm, and yield.
d. Relation between spacing and inverse of the yield.

Sowing was in August only. The plant rows were marked with ropes and pointed sticks. The experimental layout was of the Split-plot type with the whole- and sub-plots grouped in Randomized Blocks. The plot size was 1.2 m × 3 m. The whole-plot treatments were inter-row spacings of 10.2, 15.2, 20.3, 30.5, 40.6 and 61.0 cm (4, 6, 8, 12, 16 and 24 inches). The sub-plot treatments were intra-row spacings of 2.5, 5.1, 7.6, 10.2, 12.7, 15.2, 20.3, 25.4 and 30.5 cm (1, 2, 3, 4, 5, 6, 8, 10 and 12 inches). In addition there were, on both sides of each whole-plot, observation plots of 1.2 m × 3 m, in which seed was broadcast at a rate of 9 kg per ha; the seed was raked in after planting. Possible number of plants per ha for each treatment is presented in Table 18.

TABLE 18. Possible number of plants per ha in 10,000 for different spacing combinations

Intra-row spacing (cm)	(in)	Inter-row spacing cm: 10.2 in: 4	15.2 6	20.3 8	30.5 12	40.6 16	61.0 24
2.5	1	387.5	258.3	193.7	129.2	96.9	64.6
5.1	2	193.7	129.2	96.9	64.6	48.4	32.3
7.6	3	129.2	86.1	64.6	43.1	32.3	21.5
10.2	4	96.9	64.6	48.4	32.3	24.2	16.1
12.7	5	77.5	51.7	38.7	25.8	19.4	12.8
15.2	6	64.6	43.1	32.3	21.5	16.1	10.8
20.3	8	48.4	32.3	24.2	16.1	12.1	8.1
25.4	10	38.7	25.8	19.4	12.9	9.7	6.5
30.5	12	32.3	21.5	16.1	10.8	8.1	5.4

For the broadcast treatment the possible number of plants per ha in 10,000 was 329,9, assuming a 1000 seeds weight of 2.5 g and 100 per cent germination.

At harvesting twenty plants samples were taken from each spacing treatment and forty plants samples from the broadcast treatment. Of these capsules were counted, and stems and branches were cut short, dried at about 105°C and weighed separately. The lengths of forty randomly taken capsules were measured; 1000 seeds weights were determined. Oil contents of small seed samples were analysed at the Institute for Agricultural Research, Samaru.

4.2.2.2. Results

The germination percentage of the seed used for planting was 72.8. The experimental results are summarised in Tables 19–22 and Figures 6–8.

TABLE 19. Actual number of plants per ha expressed as a percentage of the possible number of plants per ha for different spacing combinations at Mokwa during 1971.

Intra-row spacing (cm)	(in)	Inter-row spacing cm: 10.2 in: 4	15.2 6	20.3 8	30.5 12	40.6 16	61.0 24	average	
2.5	1	35	54	44	67	58	70	55	
5.1	2	58	84	72	83	80	76	75	
7.6	3	72	84	77	87	90	84	82	
10.2	4	84	87	92	96	97	80	89	
12.7	5	97	90	98	90	90	97	94	
15.2	6	100	99	98	96	96	89	96	
20.3	8	94	92	93	93	95	83	92	
25.4	10	95	96	99	93	85	87	94	
30.5	12	99	94	96	97	90	94	95	S.E.D.a
	average	82	87	85	89	88	84	86	3
						S.E.D.b		2	
			S.E.D.c = 5						

a: Inter-row averages.
b: Intra-row averages.
c: Inter × Intra row averages.

The actual percentage of plants in the broadcast treatment, taking into account the germination percentage of 72.8 per cent, was 37.

TABLE 20. Yields in kg per ha for different spacing combinations at Mokwa during 1971.

Intra-row spacing (cm)	(in)	Inter-row spacing cm: 10.2 in: 4	15.2 6	20.3 8	30.5 12	40.6 16	61.0 24	average	
2.5	1	395	405	373	475	428	375	408	
5.1	2	448	500	495	609	473	387	485	
7.6	3	619	423	566	542	464	418	505	
10.2	4	511	476	642	534	473	403	507	
12.7	5	552	495	560	475	473	405	493	
15.2	6	457	556	555	488	456	385	483	
20.3	8	558	445	564	314	431	349	444	
25.4	10	496	492	490	507	373	270	438	
30.5	12	450	499	479	477	286	288	413	S.E.D.a
	average	498	477	525	491	429	364	464	45
						S.E.D.b		20	
				S.E.D.c = 48					

a: Inter-row averages.
b: Intra-row averages.
c: Inter × Intra-row averages.

The yield of the broadcast treatment was 337 kg per ha.

TABLE 21. 1000 seeds weights in mg for different spacing combinations at Mokwa during 1971.

Intra-row spacing (cm)	(in)	Inter-row spacing cm: 10.2 in: 4	15.2 6	20.3 8	30.5 12	40.6 16	61.0 24	average
2.5	1	2196	2268	2162	2326	2167	2126	2207
5.1	2	2178	2246	2216	2217	2156	2076	2181
7.6	3	2134	2153	2116	2177	2124	2184	2148
10.2	4	2201	2173	2236	2118	2067	2083	2147
12.7	5	2182	2124	2148	2147	2129	2246	2163
15.2	6	2073	2196	2165	2129	2093	2160	2136
20.3	8	2125	2097	2088	2167	2102	2058	2106
25.4	10	2146	2119	2062	2160	2013	2123	2104
30.5	12	2169	2168	2128	2085	1999	2113	2110
	average	2156	2172	2147	2170	2095	2130	2145

For the broadcast treatment the 1000 seeds weight amounted to 2159.

TABLE 22. Oil content in per cent for different spacing combinations at Mokwa during 1971.

Intra-row spacing (cm)	(in)	Inter-row spacing cm: 10.2 in: 4	15.2 6	20.3 8	30.5 12	40.6 16	61.0 24	average
2.5	1	56.34	56.50	55.71	55.74	57.28	56.58	56.36
5.1	2	57.68	56.79	56.80	56.01	53.39	56.17	56.14
7.6	3	56.48	56.52	56.67	55.99	54.28	54.60	55.76
10.2	4	57.38	57.19	57.13	56.65	56.30	55.65	56.72
12.7	5	57.35	56.92	57.18	56.35	56.59	55.50	56.65
15.2	6	57.01	57.40	57.22	56.82	56.63	55.99	56.85
20.3	8	57.87	57.36	56.54	55.90	56.57	54.82	56.51
25.4	10	56.72	57.21	56.65	55.44	53.52	54.16	55.62
30.5	12	57.35	57.56	56.64	56.02	55.79	54.55	56.32
	average	57.13	57.05	56.73	56.10	55.59	55.34	56.32

For the broadcast treatment the oil content amounted to 55.90 per cent.

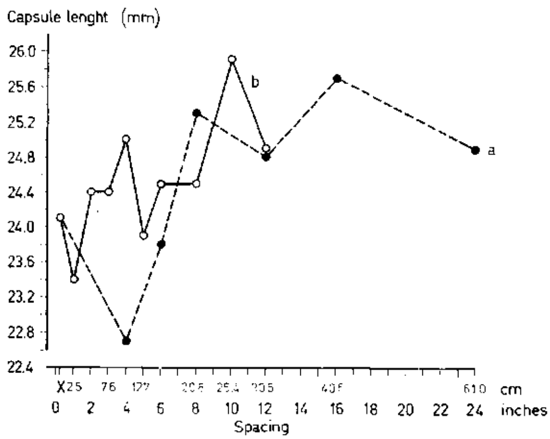


FIG. 6. Length of capsules for different inter-row (a) and intra-row (b) spacing treatments at Mokwa during 1971.

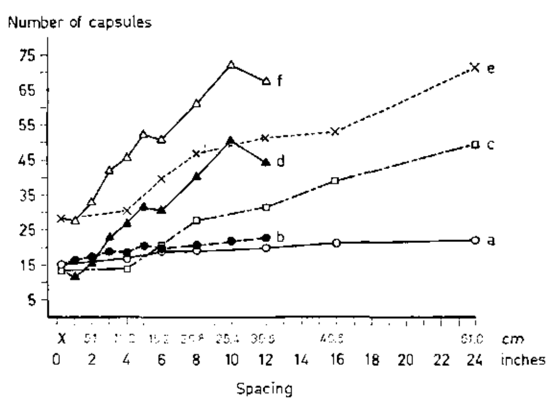


FIG. 7. Number of capsules per plant on stem (a and b), branches (c end d) and total (e and f) for different inter-row (a, c and e) and intra-row (b, d and f) spacing treatments at Mokwa during 1971.

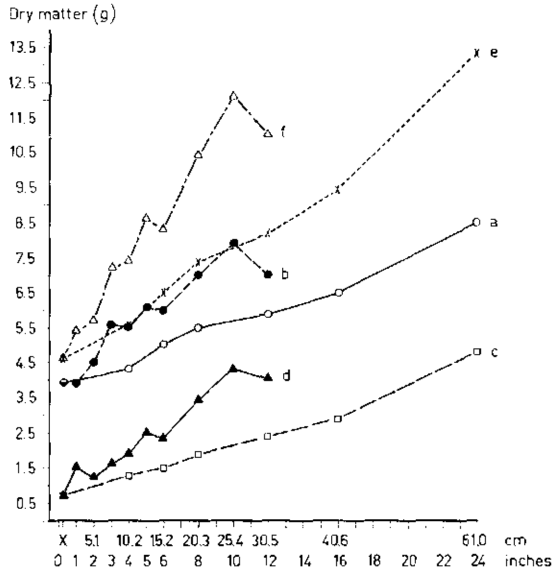


FIG. 8. Dry matter of stem (a and b) and branches (c and d) and total (e and f) in g per plant for different inter-row (a, c and e) and intra-row (b, d and f) spacing treatments at Mokwa during 1971.

4.2.2.3. Discussion and conclusions

The average yield data for inter- and intra-row spacings shown in Table 20 can be analysed like those of Table 17 (4.2.1.3.). Corresponding formulas so found read:

$(a_1')\quad Y = 607 - 4.1x_1 \qquad (t = 11.0^{**})$
$(a_2')\quad Y = 545 - 4.3x_2 \qquad (t = 13.5^{***})$
$(e_1')\quad O_{s1}^{-1} = 144 + 2.1s_1 \qquad (t = 13.8^{**})$
$(e_2')\quad O_{s2}^{-1} = 179 + 2.0s_2 \qquad (t = 11.4^{***})$

The subfix 1 and 2 denotes average inter- and intra-row spacing respectively. The average value for the yield at infinite plant density, estimated with these formulas, amounts to 601 kg per ha. However, at inter-row spacings below 20.3 cm and intra-row spacings below 10.2 cm, average yield depressions occur.

More interesting than the above regressions would be a yield-spacing relation of good descriptive value for the experimental yield data as a whole. Therefore a number of regression formulas has been tested. One of those was based on a formula proposed by DUNCAN and successfully applied by MARIJNEN (1963):

(f) $\quad \text{Log}\, y = \log K + bx$

in which y = yield per plant, x = plant density and K and b are constants. Another one was based on a formula developed by BLEASDALE and NELDER (1960) and often used by BLEASDALE (1966 and 1967):

(g) $\quad w^{-\theta} = \alpha + \beta\rho^{\phi}$

in which w is the yield per plant, ρ is the plant density and α, β, θ and ϕ are constants for any set of data.

First linear, quadratic and cubic regressions of spacing variables on yield were calculated and checked on their descriptive value (1, 2 and 3) and further investigated were regressions based on formulas from DE WIT (1960) (4, 5 and 6) MARIJNEN (1963) (7), and BLEASDALE and NELDER (1960) (8). In these Y is yield in kg per ha, x_1 is inter-row spacing in cm and x_2 is intra-row spacing in cm.

	Regression	R^2
(1)	$Y = -2.76\,x_1 - 1.78\,x_2 + 571$	0.378
(2)	$Y = 3.37\,x_1 + 13.35\,x_2 - 0.06\,x_1^2 - 0.34\,x_2^2 - 0.14\,x_1x_2 + 396$	0.565
(3)	$Y = 22.35\,x_1 + 46.30\,x_2 - 2.45\,x_1^2 - 0.48\,x_2^2 - 0.60\,x_1x_2 + 0.005\,x_1^3 + 0.04\,x_2^3 + 0.003\,x_1^2x_2 + 0.05\,x_1x_2^2 + 124$	0.638
(4)	$Y^{-1} = 0.97 \times 10^{-6}\,x_1x_2 + 4.14 \times 10^{-5}\,x_1x_2^{-1} - 0.29 \times 10^{-7}\,x_1^2 + 0.27 \times 10^{-3}$	0.592
(5)	$Y^{-1} = -2.42 \times 10^{-5}\,x_1 - 0.80 \times 10^{-4}\,x_2 + 0.18 \times 10^{-5}\,x_1^2 + 1.12 \times 10^{-6}\,x_2^2 + 0.33 \times 10^{-6}\,x_1x_2 + 2.71 \times 10^{-3}$	0.660
(6)	$Y^{-1} = -0.93 \times 10^{-4}\,x_1 - 2.04 \times 10^{-4}\,x_2 + 1.12 \times 10^{-5}\,x_1^2 + 1.34 \times 10^{-6}\,x_2^2 + 0.25 \times 10^{-5}\,x_1x_2 - 0.19 \times 10^{-7}\,x_1^3 - 0.20 \times 10^{-6}\,x_2^3 - 0.08 \times 10^{-7}\,x_1^2x_2 + 0.09 \times 10^{-7}\,x_1x_2^2 + 3.68 \times 10^{-3}$	0.702
(7)	$\text{Log}\,Yx_1x_2 = -127.39\,x_1^{-1}x_2^{-1} + 0.20\,x_1^{-1}x_2 - 71.53\,x_1^{-2} + 10.67$	0.864
(8)	$Y^{-1}x_1^{-1}x_2^{-1} = 16.71 \times 10^{-3}\,x_1^{-1}x_2^{-1} + 1.89 \times 10^{-5}x_1^{-1}x_2 - 54.71 \times 10^{-4}\,x_1^{-2} - 1.16 \times 10^{-5}$	0.978

The last equation is outstanding in its descriptive value and it is used to estimate at what spacing the maximum yield is expected to be obtained. In a general form the formula can be written as follows:

$$Y^{-1}X_1^{-1}X_2^{-1} = aX_1^{-1}X_2^{-1} + bX_2X_1^{-1} + cX_1^{-2} + d$$

from which the equation is obtained:

$$Y = (a + bX_2^2 + cX_2X_1^{-1} + dX_1X_2)^{-1}$$

Differentiating Y with respect to X_1 and X_2 and putting the differential quotient equal to 0 yields the following equations for $X_{1(\max)}$ and $X_{2(\max)}$:

$$X_{1(\max)} = c^{1/2}d^{-1/2}$$

$$X_{2(\max)} = -\frac{c}{2X_1b} - \frac{dX1}{2b}$$

From these equations the maximum yield is estimated to be obtained at an inter-row spacing of 21.6 cm and an intra-row spacing of 13.5 cm. This is an interesting result that agrees fairly well with other experimental data given in 4.2.

The number of capsules per plant located on the stem increased slightly at wider spacing; more pronounced was the increase for capsules located on the branches. The capsule length showed a trend of increase at wider spacing, but a good deal of variation occurred especially for the intra-row averages. The 1000 seeds weights failed to show a clear spacing effect and so did the average oil content figures for different intra-row spacings, but wider distances between the rows were connected with lower average oil content figures. The dry matter weights of stems and branches increased considerably with lower plant densities.

4.3. General discussion and conclusions

Recommended and practiced plant densities listed in Table 14 do not exceed 225,000 plants per ha, but other figures quoted suggest that higher densities often result in higher yields. The type of cultivar in respect of branching is of course of influence.

In view of soil and water conservation the practice of planting on ridges, and for many crops on ridges 91 cm apart, has been recommended in Nigeria since long. If this practice is adhered to and under conditions similar to those described for the experiments, a spacing of 5 cm on the ridges is to be recommended. The Igbirra method of sowing (2.2.5.) would improve greatly by adopting this method.

Where the practice of ridge planting can be abandoned, closer spacing between the rows than 91 cm results in a significant yield increase. The highest actual yield obtained in the 1971 flat planted experiment was 642 kg per ha for 20.3 cm inter-row and 10.2 cm intra-row spacing, and with Bleasdale and Nelder's spacing formula it was estimated that at an inter-row spacing of 21.6 cm and an intra-row spacing of 13.5 cm a yield maximum was to be expected. Both technically and from a weed control point of view this spacing is well acceptable and it can be approximated by drilling about 6 kg per ha in rows 22 cm apart, followed by a little thinning if and where necessary. The number of plants per ha will be about 345,000. In farmer's fields, where the Tiv method of sowing was applied (2.2.5.), high densities of 459,269–908,969 plants per ha were observed; plant growth is usually irregular, uneven distribution of the plants over the farm enhances mutual competition and weed control problems occur frequently. The Tiv method of sowing is comparable with the broadcasting treatment in the 1971 flat planted experiment, where the yield was 337 kg per ha or 52 per cent of the highest yield obtained. It is concluded that better results can be obtained if, instead of the Tiv method of sowing, the – more laborious – method of row planting is adopted.

5. SOWING DATE AND CROP GROWTH

Most annual crops of some importance in Nigeria, including groundnuts, sorghum, maize, cowpea, soya bean, castor and sunflower, have been subjected to sowing date experiments (Annual Reports of Institute for Agricultural Research, Samaru and of Federal Department of Agricultural Research, Ibadan). General experience is that early sowing favours crop growth and delay of sowing causes yield reduction. This is the farmers' experience too. Unfortunately early sowing often results in harvesting during the wettest months of the rainy season, which, especially for seed crops, causes major drying problems.

Sowing date effects are of importance for the cultivation of sesame in many countries (WEISS, 1971) and a thorough understanding of the causes are of interest for production improvement. In view of the possible factors playing a role in relation to sowing date differences, the following is to be considered.

(a) *General ecology*

According to PURSEGLOVE (1968) sesame is cultivated in tropical and subtropical regions, in plains and up to an elevation of 1,200 m, and mainly in the dry and hot tropics in areas with an annual rainfall of 500–1,125 mm. It can tolerate periods of drought, but does not tolerate waterlogging. It prefers light, well drained soils that will retain adequate moisture, and it does reasonably well on poor soils.

(b) *Daylength*

Interesting observations were made by RHIND (1935) in Burmese sesames. Since long two distinct types had been recognised: Early ones, sown from April to the end of June and late ones, sown from September to October. He found that late types would not flower (a) when sown early and (b) when sown late, if additional light was given after sunset for two or more hours. The early types however produced flowers when sown late, showing delay of flowering when additional light was supplied after sunset. From the latter the best yields were obtained under long-day conditions. Similar types have been recognised at Mokwa and correspondingly the cultivar Yandev 55 would have to be classified as early in type.

GHOSH (1955) studied the effect of the photoperiod on various plant characters of sesame. The different photoperiods however were applied during periods varying from four to six weeks only, beginning ten days after sowing. Shortening the photoperiod to 7 and 9 hours per day caused earlier flowering, a decrease of vegetative vigour and increased capsule production.

MATSUOKA (1960) found for sesame cultivars from different countries correlations between daylength variation due to date of sowing and several plant characters. In general plant length, days to flowering and number of leaf pairs were positively correlated with daylength. In studies to investigate the light sensitivity of sesame, he noted that the period from sowing to flowering, the height to the first capsule and the number of branches per plant increased, when the daylength increased from 8 to about 14 and to 24 hours, but the number of capsules decreased for his African cultivars (MATSUOKA, 1959 and 1960).

SMILDE (1960), studying the influence of light and temperature on the vegetative and reproductive development of sesame, found that seedlings were not sensitive to the length of the photoperiod for three to eight days after emergence, depending on the cultivar. Under favourable photoperiodic conditions even the small area of the cotyledons was sufficient for floral induction. The response was investigated at photoperiods ranging from 5–24 hours and consisting of a basic illumination of daylight supplemented with different periods of weak fluorescent light. The number of days to floral initiation and flowering was minimal at photoperiods ranging from 10–13 hours, consisting of at least 8 hours daylight; the delay at photoperiods of 5–10 hours was mainly caused by restricted photosynthesis, resulting in a decline in growth. Although being accelerated by a short-day break, in most cultivars floral initiation and flowering occurred eventually under long-day conditions, even at 20–24 hours photoperiods. At photoperiods of the same length no difference was found between basic illumination periods of 10 and 13 hours, but in most cultivars reduction of the daylight period to 8 hours or less caused a delay in floral initiation and flowering, especially at long photoperiods. Within the group of cultivars originating from low latitudes various degrees of photoperiodic sensitivity occurred, but all cultivars from higher latitudes were rather insensitive. Stem length, dry weight of the stem basis, number of leaves and leaf size, vegetative vigour, number of flowers and capsules and seed production per plant increased as the photoperiod, irrespective of its composition, was extended from 6–20 hours. It was suggested that supplemental light influences the production of dry matter owing to its effect on the leaf area and the time of flowering. Vegetative development and seed production proved to be closely interconnected, but the connection was more or less confused by a competition between the formation of flowers and the development of capsules. WEISS (1971) reviews the literature about the influence of daylength on sesame. He states that the consequences of varying photoperiods on the growth and flowering of sesame have been widely studied, since this is one of the major factors influencing yield. However the issue is a little confused by reviewing at the same place the influence of daylength, light intensity and sowing date. From work he quotes it may be concluded that a longer daylength not necessarily causes a yield increase.

Summarising it is concluded that flowering is delayed and vegetative growth increases with longer photoperiods, but the capsule and seed production may be positively or negatively affected depending on the cultivar.

(c) *Light intensity*

From a study of data on intercropping sesame with taller crops it would appear according to WEISS (1971) that the yield of sesame is substantially reduced irrespective of the root competition. IL'INA (1959) found that temporary shading at early growth stages commencing with differentiation of the growing point till formation of the pollen tetrads has a neutral or beneficial effect on plant productivity, but permanent shading or temporary shading during the formation of the flowers, capsules and seeds adversely affected plant growth. In India it was noted that cloudy or dull periods at flowering reduced yields. MOURSE and ABD EL GAMAD (1963) found that shading to 50 per cent light interception reduced the yield and the dry matter production. MAZZANI (1964) is of the opinion that sesame needs much light for its growth.

(d) *Temperature*

In studies to investigate the temperature sensitivity of sesame MATSUOKA (1959 and 1960) noted that for his African cultivars the number of days from sowing to flowering, the height to the first capsule and the number of branches per plant was more for plants grown in a vinyl house under higher temperature than under normal conditions, but the number of capsules per plant was less.

SMILDE (1960) found in a greenhouse in the Netherlands that the optimum germination temperature ranged from 32 to 35 °C and that stem growth and production of leaves increased as the average temperature was raised from 24 to 33 °C. A constant temperature of 24–27 °C was optimal for early flower initiation, whereas both high (33 °C) and low (15 °C) night temperatures caused a delay. The retarding effect of high and low night temperatures was more or less counteracted by low respectively high day temperatures. Moreover, low night temperatures offset the retarding effect of long photoperiods. WEISS (1971) refers to work of KOSTRINSKY (1955) in which the total number of heat units required by sesame during the three to four months growth period is given as 2,700 °C. A seed bed temperature of 24 °C is considered adequate in the field and temperatures of 25–27 °C encourage initial growth and flower formation. A temperature of less than 18 °C after emergence will severely retard growth.

(e) *Rainfall*

Literature on the influence of rainfall on the growth of sesame seems somewhat ambiguous. There is agreement that waterlogging is harmfull (U.S.D.A., 1958; PARTHASARATHY et al., 1949). The impression is further gained on one side that sesame prefers to grow in a relatively dry, light, well drained soil.

KASHI RAM and MADHAVA ROW (1931) conducted pot experiments in India with sesame growing in the open in soil that varied in clay: sand proportion from all clay to ¼ clay: ¾ sand. They found that invariably the lighter soils gave better growth of roots and earial parts and higher yields than the soils with a larger proportion of clay. JOHN et al. (1940) described a wild sesame from Malabar, mainly because of its unique character that it could withstand heavy rainfall without adverse effects, which none of the cultivated types could. KOSTRINSKY (1959) noticed in his experiments in Israel that sesame is relatively drought resistant and suffers from excessive moisture. ITO and MATSUOKA (1960) who worked with cultivars from different countries, calculated the ratio of the yield obtained in the wet year 1957 and in the dry year 1956 and discovered that cultivars from Africa and Indonesia and part of the late cultivars of India showed low values for the said ratio. However, they suggested that this was attributable to the high temperature and plenty sunlight in the drought year, which favour the growth of late cultivars, and to the increased damage by pests and diseases during the wet year. IRVINE (1969) indicated that sesame thrives best in the drier parts of West Africa, away from the closed forest. HACK (1970) carried out experiments in the Central Sudan on plant emergence at varied air-filled pore space of the soil and observed that cotton, groundnuts and kenaf emerged well when 20 per cent of the pore space was filled with air while sesame did so only at 40 per cent.

Although one gets the impression that sesame would grow optimally in drier areas, literature on the other side suggests that sesame can tolerate well more precipitation as long as no waterlogging occurs for a period longer than a couple of hours (U.S.D.A., 1958). In the Sudan (1954) it was experienced that 380 mm is sufficient for sesame in the sandy dunes west of the White Nile, but in parts of the Fung and Gedaref districts very good crops are grown in permeable clay on a rainfall of about 635 mm; provided the soils are well drained, sesame will thrive under heavy rainfall. ABDOU et al., (1970) found in the U.A.R. that during a growth period of about 80 days sesame showed an increase in yield at an increase of irrigation water up to the highest dose of 1,446 cubic meter per ha. MAZZANI and ALLIEVI (1969) concluded from results of rotation experiments in Venezuela that sesame yields were clearly related to hydrological balances. Deficiencies in the balance during the growth cycle badly affected seed production, whereas yields under excessive rains reached approximately the same level as when the balance was equilibrate. GARCIA et al. (1971) found in Venezuela a positive correlation between yield and rainfall in the range of 200–600 mm. Where the precipitation exceeded 700–800 mm, yields were reduced. From West to East Africa, according to WEISS (1971) sesame is grown generally in areas too dry for groundnuts with a rainfall range of 400–750 mm. In the Sudan it is grown in the 300–600 mm rainfall areas and with 500 mm excellent crops are produced. However, a rainfall up to 850 mm will be tolerated if soils are well drained. He considers the following distribution optimal: Germination to first bud formation: 34 per cent; bud formation to main flowering; 45 per cent; main flowering to maturity: not more than 20 per cent, falling as seeds are filling and ceasing as first pods begin to ripen.

In a summary it is concluded that rainfall may be limiting for sesame production if it is insufficient, or if the distribution is not optimal, or if it is excessive, and excessive rainfall occurs only when a condition of water logging prevails or is approximated.

Side effects of heavy rainfall, thought of to be a possible factor of importance for a planting date effect, are (1) the formation of a surface cap (see 3.1.2.), (2) leaching of nutrients, nitrogen in particular and (3) increased disease incidence.

The following paragraphs give first a summary of the experimental evidence of a planting date effect on yield, observed in Provincial Experimental Stations and at Mokwa (5.1. and 5.2.). The effect of planting date on various plant characters is more closely looked at in 5.3., while in 5.4. experiments are described in which the influence of the planting date on the dry matter production during the growing season is investigated; different *N* treatments were included to trace their interaction with planting date and to find possible evidence of *N* leaching and its effect on plant growth.

Delay of sowing seems to reduce the yield chiefly by suppressing the branching. It was tried to counteract this effect by top-cutting plants to stimulate the branching; this is discussed in 5.5.

The influence of the formation of a surface cap, of leaching and of shade on plant growth and yield were investigated in experiments described in 5.6–5.8. A general evaluation and discussion of the results follows in 5.9.

5.1. Effect of sowing date observations 1

86 Sowing date experiments have been carried out at Provincial Experimental Stations and at Mokwa during the years 1956–1962 (Steele and Stonebridge, 1956–1962, unpublished results). These may be classified as early sowing date experiments, having the first sowing date as early as possible after the onset of the rains, and late sowing date experiments with the first sowing date in August or later.

The experiments consisted of two blocks of plots, each block having the full series of sowing dates tested. Sowing dates were allotted to the plots systematically and sowing commenced at opposite ends of the blocks and progressed in opposite directions. Most experiments had a plot size of two ridges, 91 cm apart and 10.9 m long. Sowing was on the ridges at a spacing of 15 cm and thinning was most times to two plants per stand. The cultivar used was Yandev 55 and sowing was at regular intervals and in most cases every two days. The experimental sites were distributed over five of the six Northern States at twenty-eight different places. There were 44 early experiments and 42 late experiments during the six years' period of which 16 and 29 respectively failed to produce more than 100 kg per ha for any one sowing date. The low yields of these experiments were caused by a range of different factors as poor rainfall distribution, severe insect or disease attack, damage by bush fowl etc.

The results of the experiments are as follows summarized in Figures 9 and 10. The yields of the sowing date treatments have been converted for each individual experiment to a percentage of the yield of the best producing sowing date of that experiment, and averages over all experiments have been calculated in two ways:

(a) For the first and subsequent weeks of sowing, disregarding the actual date of sowing and regarding only the order of sowing (Fig. 9). The effect so observed may be called a sowing date delay effect.

(b) For the actual weeks of sowing during the various months (Fig. 10).

Fig. 9 shows that for an early crop delay of sowing causes rapidly substantial seed losses, and immediate sowing with the onset of the rains is to be recom-

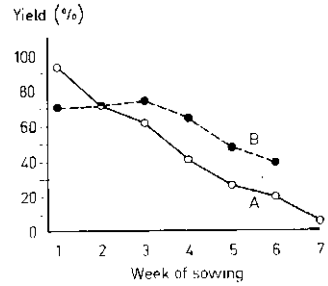


FIG. 9. Average yield in per cent for Effect of sowing date observations 1, regarding the weekly order of sowing only.
A = early sowing. B = late sowing.

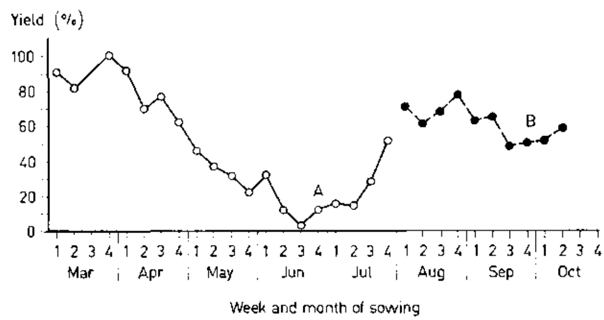


FIG. 10. Average yield in per cent for Effect of sowing date observations 1 for different weeks of sowing.
A = early sowing. B = late sowing.

mended. For the late crop some delay of sowing as from early August caused a little yield increase. Fig. 10 suggests that March and April are the months to sow sesame in areas where an early crop is grown, and for late sesame sowing dates during August gave on an average the highest yields.

5.2. DATE OF SOWING X FERTILIZER EXPERIMENT

The Date of sowing × fertilizer experiment (STONEBRIDGE and VAN RHEENEN, 1963, unpublished results) was carried out at Mokwa during 1963. Sowing dates were 23rd March, 27th May and 2nd September and fertilizer applications were at levels of nil and 125 kg per ha both for sulphate of ammonia and superphosphate. The design of the experiment was a Randomized Block, the cultivar sown was 57/244/11B, the plot size was five ridges 91 cm apart and 10.9 m long, the spacing was 15 cm on the ridges and thinning was to one plant per stand.

The results showed no beneficial significant fertilizer effect and no significant interaction of sowing date × fertilizer, but the sowing date effect was significant and yields expressed as percentage of the highest yield for the first, second and third sowing date were 100, 40 and 68 respectively. The average yield was 261 kg per ha.

5.3. EFFECT OF SOWING DATE OBSERVATIONS 2

For a better understanding of the effect of sowing date, observations were made on plants of different sowing dates growing in pots and on ridges in a nursery during the years 1964 and 1965.

5.3.1. *Materials and methods*

Pots used were of black polyethylene, 25.4 cm high and 11.4 cm in diameter with a hole in the bottom and holes in the side. The pots were filled with a mixture of equal parts of sand and compost. The compost was passed through a sieve with 1.3 × 1.3 cm holes. Fertilizers were applied at a rate of 6.0 g sulphate of ammonia, 7.0 g superphosphate and 2.1 g muriate of potash per pot and the $N{:}P{:}K$ ratio so obtained was 1:1:1. Root growth was not entirely restricted to the pot for the treatments in the open. Ridges made were approximately 25 cm high, 30 cm wide at the top and 61 cm wide at the basis; no fertilizers were applied. A screened house with wire gauze, 4.5 m long × 2.7 m wide × 2.2 m high, was used to take one of the treatments under observation. The reduction of the light intensity inside the screened house was measured by means of two tube solarimeters. It amounted to approximately 58 per cent.

For one of the treatments the daylength was reduced with the help of movable cages and double sheets of black polyethylene of 0.01 cm thickness, which were placed in position to cover the plants in the evening before sunset and which were removed about half an hour after sunset. For another treatment the daylength was extended by placing a light box, fitted with eight fluorescent tubes of 40 watt each, over the plants at about 30 cm distance shortly before sunset and by removing the light box again after the required daylength extension had been achieved. In both cases the photoperiodic effect of twilight was neglected. Part of the treatments were sprayed with the insecticides Gammalin and Didimac (B.H.C. and D.D.T.) and part of the treatments remained unsprayed.

Seeds were pregerminated in petridishes to increase the uniformity of the plants within the treatments. Each treatment consisted of fifteen plants with one plant per stand and 15 cm spacing between the plants. Plants in some of the treatments received water as required throughout the season, but others received water during the first two weeks after sowing only. The different treatment combinations used are tabulated below and +, − and 0 mean that the first, the second and the third treatment respectively was applied.

Sowing in 1964 started on 9th April, continued till 23rd September and was weekly for A, B and C, fortnightly for D and E or sometimes ones in four weeks, and weekly again for F but only as from 27th August.

Treatments			Treatment combinations	
(+)	(−)	(0)	1964 A B C D E F	1965 A′G H
Pots	Ridges		+ − − + + +	+ + +
Open	Screened house		+ + + − + +	+ + +
Insecticide	No insecticide		+ + + + − +	+ + +
Watering	No watering		+ + − + + −	+ + +
Daylength extended	Daylength reduced	Daylength normal	0 0 0 0 0 0	0 − +

Sowing dates for A′, G and H were 17th May and 31st August and for G and H the daylength was so much reduced and extended respectively that it was as if sowing had been on 31st August and 17th May respectively regarding daylength only.

Observations were made on the following characters:

(a) Days from sowing to flowering and from sowing to harvesting.

(b) Position of the lowest flower on the stem recorded as number of nodes between the cotyledons and the first flower.

(c) Incision of the leaf margin scored according to its relative length when compared with its nearest lateral vein as follows:

Leaf incision		Score	
Classification	Relative length	1965	1964
Entire	0	0	14
Serrate	0–1/8	5	14
Lobed	1/8–1/4	15	14
Lobed	1/4	20	14
Lobed	1/4–2/4	30	14
Incision half-way	2/4	40	55
Parted	2/4–3/4	50	55
Parted	3/4	60	55
Parted	3/4–4/4	70	55
Compound	4/4	80	80

(d) Length of the stem and of the branches at harvest, the latter by grouping the branches in classes of 5.1–12.7, 12.7–25.4, 25.4–50.8 cm (2–5, 5–10, 10–20 inches) etc. and by multiplying the number per class with the class mean.

(e) Number of capsules on stem and branches and seed yield.

Characters under (a), (b) and (c) are expected to show influences of daylength differences due to different dates of sowing. Characters under (d) provide a measure of the growth vigour of the plants and those under (e) represent their yielding capacity.

5.3.2. *Results*

The number of days from sowing to flowering and harvesting observed in 1964 are shown in Fig. 11.

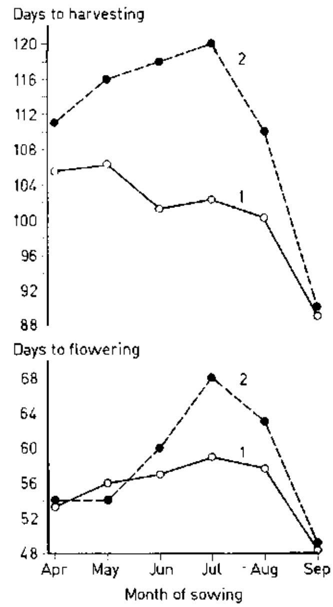


FIG. 11. Effect of sowing date observations 2, 1964. Number of days from sowing to flowering and from sowing to harvesting.
1. Average for treatments A, B and C.
2. For treatment D.

There was the tendency of delay of flowering with delay of sowing till July, after which flowering was earlier again; the number of days from flowering to harvesting varied little for the different sowing dates except for those at the end of August and during September when it was short with a minimum of eighty-nine days. Treatment D, sown in the screened house, flowered on an average about nine and five days later than A, B, and C during July and August sowing respectively, and except during September sowing it needed considerably more time to mature. Treatment F with no watering from two weeks after sowing showed very little difference in days to flowering and harvesting from treatment A with continued watering. So did treatments B and C.

During 1965 flowering of A′ and G was 48 and 42 days after sowing in May respectively and flowering of A′ and H was 49 and 55 days after sowing in August respectively. Corresponding figures for harvesting were 96 and 87 for May sowing and 98 and 119 for August sowing. The movable cage, which reduced the daylength, had caused 6 days and 9 days advancement in flowering and harvesting respectively and the light box which extended the daylength, had caused 6 and 21 days delay in flowering and harvesting respectively.

The position of the lowest flower on the stem for the various treatments in 1964 is given in Table 23.

TABLE 23. Effect of sowing date observations 2, 1964. Postition of the lowest flower on the stem given as number of nodes between the cotyledons and the first flower.

Month of sowing	Treatment						
	A	B	C	D	E	F	Average A–E
April	10.4	10.4	10.5	9.4	10.1	–	10.2
May	11.2	11.1	11.3	9.6	10.8	–	10.8
June	9.6	10.0	10.5	9.1	9.7	–	9.8
July	9.3	8.2	8.8	9.3	8.8	–	8.9
August	8.9	8.8	8.5	9.3	8.5	9.7	8.8
September	9.3	8.8	8.8	7.8	8.7	10.0	8.7

The lowest flower on the stem raised in position from April to May, dropped during June and July and raised a little again for September sowing for most treatments, but not so for the one in the screened house.

During 1965 the position of the lowest flower for A′ and G with planting in May was 10.9 and 8.5 respectively, and for A′ and H, August planting, 9.7 and 11.3 respectively, showing differences of 2.4 and 1.6 due to the cage and the light box, which reduced respectively extended the daylength.

Leaf incision scores are presented in Table 24.

TABLE 24. Effect of sowing date observations 2, 1964. Average leaf incision scores for leaves on node 8, cotyledons not included to determine the position.

Sowing dates	Treatment				
	A	B	C	D	Average
9/4– 7/5	80.0	69.6	75.0	39.5	66.0
14/5–11/6	75.5	73.4	74.2	22.7	61.5
18/6–16/7	14.0	54.3	70.7	30.1	42.3
23/7–20/8	51.2	49.4	52.5	14.0	41.8
27/8–23/9	58.2	63.5	63.5	23.2	52.1

The leaf incision score dropped during June, July and August and increased again during September sowing. The plants in the screened house differed in respect of leaf incisions very clearly from plants of other treatments. Table 25 shows leaf incision scores for 1965.

The treatment to reduce the daylength from A′ to G decreased the score and the treatment to extend the daylength from A′ to H increased the score.

Plant length and length of branches at harvest observed in 1964 are shown in Fig. 12.

TABLF 25. Effect of sowine date observations 2, 1965. Average leaf incision scores for leaves on modes 1-5 and 6-10, cotxledons not included to determine the position.

Sowing date	Treatment					
	A′ Node		G Node		H Node	
	1-5	6-10	1-5	6-10	1-5	6-10
17/5	7.8	44.2	5.6	24.2	–	–
31/8	4.8	10.6	–	–	5.7	37.8

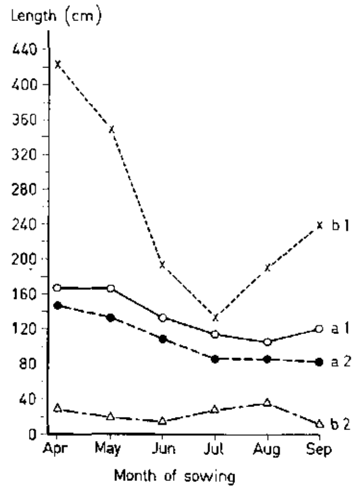


FIG. 12. Effect of sowing date observations 2, 1964. Length of stem (a) and branches (b).
1. Average for treatments A, B and C.
2. For treatment D.

The stem length decreased after May and increased again during September sowing. The length of the branches decreased after April and increased after July sowing. The screened house, for treatment D, reduced the stem length and depressed strikingly the branching. Stem length of treatment A for August and September sowing was 119 and 133 respectively, and for treatment F with no continued watering 142 and 139 cm respectively, and the corresponding branch length amounted to 203 and 269 cm for A and 345 and 531 cm for F respectively. During 1965 the stem length for A′ and G, sown in May, amounted to 182 and 169 cm respectively, and for A′ and H, sown in August, 158 and 189 cm respectively. Corresponding branch lengths were 521 and 409 cm for A′ and G and 493 and 503 cm for A′ and H respectively.

Numbers of capsules per stem and per plant at harvest, observed in 1964, are given in Fig. 13. Seed yields in gram per plant are shown in Table 26.

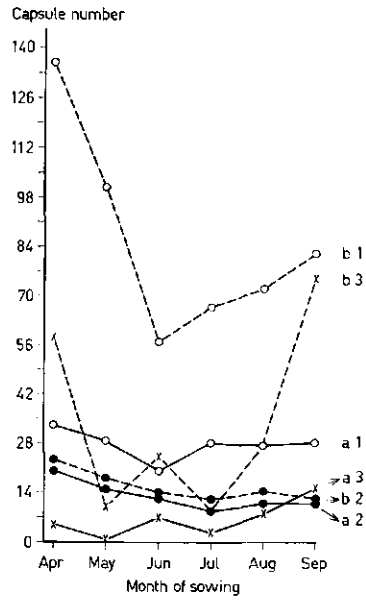


FIG. 13. Effect of sowing date observations 2, 1964. Number of capsules per stem (a) and per plant (b).
1. Average for treatments A, B and C.
2. For treatment D.
3. For treatment E.

TABLE 26. Effect of sowing date observations 2, 1964. Seed yield in gram per plant.

Month of sowing	Treatment						
	A	B	C	D	E	F	Average A–E
April	22	15	15	3	7	–	12
May	14	12	14	3	1	–	9
June	4	4	5	1	2	–	3
July	5	6	11	1	1	–	5
August	9	8	7	1	3	14	6
September	12	7	8	2	12	16	8

In general there was a decline in number of capsules per plant and seed yield from April till June–July, followed by an increase in August and September. Differences were caused mainly by the contributions from the branches. Treatment D, grown in the screened house, yielded poorly and the unsprayed treatment E gave also poor yields because of insect attack. Treatment F with no more watering two weeks after sowing did very well when compared with treatment A.

During 1965 the number of capsules per plant for A′ and G, sown in May, amounted to 175 and 152 respectively, and for A′ and H, sown in August, 160 and 185 respectively. Corresponding seed yields were 15 and 18. grams and 23 and 27 grams respectively.

5.3.3. *Discussion and conclusions*

In accordance with previous results, yields decreased with delay of sowing and improved again at the end of the season. Plant vigour, expressed in stem length and branching, showed a similar trend. So did the relative extent of leaf incision and the position of the lowest flower on the stem, although the increase of the latter at the end of the season was very small or absent. The number of days to flowering increased till July and decreased rapidly in September sowing.

In addition two observations seem to provide information relevant to the observed sowing date effect:

(a) The plants in the screened house showed very poor branching and produced low yields, most likely due to the 58 per cent light reduction.

(b) The treatment to reduce the daylength caused earlier flowering, earlier harvesting, lower flower position, less leaf incision, a little less vigour and a somewhat smaller capsule yield; the seed yield was not reduced. The treatment to extend the daylength had the opposite effect but gave a seed yield increase.

5.4. Sowing date and crop growth experiments 1, 2 and 3

During 1967, 1968 and 1971 sowing date experiments were carried out in which dry matter production and leaf area were estimated by taking plant samples at regular time intervals during the growth period. In the first experiment two different cultivars were used, the well branched cultivar Yandev 55 and the practically unbranched cultivar Dulce, and in the two other experiments only Yandev 55 was sown. In 1968 and 1971 the plots of different sowing dates were spacially isolated to avoid possible insect and disease effects from previously sown treatments. Two different *N* treatments were superimposed on the planting date treatments during 1967 and 1968, while two more *N* treatments were added in 1971 with a view to detect a suspected effect of *N*-leaching due to heavy rains.

5.4.1. *Materials and methods*

Main information on materials used and methods applied for the three experiments is tabulated below.

Crops were sprayed frequently with insecticides for leaf-curl and leaf roler control and during 1968 and 1971 also with a fungicide for the control of leaf-spot.

Before drying in ventilated heat ovens plants were divided in root, stem + branches + petioles, leaf laminas, and flower buds + flowers + capsules. The cork bore method was used for leaf area determinations; the diameter of the bore was 9 mm.

Chemical analyses of leaf and plant samples were carried out at Shika Agri-

Materials and methods	Experiment 1 ('67)	Experiment 2 ('68)	Experiment 3 ('71)
Layout	4×2^2 Factorial	Split-plot	Split-plot
Replications	3	4	5
Treatments:			
Sowing dates	20–4, 31–5, 10–8 and 31–8	15–4, 15–7 and 2–9	21–5, 15–6, 9–7 3–8 and 27–8
N-application*	*N*1 and *N*2(2)	*N*1 and *N*2(2)	*N*1, *N*2(2), *N*2(1) and *N*2(4)
Cultivars	Yandev 55 and Dulce	Yandev 55	Yandev 55
Manure (other than *N*)**	*P*	*P*	$P + K$
Plot size	10 ridges, 91 cm apart and 7.3 m long	5 ridges, 91 cm apart and 5.5 m long	10 ridges, 91 cm apart and 9.1 m long
Spacing	15 cm on the ridges	15 cm on the ridges	15 cm on the ridges
Sampling frequency	Fortnightly	Ones in 3 weeks	Weekly
Number of sample plants per plot	10	5	10
Oven temperature (°C)	105	85	105
N, *P* and *K* analysis	Leaves	Leaves	Whole plants

* *N*1 = 250 kg sulphate of ammonia per ha at sowing.
*N*2(2) = 250 kg sulphate of ammonia per ha at sowing + 250 kg sulphate of ammonia per ha at commencement of flowering (1967) or appearance of flower buds (1968 and 1971).
*N*2(1) = 500 kg sulphate of ammonia per ha at sowing.
*N*2(4) = 125 kg sulphate of ammonia per ha at sowing and 125 kg sulphate of ammonia per ha every three weeks after sowing, three times; total application 500 kg per ha.
** *P* = 125 kg superphosphate per ha at sowing.
K = 125 kg muriate of potash per ha at sowing.

cultural Research Station and Institute for Agricultural Research at Samaru. Apart from *N*, *P* and *K* also *Zn*, *Ca* and *Mg* determinations were carried out in 1971. In the same year soil samples were taken to a depth of 90 cm with 15 cm intervals for weeks 1–7, 10 and 13 after sowing in each plot of treatment *N*2(1). The samples were bulked per treatment, dried at 105 °C and analysed at Samaru for *N* content.

5.4.2. *Results*

The results are presented in the following order. The growth analysis formulae are those FISHER (1921), GREGORY (1926) and RADFORD (1967) proposed.
(a) Total dry matter production.
(b) Crop growth rate (C.G.R.): $\frac{W2-W1}{t2-t1} \times \frac{10}{S}$ in kg dry matter per ha per day

$W2$ = dry matter production in g at time t2
$W1$ = dry matter production in g at time t1
S = sample area in m^2.

(c) Leaf area index (L.A.I.): $\frac{A}{S}$ as leaf area per ground area planted

A = leaf area
S = sample area.

(d) Net assimilation rate (N.A.R.)

$$\frac{W2-W1}{t2-t1} \times \frac{\ln A2 - \ln A1}{A2-A1} \text{ in g per dm}^2 \text{ per week}$$

$W2$ and $W1$ as for (b)
$A2$ = leaf area in dm^2 at time $t2$
$A1$ = leaf area in dm^2 at time $t1$.

(e) Results of chemical analyses of plant material and soil samples.

(f) Production figures and miscellaneous observations.

Total dry matter production of treatment $N1$ and dry matter production ratios of $N2(2)$: $N1$ for three different sowing dates in each experiment are presented in Fig. 14–a1, a2, b and c.

The total dry matter production curves have in common an increase steeper for the first than for the later sowing dates. The shape of the curves of the last sowing dates when compared with that of the middle sowing dates reminds of the previously observed improvement for sowing later during the season.

The dry matter production ratios for the $N2(2)$ and $N1$ treatments in *a*.1, *a*.2 and *b* seem to suggest an interaction of the application of the second N dosis with the date of sowing, which might be explained by an N leaching effect of different magnitude during different times of the year.

TABLE 27. Total dry matter production in gram per 10 plants for planting dates 21–5, 9–7 and 27–8, 1971 and samples of 5–15 weeks after sowing. S.E.D.1 and 2: at same and different sowing dates respectively.

Week	21–5 Treatment				9–7 Treatment				27–8 Treatment				S.E.D.1	S.E.D.2
	$N1$	$N2$ (2)	$N2$ (1)	$N2$ (4)	$N1$	$N2$ (2)	$N2$ (1)	$N2$ (4)	$N1$	$N2$ (2)	$N2$ (1)	$N2$ (4)		
5	11	12	13	10	5	4	7	4	11	10	10	8	1.5	2.0
6	32	32	39	32	12	12	17	11	60	54	55	50	3.2	4.8
7	81	82	97	73	34	30	44	29	102	103	93	102	7.3	10.5
8	158	168	215	161	80	91	126	78	196	205	196	187	12.7	16.2
9	281	329	360	291	145	183	211	185	267	275	289	251	22.1	28.3
10	419	418	578	440	215	236	277	261	313	303	292	273	38.1	41.2
11	700	729	774	678	271	276	349	330	350	348	337	350	55.0	54.9
12	600	876	960	895	324	335	384	412	341	358	394	340	59.3	74.7
13	732	981	1118	1014	329	295	344	365	307	313	364	345	65.2	74.0
14	605	939	889	800	326	253	355	321	296	351	325	289	63.6	76.3

Such an effect would manifest itself if the same total amount of *N* was applied at different time intervals during the growth season, as was done during 1971. Table 27 shows the total dry matter figures in detail for the experiment of that year.

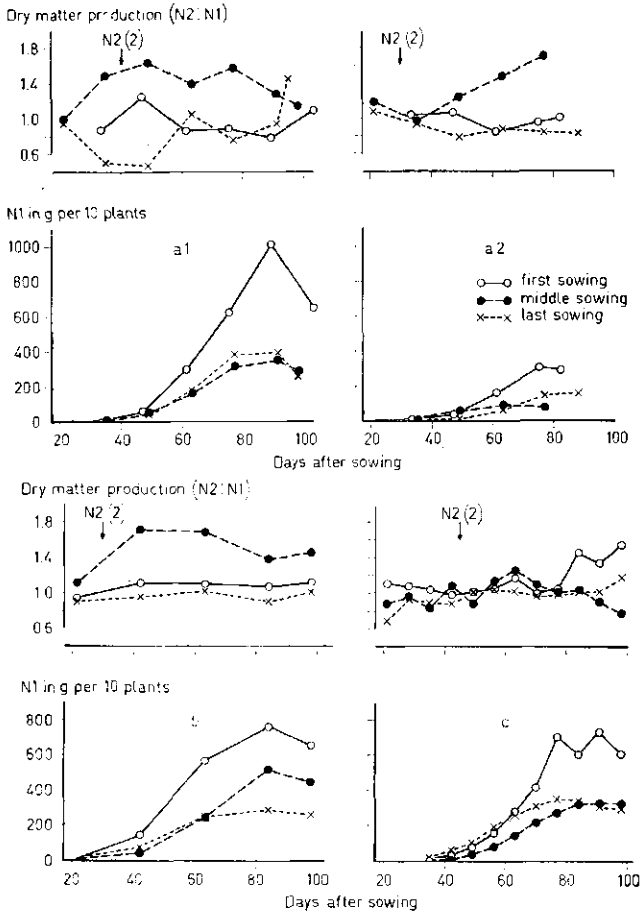


Fig. 14. Total dry matter production in g per 10 plants for treatment *N*1.
a.1: Cultivar Yandev 55, sowing dates 20–4, 31–5 and 31–8, 1967.
a.2: Cultivar Dulce, sowing dates 20–4, 31–5 and 31–8, 1967.
b: Cultivar Yandev 55, sowing dates 15–4, 15–7 and 2–9, 1968.
c: Cultivar Yandev 55, sowing dates 21–5, 9–7 and 27–8, 1971.
And corresponding dry matter production ratios of treatments *N*2(2):*N*1.
↓ *N*2(2): Application of second *N* dosis.

The small differences between treatments *N*2(2), *N*2(1) and *N*2(4) do not support the hypothesis that leaching of *N* is an important factor of the planting date effect.

Crop growth rates of treatment $N1$ are given in Fig. 15–a1, a2, b and c. Growth rate ratios of $N2(2)$: $N1$ for the three different sowing dates in each experiment at the times of sampling were:

1967: Sowing date 20–4, cultivar Yandev 55: 0.9, 1.5, 0.8, 0.9 and 0.6
1967: Sowing date 31–5, cultivar Yandev 55: 1.0, 1.5, 1.7, 1.3 and 1.8
1967: Sowing date 31–8, cultivar Yandev 55: 0.9, 0.5, 0.5, 1.2, 0.5 and 0.7
1967: Sowing date 20–4, cultivar Dulce: 1.0, 1.1, 0.8, 1.1
1967: Sowing date 31–5, cultivar Dulce: 1.2, 1.0, 1.3, 1.9
1967: Sowing date 31–8, cultivar Dulce: 1.1, 0.9, 0.7, 0.9 and 0.8
1968: Sowing date 15–4, cultivar Yandev 55: 0.9, 1.1, 1.1 and 1.0
1968: Sowing date 15–7, cultivar Yandev 55: 1.1, 1.1, 1.8 and 0.9
1968: Sowing date 2–9, cultivar Yandev 55: 0.9, 1.0, 1.1 and 0.6
1971: Sowing date 21–5, cultivar Yandev 55: 1.1, 1.2, 1.1, 1.0, 0.9, 1.0, 1.1, 1.3, 0.7, 1.1
1971: Sowing date 9–7, cultivar Yandev 55: 1.0, 0.8, 1.0, 0.8, 1.3, 0.8, 1.3, 1.4, 0.8, 0.7
1971: Sowing date 27–8, cultivar Yandev 55: 0.7, 0.7, 1.0, 0.9, 0.9, 1.2, 1.1, 1.0, 0.6, 1.2

The high crop growth rate values for the first planting dates and the differences between the middle and the last sowing date are striking. During part of the growing period the growth rate of the last sowing exceeds that of the middle sowing. The growth rate ratios for the $N2(2)$ and $N1$ treatments during 1967 and to a lesser extent during 1968 suggest the possibility of an N leaching effect. Table 28 with crop growth rates for 1971 fails to show such an effect.

TABLE 28. Crop growth rates in kg per ha per day for planting dates 21–5, 9–7 and 27–8, 1971 and samples of 4–10 weeks after planting. S.E.D.1 and 2: at same and different sowing dates respectively.

Week	Sowing date 21–5 Treatment				Sowing date 9–7 Treatment				Sowing date 27–8 Treatment				S.E.D.1	S.E.D.2
	$N1$	$N2$ (2)	$N2$ (1)	$N2$ (4)	$N1$	$N2$ (2)	$N2$ (1)	$N2$ (4)	$N1$	$N2$ (2)	$N2$ (1)	$N2$ (4)		
4	9	9	10	7	3	2	4	2	10	9	8	6	1.5	1.8
5	21	20	27	22	7	9	10	7	50	45	46	43	3.4	4.2
6	50	52	59	43	24	18	28	19	43	50	39	53	7.8	8.9
7	79	88	121	90	46	62	83	50	97	105	106	88	12.6	13.5
8	126	165	149	133	67	95	87	110	72	72	96	65	24.4	24.3
9	141	91	223	152	72	55	68	78	47	28	3	23	39.2	40.3
10	289	319	200	245	57	41	74	71	38	46	46	79	60.8	57.0

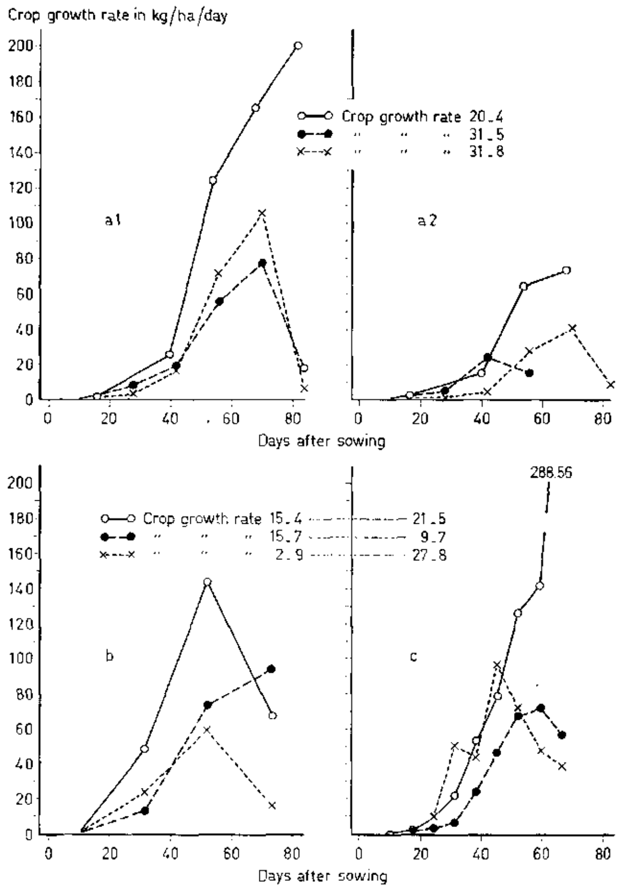


FIG. 15 Crop growth rate in kg per ha per day for treatment *N*1.
a.1: Cultivar Yandev 55, sowing dates 20–4, 31–5 and 31–8, 1967.
a.2: Cultivar Dulce, sowing dates 20–4, 31–5 and 31–8, 1967.
b: Cultivar Yandev 55, sowing dates 15–4, 15–7 and 2–9, 1968.
c: Cultivar Yandev 55, sowing dates 21–5, 9–7 and 27–8, 1971.

Leaf area indices of treatment *N*1 are shown in Fig. 16–a1, a2, b and c. Leaf area index ratios of *N*2(2): *N*1 for the three different sowing dates in each experiment at the times of sampling were:

1967: Sowing date 20–4, cultivar Yandev 55: 0.9, 1.2, 0.7, 1.0, 1.1 and 1.7
1967: Sowing date 31–5, cultivar Yandev 55: 1.0, 1.4, 1.8, 1.6, 1.7, 0.9 and 0.6
1967: Sowing date 31–8, cultivar Yandev 55: 1.0, 0.7, 0.5, 1.1, 0.8, 1.4 and 2.7
1967: Sowing date 20–4, cultivar Dulce: 1.1, 0.9, 0.7, 1.0, 1.1
1967: Sowing date 31–5, cultivar Dulce: 1.5, 1.0, 1.6, 1.3 and 2.4
1967: Sowing date 31–8, cultivar Dulce: 0.9, 1.0, 0.9, 1.1, 0.8 and 0.7
1968: Sowing date 15–4, cultivar Yandev 55: 1.0, 1.2, 1.2, 1.1 and 1.3

1968: Sowing date 15–7, cultivar Yandev 55: 1.0, 1.2, 1.8, 1.3 and 2.1
1968: Sowing date 2–9, cultivar Yandev 55: 1.0, 1.0, 1.1, 1.0 and 0.8
1971: Sowing date 21–5, cultivar Yandev 55: 1.0, 1.2, 1.1, 0.9, 0.9, 1.0, 1.1, 1.2, 1.1, 1.0, 1.7, 1.4 and 1.3
1971: Sowing date 9–7, cultivar Yandev 55: 1.0, 0.7, 0.9, 0.8, 1.1, 0.9, 1.3, 1.4, 1.2, 1.2, 1.1, 0.8 and 0.5
1971: Sowing date 27–8, cultivar Yandev 55: 0.7, 0.7, 0.9, 0.8, 0.9, 1.0, 1.0, 1.1, 0.9, 1.0, 1.1, 1.1 and 1.8

The leaf area index curves for the different years have in common that the values of the first sowing date are considerably higher than those of the later sowing dates and that the values of the last sowing date exceed for a while those of the middle sowing date, which reminds one of the shape of the total dry matter production curves and the observation that sowing later during the season may result in yield improvement.

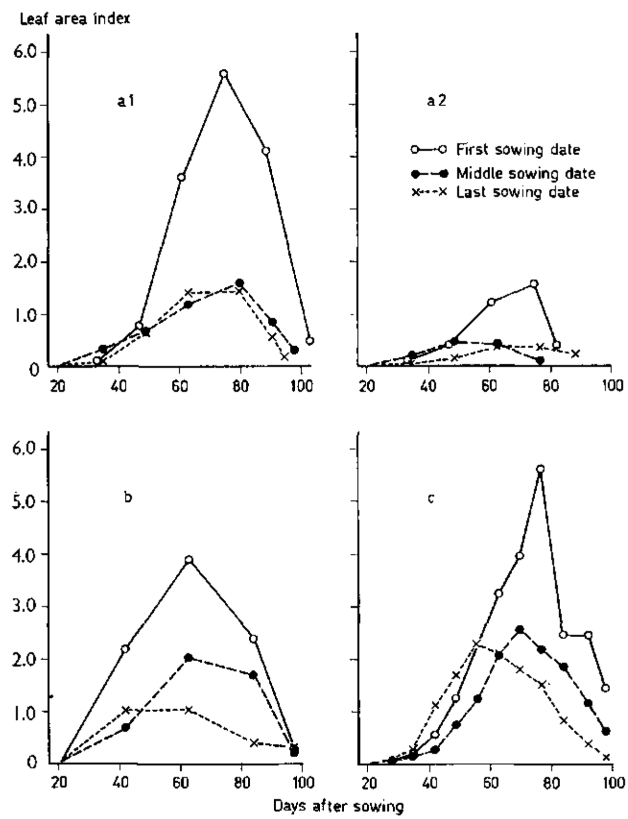


FIG. 16. Leaf area index for treatment *N*1.
a.1: Cultivar Yandev 55, sowing dates 20–4, 31–5 and 31–8, 1967.
a.2: Cultivar Dulce, sowing dates 20–4, 31–5 and 31–8, 1967.
b: Cultivar Yandev 55, sowing dates 15–4, 15–7 and 2–9, 1968.
c: Cultivar Yandev 55, sowing dates 21–5, 9–7 and 27–8, 1971.

The leaf area index ratios for the $N2(2)$ and $N1$ treatments during 1967 and to a lesser extent during 1968 suggest as for total dry matter production and for crop growth rate the possibility of an N leaching effect. Table 29 with leaf area indices for 1971 however fails to show such an effect.

TABLE 29. Leaf area indices for planting dates 21–5, 9–7 and 27–8, 1971 and samples of 3–14 weeks after planting. S.E.D.1 and 2: at same and different sowing dates respectively.

Week	Sowing date: 21–5 Treatment				9–7 Treatment				27–8 Treatment				S.E.D. 1	S.E.D. 2
	*N*1	*N*2(2)	*N*2(1)	*N*2(4)	*N*1	*N*2(2)	*N*2(1)	*N*2(4)	*N*1	*N*2(2)	*N*2(1)	*N*2(4)		
3	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.002	0.003
4	0.06	0.06	0.06	0.06	0.05	0.05	0.06	0.04	0.05	0.04	0.05	0.04	0.008	0.010
5	0.21	0.19	0.24	0.16	0.10	0.09	0.14	0.08	0.23	0.19	0.21	0.15	0.026	0.036
6	0.56	0.52	0.65	0.51	0.21	0.22	0.31	0.20	1.13	1.01	1.02	0.97	0.054	0.078
7	1.25	1.33	1.57	1.24	0.59	0.50	0.72	0.51	1.68	1.68	1.72	1.68	0.122	0.163
8	2.24	2.45	2.86	2.30	1.23	1.54	1.91	1.21	2.26	2.25	2.62	2.12	0.165	0.198
9	3.23	3.98	3.82	3.71	2.06	2.92	2.60	2.70	2.11	2.22	2.35	2.20	0.255	0.307
10	3.96	4.25	5.47	4.75	2.57	3.18	3.07	3.62	1.79	1.58	2.08	2.23	0.373	0.426
11	5.61	5.73	5.36	5.30	2.18	2.59	2.94	3.08	1.45	1.44	1.38	1.42	0.456	0.450
12	2.46	4.15	4.37	4.87	1.86	2.03	2.22	2.81	0.82	0.87	1.10	0.94	0.336	0.391
13	2.46	3.37	3.05	3.81	1.14	0.90	1.00	1.19	0.37	0.42	0.63	0.45	0.361	0.407
14	1.44	1.83	1.29	1.36	0.61	0.32	0.59	0.58	0.12	0.21	0.21	0.09	0.193	0.278

Net assimilation rates for three different sowing dates in each experiment are shown in Tables 30, a, b and c.

TABLE 30a. Net assimilation rate in g per dm² per week for cultivars Yandev 55 and Dulce, treatments $N1$ and $N2(2)$ and sowing dates 20–4, 31–5 and 31–8, 1967.

Days from sowing	cultivar, sowing date and *N* treatment: Yandev 55 20–4		Dulce 20–4		Days from sowing	cultivar, sowing date and *N* treatment: Yandev 55 31–5		Yandev 55 31–8		Dulce 31–5		Dulce 31–8	
	*N*1	*N*2 (2)	*N*1	*N*2 (2)		*N*1	*N*2 (2)	*N*1	*N*2 (2)	*N*1	*N*2 (2)	*N*1	*N*2 (2)
0–33	.31	.29	.39	.39	0–21	.15	.15	.04	.04	.12	.14	.03	.03
					21–35	.44	.51	.52	.35	.42	.39	.34	.34
33–47	.51	.63	.45	.49	35–49	.27	.28	.40	.35	.53	.53	.34	.28
47–61	.47	.41	.61	.62	49–63	.42	.32	.50	.77	.23	.33	.75	.70
61–75	.25	.27	.38	.47	63–77	.38	.42	.46	.28	–	.07	.90	.66
75–89	.11	.17	–	–	77–91	.10	–	.05	.32	–	–	.20	.26

TABLE 30b. Net assimilation rate in g per dm^2 per week for cultivar Yandev 55, treatments *N*1 and *N*2(2) and sowing dates 15–4, 15–7 and 2–9, 1968.

Days from sowing	Sowing date and *N* treatment					
	15–4		15–7		2–9	
	*N*1	*N*2(2)	*N*1	*N*2(2)	*N*1	*N*2(2)
0–21	.27	.25	.21	.24	.21	.21
21–42	.93	.58	.47	.46	.59	.61
42–63	.34	.31	.40	.47	.36	.36
63–84	.15	.13	.46	.20	.15	.08

TABLE 30c. Net assimilation rate in g per dm^2 per week for cultivar Yandev 55, treatments *N*1, *N*2(2), *N*2(1) and *N*2(4) and sowing dates 21–5, 9–7 and 27–8, 1971. S.E.D.1 and 2: at same and different sowing dates respectively.

Days from sowing	Sowing date and *N* treatment												S.E.D.1	S.E.D.2
	21–5				9–7				27–8					
	*N*1	*N*2 (2)	*N*2 (1)	*N*2 (4)	*N*1	*N*2 (2)	*N*2 (1)	*N*2 (4)	*N*1	*N*2 (2)	*N*2 (1)	*N*2 (4)		
0– 7	.43	.43	.54	.42	.30	.33	.31	.34	.33	.33	.32	.33	.024	.028
7–14	.40	.40	.47	.38	.37	.39	.37	.38	.33	.34	.38	.40	.030	.034
14–21	.39	.37	.40	.40	.30	.32	.34	.27	.32	.39	.36	.33	.038	.039
21–28	.43	.49	.44	.44	.30	.25	.30	.29	.48	.51	.46	.43	.045	.044
28–35	.39	.39	.44	.44	.30	.39	.32	.35	.52	.52	.51	.54	.049	.051
35–42	.38	.38	.37	.34	.42	.36	.36	.38	.21	.26	.20	.28	.057	.060
42–49	.32	.33	.39	.36	.35	.42	.46	.40	.34	.38	.35	.32	.053	.060
49–56	.31	.36	.31	.31	.29	.30	.27	.39	.24	.23	.27	.21	.068	.064
56–63	.28	.16	.32	.25	.22	.13	.17	.16	.17	.10	.02	.07	.076	.080
63–70	.41	.43	.27	.34	.17	.10	.18	.16	.16	.20	.19	.31	.113	.110

Average values of the Net Assimilation Rate for the first sowing date exceeded those of the middle sowing date for about 5–7 weeks, after which the ratio between the two fluctuated over and below the value 1. The average values of the Net Assimilation Rate for the first sowing date exceeded those of the last sowing date for the first 3–7 weeks after sowing, after which the ratio changed in favour of the latter for several weeks and then fluctuated over and below the value 1. The average values of the Net Assimilation Rate for the middle sowing date exceeded a little those of the last sowing date for the first 2–4 weeks after sowing, after which the ratio between the two changed in favour of the latter for several weeks and then fluctuated over and below the value 1. Differences between *N* treatments varied, not showing a clear trend, and lacking statistical significance in most cases in 1971.

Results of the chemical analyses of leaves and whole plants for *N*, *P* and *K* for three different sowing dates in each experiment are given in Tables 31, a, b and c, 32, a, b and c and 33, a, b and c.

TABLE 31a. *N* content in percentage for dried leaves of cultivars Yandev 55 and Dulce, treatments *N*1 and *N*2(2), sowing dates 20–4, 31–5 and 31–8, 1967 and different dates of sampling.

Days from sowing	cultivar, sowing date and *N* treatment				Days from sowing	cultivar, sowing date and *N* treatment							
	Yandev 55 20–4		Dulce 20–4			Yandev 55				Dulce			
						31–5		31–8		31–5		31–8	
	*N*1	*N*2(2)	*N*1	*N*2(2)		*N*1	*N*2(2)	*N*1	*N*2(2)	*N*1	*N*2(2)	*N*1	*N*2(2)
					21	5.20	5.31	5.28	5.09	4.86	4.86	4.80	5.01
33	4.90	5.10	4.88	4.98	35	4.43	4.51	5.87	5.57	4.29	4.69	5.17	5.39
47	4.94	4.82	5.15	5.26	49	3.20	4.14	4.99	5.20	3.41	4.72	4.94	4.93
61	4.53	4.50	4.35	4.70	63	3.54	4.06	4.43	4.56	3.07	3.66	4.83	4.82
75	3.74	3.66	3.63	3.89	77	3.39	4.22	3.73	4.02	3.06	3.31	4.02	3.95
89	2.96	2.86	2.58	2.93	91	3.66	3.94	2.70	2.77	–	–	2.86	2.51
103	2.54	2.59	–	–	98	3.60	3.60	2.53	2.74	–	–	–	–
av.	3.94	3.92	4.12	4.35	av.	3.86	4.25	4.22	4.28	3.74	4.25	4.44	4.44

TABLE 31b. *N* content in percentage for dried leaves of cultivar Yandev 55, treatments *N*1 and *N*2(2), sowing dates 15–4, 15–7 and 2–9, 1968 and different dates of sampling.

Days from sowing	Sowing date and *N* treatment					
	15–4		15–7		2–9	
	*N*1	*N*2(2)	*N*1	*N*2(2)	*N*1	*N*2(2)
21	6.16	5.91	4.99	5.11	5.47	5.66
42	4.68	5.51	5.24	5.76	4.98	5.39
63	2.96	3.64	3.31	4.23	3.77	4.38
84	2.20	2.88	2.41	3.15	2.77	3.10
98	2.32	2.52	2.38	2.75	2.49	3.02
average	3.66	4.09	3.67	4.20	3.90	4.31

TABLE 31c. *N* content in percentage for dried whole plants of cultivar Yandev 55, treatments *N*1, *N*2(2), *N*2(1) and *N*2(4), sowing dates 21–5, 9–7 and 27–8, 1971 and different dates of sampling.

Days from sowing	Sowing date and *N* treatment											
	21–5				9–7				27–8			
	*N*1	*N*2(2)	*N*2(1)	*N*2(4)	*N*1	*N*2(2)	*N*2(1)	*N*2(4)	*N*1	*N*2(2)	*N*2(1)	*N*2(4)
21	3.85	3.91	4.39	3.58	3.70	3.44	4.10	3.18	4.55	4.38	4.69	4.10
42	3.48	3.77	3.94	3.82	3.79	3.47	3.94	3.86	4.34	4.15	4.36	4.44
63	1.70	2.38	1.93	2.20	2.16	3.02	2.65	2.75	1.89	1.79	2.48	2.19
77	2.33	2.68	2.75	3.02	4.40	5.37	4.82	5.54	3.01	3.85	2.88	3.15
average	2.84	3.19	3.25	3.16	3.51	3.83	3.88	3.83	3.45	3.54	3.60	3.47

It is noted that in 1967 the *N* contents for Yandev 55, first planting date, exceeded those of the middle sowing date during the first 9 weeks, after which the opposite was observed; for Dulce the first sowing date was all the time higher in *N* content. The last sowing date, however, had on an average somewhat higher values than the first sowing date, The differences between treatments *N*1 and *N*2(2) were small for the first and last sowing date and more pronounced and in favour of *N*2(2) for the middle sowing date.

During 1968 differences in *N* content between the different planting dates were small; the last planting date showed the highest average values. Treatment *N*2(2) had higher *N* contents than treatment *N*1 and more so for the middle sowing date and also the first sowing date than for the last sowing date.

During 1971 the first sowing date showed the lowest *N* content figures, followed by the last and the middle sowing date respectively. Differences between treatments with equal amounts of 500 kg sulphate of ammonia per ha were small; treatment *N*1 with half the amount showed lower *N* content figures, but for the last sowing date the differences were small.

TABLE 32a. *K* content in percentage for dried leaves of cultivars Yandev 55 and Dulce, treatment *N*1 and *N*2(2), sowing dates 20–4, 31–5, and 31–8, 1967 and different dates of sampling.

Days from sowing	cultivar, sowing date and *N* treatment				Days from sowing	cultivar, sowing date and *N* treatment							
	Yandev 55 20–4		Dulce 20–4			Yandev 55				Dulce			
						31–5		31–8		31–5		31–8	
	*N*1	*N*2(2)	*N*1	*N*2(2)		*N*1	*N*2(2)	*N*1	*N*2(2)	*N*1	*N*2(2)	*N*1	*N*2(2)
					21	2.11	2.22	1.67	1.45	2.30	1.89	1.96	1.75
33	1.85	1.72	2.18	1.61	35	2.07	1.88	1.50	1.44	2.08	2.12	1.41	1.50
47	1.81	2.03	2.17	2.19	49	0.86	1.02	1.15	1.22	1.23	1.32	1.29	1.29
61	1.65	1.54	1.72	1.70	63	1.25	1.35	0.90	0.91	1.48	1.61	1.10	1.07
75	1.65	1.05	1.00	1.69	77	0.93	1.35	0.26	0.24	0.89	0.94	0.34	0.39
89	1.42	1.52	0.97	0.96	91	0.65	0.86	1.06	1.20	–	–	1.31	1.19
103	0.73	1.03	–	–	98	0.89	0.72	1.15	1.30	–	–	–	–
average	1.52	1.48	1.61	1.63	average	1.25	1.34	1.10	1.11	1.60	1.58	1.24	1.20

TABLE 32b. *K* content in percentage for dried leaves of cultivar Yandev 55, treatments *N*1 and *N*2(2), sowing dates 15–4, 15–7 and 2–9, 1968 and different dates of sampling.

Days from sowing	Sowing date and *N* treatment					
	15–4		15–7		2–9	
	*N*1	*N*2(2)	*N*1	*N*2(2)	*N*1	*N*2(2)
42	1.80	1.61	1.77	1.70	1.91	1.77
63	1.22	1.24	1.20	1.15	1.82	1.80
84	0.82	0.96	1.29	1.42	1.41	1.48
98	0.47	0.43	0.73	0.96	1.32	1.48
average	1.08	1.06	1.25	1.31	1.62	1.63

TABLE 32c. *K* content in percentage for dried whole plants of cultivar Yandev 55, treatments *N*1, *N*2(2), *N*2(1) and *N*2(4), sowing dates 21–5, 9–7 and 27–8, 1971 and different dates of sampling.

Days from sowing	Sowing date and *N* treatment											
	21–5				9–7				27–8			
	*N*1	*N*2(2)	*N*2(1)	*N*2(4)	*N*1	*N*2(2)	*N*2(1)	*N*2(4)	*N*1	*N*2(2)	*N*2(1)	*N*2(4)
21	4.81	5.00	4.81	5.00	5.08	4.71	4.61	4.27	4.02	3.72	3.75	4.05
42	4.38	4.35	4.76	4.95	4.28	4.36	4.12	4.38	4.27	4.49	4.61	4.48
63	3.77	4.00	3.39	3.70	3.80	3.36	3.11	3.78	2.75	2.38	2.52	2.62
77	1.84	2.11	2.00	1.90	2.35	2.84	2.20	2.53	1.45	1.44	1.58	1.46
average	3.70	3.87	3.74	3.89	3.88	3.82	3.51	3.74	3.12	3.01	3.12	3.15

During 1967 *K* contents of the leaves were on an average highest for the first sowing date and lowest for the last sowing date. Differences between the two *N* treatments were small. Average values for Dulce were higher than for Yandev 55.

During 1968 the trend of the *K* content values in relation to sowing date was opposite to that of 1967: *K* contents were higher at later sowing dates. The differences between the *N* treatments were small.

During 1971 *K* contents of the last sowing date were lower than those of the previous sowing dates. Further differences, also those between the *N* treatments were not consistent. For the middle sowing date *N*1 had the highest values.

TABLE 33a. *P* content in percentage for dried leaves of cultivars Yandev 55 and Dulce, treatments *N*1 and *N*2(2), sowing dates 20–4, 31–5 and 31–8, 1967 and different dates of sampling.

Days from sowing	cultivar, sowing date and *N* treatment				Days from sowing	cultivar, sowing date and *N* treatment							
	Yandev 55 20–4		Dulce 20–4			Yandev 55				Dulce			
						31–5		31–8		31–5		31–8	
	*N*1	*N*2 (2)	*N*1	*N*2 (2)		*N*1	*N*2 (2)	*N*1	*N*2 (2)	*N*1	*N*2 (2)	*N*1	*N*2 (2)
					21	.02	.05	.52	.48	.05	.03	.50	.52
33	.26	.22	.29	.28	35	.41	.33	.47	.52	.21	.08	.51	.52
47	.31	.34	.43	.47	49	.69	.62	.44	.44	.83	.71	.47	.50
61	.17	.17	.20	.17	63	.38	.30	.25	.25	.35	.32	.47	.37
75	.16	.13	.15	.12	77	.30	.31	.16	.19	.27	.24	.27	.23
89	.20	.22	.22	.22	91	.31	.28	.13	.13	–	–	.19	.17
103	.22	.21	–	–	98	.30	.24	.15	.11	–	–	–	–
average	.22	.22	.26	.25	average	.34	.30	.30	.30	.34	.28	.40	.39

TABLE 33b. *P* content in percentage for dried leaves of cultivar Yandev 55, treatments *N*1 and *N*2(2), sowing dates 15–4, 15–7 and 2–9, 1968 and different dates of sampling.

Days from sowing	Sowing date and *N* treatment					
	15–4		15–7		2–9	
	*N*1	*N*2(2)	*N*1	*N*2(2)	*N*1	*N*2(2)
42	.47	.48	.50	.49	.41	.38
63	.29	.31	.32	.31	.26	.27
84	.25	.26	.25	.25	.16	.15
98	.26	.26	.25	.25	.16	.15
average	.32	.33	.33	.33	.25	.24

TABLE 33c. *P* content in percentage for dried plants of cultivar Yandev 55, treatments *N*1, *N*2(2), *N*2(1) and *N*2(4), sowing dates 21–5, 9–7 and 27–8, 1971 and different dates of sampling.

Days from sowing	Sowing date and *N* treatment											
	21–5				9–7				27–8			
	*N*1	*N*2(2)	*N*2(1)	*N*2(4)	*N*1	*N*2(2)	*N*2(1)	*N*2(4)	*N*1	*N*2(2)	*N*2(1)	*N*2(4)
21	.32	.33	.35	.36	.48	.46	.44	.41	.44	.40	.43	.45
42	.34	.34	.36	.32	.39	.40	.40	.38	.38	.38	.36	.36
63	.21	.24	.24	.25	.28	.29	.28	.27	.15	.16	.18	.15
77	.28	.32	.33	.33	.63	.50	.59	.53	.26	.27	.27	.25
average	.29	.31	.32	.32	.45	.41	.43	.40	.31	.30	.31	.30

During 1967 *P* contents of the first sowing date were lower than those of the middle and last sowing dates. For Yandev 55 the middle sowing date was on an average somewhat higher in *P* content than the last sowing date and for Dulce the opposite was observed. Differences between *N* treatments were small.

During 1968 the last sowing date had lower *P* content values than the first and middle sowing date, and further differences between sowing dates and *N* treatments were small.

During 1971 *P* contents of the whole plants of the second sowing date were higher than those of the first and last sowing date, which in turn, similar to the *N* treatments, showed little differences between each other.

Results of the chemical analyses of whole plants for *Zn* at four different dates of sampling and for *Ca* and *Mg* at one sampling date in 1971 are shown in Table 34. The average (1) *Zn* figures over four sampling dates are higher for the first sowing date than for the other sowing dates, but this is caused by the high values of the first sampling date, 21 days after sowing. If the results of the first sampling date are left out, the middle sowing date shows the highest average *Zn* content values, followed by the first and the last sowing date. The *Ca* content figures are on an average lower for the last sowing date than for the first and middle sowing date; the differences between the latter two are small. The *Mg* content figures were on an average highest for the middle sowing date, followed by those of the first and last sowing date.

TABLE 34. *Zn* content in p.p.m. and *Ca* and *Mg* content in percentage for dried whole plants of cultivar Yandev 55, treatments *N*1, *N*2(2), *N*2(1) and *N*2(4), sowing dates 21–5, 9–7 and 27–8, 1971 and different dates of sampling; average (1) over all four dates of sampling and average (2) over the last three dates of sampling only.

Days from sowing	Element	Sowing date and *N* treatment											
		21–5				9–7				27–8			
		*N*1	*N*2(2)	*N*2(1)	*N*2(4)	*N*1	*N*2(2)	*N*2(1)	*N*2(4)	*N*1	*N*2(2)	*N*2(1)	*N*2(4)
21	*Zn*	193	124	181	227	77	101	95	70	88	72	122	72
42	*Zn*	79	82	64	68	104	65	55	68	59	60	55	51
63	*Zn*	36	44	39	41	33	42	39	42	35	38	37	34
77	*Zn*	49	68	54	59	71	81	81	79	59	61	51	56
av(1)	*Zn*	89	80	85	99	71	72	68	65	60	58	66	53
av(2)	*Zn*	55	65	52	56	69	63	58	60	51	53	48	47
63	*Ca*	1.42	1.42	1.83	1.44	1.41	1.44	1.63	1.50	1.22	1.41	1.13	1.18
63	*Mg*	.31	.30	.40	.32	.40	.32	.37	.32	.30	.35	.25	.31

Results of the chemical analyses of soil samples for mineral *N*, $N0_3$ only, for three different sowing dates in 1971 and three different depths of sampling are shown in Fig. 17.

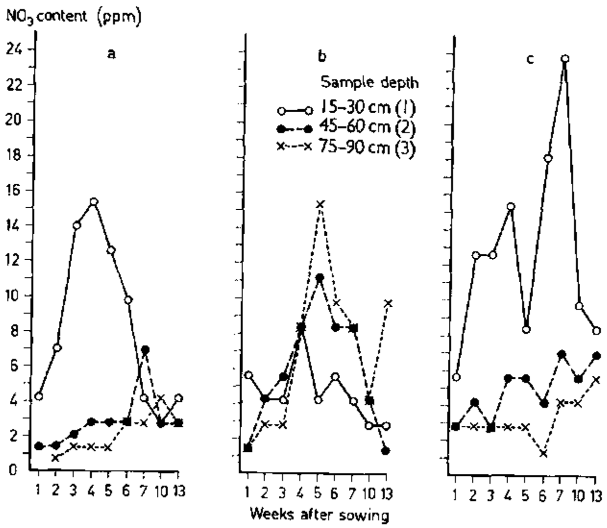


FIG. 17 $N0_3$ content in p.p.m. of dry soil for samples taken in treatment *N*2(1) of sowing dates 21–5 (a), 9–7 (b) and 27–8 (c), 1971 at three different depths of sampling.

The number of weeks between the times the maxima of the curves (1) and (2) occur is three for the first sowing date, (a), and one for the middle sowing date, (b), while for the last sowing date, (c), curve (2) possibly has not reached its maximum yet.

Table 35 presents seed yields for the different experiments.

TABLE 35. Seed yields as percentage of the highest yield obtained per treatment combination in sowing date and crop growth experiments 1, 2 and 3.

a. for cultivars Yandev 55 and Dulce, treatments *N*1 and *N*2(2) sown at different dates in 1967.

Date of sowing	Cultivar and *N* treatment			
	Yandev 55		Dulce	
	*N*1	*N*2(2)	*N*1	*N*2(2)
20–4	100	99	65	56
31–5	49	38	23	27
10–8	72	93	17	19
31–8	53	66	31	29

b. for cultivar Yandev 55, treatments *N*1 and *N*2(2) sown at different dates in 1968.

Date of sowing	Cultivar and *N* treatment Yandev 55	
	*N*1	*N*2(2)
15–4	95	95
15–7	76	100
2–9	52	61

c. for cultivar Yandev 55, treatments *N*1, *N*2(2), *N*2(1) and *N*2(4) sown at different dates in 1971.

Date of sowing	Cultivar and *N* treatment Yandev 55					
	*N*1	*N*2(2)	*N*2(1)	*N*2(4)		average
21–5	100	86	90	78	88	
15–6	69	74	75	57	69	
9–7	35	33	44	28	35	
3–8	44	41	46	51	45	
27–8	61	71	69	62	66	S.E.D.x
average	62	61	65	55	61	4.7
			S.E.D.y		6.8	
	S.E.D.z = 10.5					

x: *N* treatment averages.
y: sowing date averages.
z: *N* treatment × sowing date averages.

It is noted that spreading of the *N* fertilizer application by distributing part doses at different times during the season in 1971 finally did not give the results hoped for.

Further observations taken during 1971 were for the following characters (compare 5.3.) and the results are shown in Table 36.

a. Days from sowing to the opening of the first flower (first flowering), to flowering of 50 per cent of the plants (50 per cent flowering) and to maturity.
b. Position of the lowest flower on the stem recorded as number of nodes between cotyledons and first flower.
c. Incision of the leaf margin of the first 12 leaf pairs, cotyledons not included, scored as described in 5.3.1. for 1965.

TABLE 36. Number of days from sowing to first flowering, to 50 per cent flowering and to maturity; position of the lowest flower on the stem and average leaf incision score for the first 12 leaf pairs, cotyledons not included, for the four different *N* treatments and five different sowing dates of 1971.

Date of sowing	Number of days from sowing to			Position lowest flower	Average leaf incision
	first flowering	50 per cent flowering	maturity		
21–5	46.0	56.4	105	11.3	23.5
15–6	51.1	54.0	105	9.9	14.8
9–7	53.0	60.0	102	8.7	10.0
3–8	53.7	59.0	105	7.8	10.3
27–8	47.0	52.0	104	8.3	15.2
S.E.D.	0.23	0.23		0.14	1.83
N treatment					
*N*1	50.2	55.6	104	9.1	14.6
*N*2	50.2	56.6	104	9.2	13.8
*N*3	50.2	55.8	104	9.3	17.4
*N*4	49.9	57.1	104	9.2	13.2
S.E.D.	0.20	0.15		0.07	1.17

The tendency of delay of flowering with delay of sowing and earlier flowering again later during the season as observed previously (5.3.2.) is noticed here. The period from sowing to maturity varied little again. The lowest flower on the stem dropped in position after the first sowing date in May and raised again a little at the last sowing date. The leaf incision score dropped after the first sowing date and increased again at the last sowing date.

5.4.3. *Discussion and conclusions*

After the presentation of the results for each subject in 5.4.2. comments and conclusions were made already to make the data more easy to read. Only the main observations and conclusions are reiterated here.

a. Total dry matter production, crop growth rate, leaf area index and seed yields showed a common feature in response to planting date: Early planting resulted in high values, delay of planting caused a decrease and late planting at the end of August and during early September tended to provoke a (temporary) improvement.

b. During the first one to two months after sowing the N.A.R. showed higher values for the first than for the middle and last sowing dates. However the last sowing date exceeded the middle and first sowing date for some weeks later during the growth cycle.

c. Results of the chemical analyses for *N*, *P*, *K*, *Zn*, *Mg*, and *Ca* gave no indication that growth differences, observed for different planting dates, were in one way or the other related to the availability of these elements.

d. Results of chemical analyses of soil samples, although questionable, could possibly be explained by movement of *N* in the soil at different rate for different planting dates: The middle sowing date seemed to show a quicker movement than the first and last sowing date. However, differences in plant growth and yield between sowing dates could not be explained by *N* leaching.

e. Spreading of the *N* fertilizer application during the growth season caused no significant yield increase over the all-at-once application prior to planting.

5.5 The effect of top-cutting on yield

It is common experience that delay of sowing causes reduction of plant vigour, branching and yield. On the other hand sesame plants, of which the tops have been naturally damaged, are frequently more vigorous and show profuse branching. This suggests that removal of the plant tops may increase the yield of late sown sesame.This was experimentally investigsted during 1965–1967.

5.5.1. *Materials and methods*

The cultivar Yandev 55 was sown in all three trials.

There were two treatments in 1965:

a. The tops were cut with a razor blade just under the lowest flower-buds at the time when these were visible on most plants. Twelve days later cutting was carried out on those plants which showed no flowerbuds at the first cutting.

b. Untreated; the plants were allowed to grow normally.

There were four treatments in 1966:

a. The extreme tops of the plants were pinched out between finger and thumb nail when flowerbuds were visible on all plants.
b. As treatment (a), but one week later.
c. As treatment (a), but two weeks later.
d. Untreated; the plants were allowed to grow normally.

There were two treatments in 1967:

a. The extreme tops of the plants were cut with a razor blade 35 days after sowing.

b. Untreated; the plants were allowed to grow normally.

A Randomized Block Design with eight replications and two 4 × 4 Latin Squares were used in 1965 and 1966 respectively. In both experiments plots were eight ridges, 91 cm apart and 7.3 m long. In 1967 the two treatments were part of a 2^3 factorial combination laid out in a Latin Square. Plots were 5.5 m × 5.5 m. Plant spacing was always 15 cm × 91 cm and thinning was to one plant per stand. Sulphate of ammonia and superphosphate were applied at rates of 250 and 125 kg per ha respectively, prior to sowing.

In 1965 and 1966 twenty plants per plot were sampled systematically from the four middle ridges and the following factors were recorded:
Number of primary branches.
Number of secondary branches.
Number of capsules on main stem.
Number of capsules on primary branches.
Number of capsules on secondary and higher-order branches.
Branches shorter than 5 inches were discarded.

5.5.2. *Results*

The results for 1965 and 1966 are summarized in Table 37.

TABLE 37. Effect of top cutting and pinching on branching and yield in 1965 and 1966.

Factor	Treatment		S.E.D.	Treatment				S.E.D.
	top cutting	no top cutting		pinching			no pinching	
				(a)	(b)	(c)		
Seed yield in kg per ha	594	613	47	390	409	409	407	38
Number per plant:								
primary branches	4.7	4.3	0.2	3.6	3.6	3.6	3.6	0.2
secondary branches	3.9	2.1	0.3	0.4	0.4	0.5	0.4	0.1
capsules on main stem		18.7		10.7	17.9	19.1	19.7	0.9
capsules on pirmary branches	56.5	45.9	3.5	43.2	44.6	44.6	43.7	2.3
capsules on secondary and higher order branch.	22.3	12.0	1.7	1.8	2.9	2.8	2.1	0.7
capsules total	78.8	76.6	4.0	55.7	65.4	66.6	65.4	2.3

Pinching (a), (b) and (c) = Pinching when flowerbuds visible, one week later and two weeks later respectively

In 1967 the treatment with top cutting yielded 709 kg per ha and the treatment with no top cutting 683 kg per ha; the difference was not statistically significant.

5.5.3. *Conclusions*

Neither top cutting nor pinching out the tops of the plants increased seed yield or total number of capsules per plant. The number of secondary branches and the number of capsules on the primary and higher-order branches was significantly greater in 1965 for top cutting than for the control. The method of pinching out the tops of the plants, used in 1966, caused no significant increase in any of the factors listed. The attempt to increase yield by stimulating branching, so counteracting the effect of delay of sowing on branching and yield, failed.

5.6. The effect of soil cultivation on yield

Loamy sand soils with a high proportion of fine sand may form a surface cap through the action of beating rain (see 3.1.2.). Consequently adequate soil aeration may be prevented, the rate of water infiltration is reduced and run-off may occur. It was thought that opening of the soil by raking after rains would annihilate the capping effect and improve crop growth, especially later in the season when rainfall is usually heavy. It was also considered that the said effect was possibly connected with the sowing date effect under discussion and in this context the following two experiments were carried out during 1967 and 1971.

5.6.1. *Materials and methods*

In 1967 the cultivar sown was Yandev 55. In 1971 the cultivars sown were – in order of decreasing length of growing season – 65B-61, Yandev 55, A/1/7 and Type 5.

In both experiments two different soil cultivation methods were practiced:

a. Careful raking about 2–4 cm deep and at a distance of 5–8 cm away from the plants.
b. Untreated. Apart from weeding when necessary, no soil cultivation was practiced.

In 1967 the two treatments were part of a 2^3 factorial combination, laid out in a Latin Square. Another pair of treatments was ridge planting and flat planting.

In 1971 a Split-plot Design was used with the cultivars as main plot treatments and the cultivation practices as sub-plot treatments. There were four replications. Plot size was 5.5 m × 5.5 m in 1967 and 4 ridges, 91 cm apart and 5.5 m long in 1971. Plant spacing for both experiments was 15 cm × 91 cm and thinning was to one plant per stand. Superphosphate and *N* fertilizers (sulphate of ammonia in 1967 and nitrochalk in 1971) were applied at rates of 125 and 250 kg per ha respectively. Sowing dates were 26-8-1967 and 11-8-1971. Seed weights per plot were determined and in 1971 in addition total sun-dried plant material after threshing, roots not included.

5.6.2. *Results*

Seed yields for the raking treatment and for the control in 1967 were 668 and 725 kg per ha respectively, S.E.D. being 18 kg per ha. There was no statistically significant difference between ridge and flat planting.

Table 38 shows seed yields and plant weights obtained in 1971. The colour of the leaves in the case of raking was slightly lighter than in the case of no raking. Type 5 was more pronounced in this respect than the other cultivars.

TABLE 38. Effect of soil cultivation on yield, 1971. Seed yields and total sun-dried plant material after threshing, roots not included, in kg per ha.

cultivar	Seed yield			S.E.D. a	Plant material			S.E.D. a
	Raking	No raking	Average		Raking	No raking	Average	
65B-61	643	712	677		2259	2371	2315	
Yandev 55	441	469	455		1513	1464	1488	
A/1/7	614	557	586		1864	1800	1832	
Type 5	216	244	230		748	836	792	
Average	478	495	487	14	1596	1618	1607	66
S.E.D.b			38				152	
S.E.D.c		27				133		

a: Cultivation averages.
b: Cultivar averages.
c. Cultivation × cultivar averages.

5.6.3. *Conclusions*

Disturbing the formation of a surface cap by raking after each rain rather reduced – significantly so in 1967 – than increased the seed yield. It had no significant effect on total sun-dried aerial plant material.

It is concluded that the formation of a surface cap is not likely to play an important role in relation to yield differences, observed between different sowing dates.

5.7. THE EFFECT OF PLASTIC SOIL COVER ON YIELD

It has been suggested that during the dry season the available N in the soil increases and that it decreases with the onset of the rains because of leaching, which in turn would cause partly or largely the discussed sowing date effect.

By protecting the soil against rainfall with plastic sheets for some period after the end of the dry season, early planting could be imitated later during the rainy season and the effect of the imitation on yield could be estimated. An experiment of this type was carried out in 1971.

5.7.1. *Materials and methods*

The cultivars 65B-61, Yandev 55, A/1/7 and Type 5 were used to test the following two treatments.

a. The soil was covered with plastic sheeting each time before the rain started by roling it off from a metal drain pipe. The cover was removed again after the rain had stopped by roling it back on the pipe.

b. Untreated. The soil was left open; weeds were removed.

A Split-plot Design was used with the cultivars as main plot treatments and the cover versus no cover as sub-plot treatments. There were four replications. The plastic sheeting covered an area of 3.6 × 5.5 m and the central section of two ridges, 91 cm apart and 3.6 m long was harvested as net plot.

Soil samples from all Yandev 55 plots with and without cover were taken to a depth of 90 cm with 15 cm intervals shortly before the plots with cover were to be exposed to rain. The samples were bulked per treatment, dried at 105 °C and analysed at Samaru for *N* content.

No fertilizers were applied. Plant spacing was 15 cm on the ridges and thinning was to one plant per stand. The sowing date was 4-9-1971.

Seed weights per plot and total sun-dried plant material after threshing, roots not included, were determined.

5.7.2. *Results*

Table 39 presents seed yields and plant weights and Fig. 18 shows *N* contents of soil samples for NO_3 and NH_4 separately.

TABLE 39. The effect of plastic soil cover on yield. Seed yield and total sun-dried plant material after threshing, roots not included, in kg per ha.

cultivar	Seed yield			S.E.D. a	Plant material			S.E.D. a
	Cover	No cover	Average		Cover	No cover	Average	
65B-61	278	231	255		1248	1168	1208	
Yandev 55	267	229	248		932	997	964	
A/1/7	228	242	235		1137	1010	1074	
Type 5*	131	60	96		373	181	277	
Average	226	190	208	18	923	839	881	69
S.E.D.b			32				120	
S.E.D.c		36				138		

a: cover versus no cover averages.
b: cultivar averages.
c: cover versus no cover × cultivar averages.
*: Diseased.

5.7.3. *Discussion and conclusions*

Average differences in yield and production of plant material between the cover and no-cover treatments were not significant at $P = .05$. Cultivar differences were very significant. The interaction effect of cover versus no cover x cultivars was again not significant.

The *N* content of the soil before sowing in early September was considerably higher for the cover than for the no-cover treatment, but only to a depth of 30 cm. It is concluded that the results do not support the hypothesis that leaching of available *N* after the rains have started, is a main factor in the observed planting date effect.

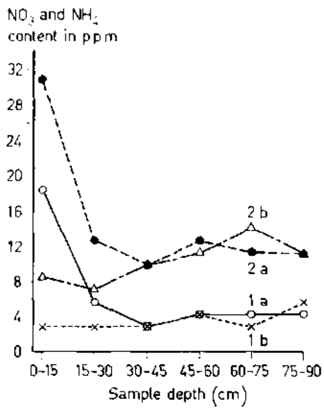


FIG. 18. The effect of plastic soil cover on yield.
NO_3 (1) and NH_4 (2) content in p.p.m. of dry soil from covered (a) and uncovered (b) plots just before exposure to rain. Sample depth to 90 cm with 15 cm intervals.

5.8. THE EFFECT OF SHADE ON YIELD

The increase of cloud cover after the onset of the rains and consequently the reduction of solar radiation available for the plants may be a factor that causes yield reduction when sowing is delayed. With this in mind, two experiments were carried out in 1971 in which the effect of shading on yield and on some other characters was investigated.

5.8.1. *Materials and methods*

The cultivar Dulce was used because its plants are short and mature early and its response to sowing date differences was investigated earlier (5.4.).

Shade was induced by means of framed wire gauze of two different mesh, (a) and (b), which was kept over the plants at a distance of about 15 cm or less. The frames were 2.7 m long and 0.9 m wide.

The reduction of solar radiation caused by these screens was measured at Samaru with Kipp solarimeters, by placing the screens at 97 cm from the ground (about maximum plant height), in directions N.N.E. and N.N.W. in accordance with the direction of the ridges in the experiments, and by fixing the solarimeters at 48 cm from the ground, either in the centre under the screens (a) and (b), or in the open (c). Readings were every five minutes and the mean values per half hour have been tabulated below. Ratios were calculated as percentages.

There were three different treatments in the experiments:

a. Shading with screen (a).
b. Shading with screen (b).
c. Untreated. Plants without screen.

The experiments followed the Randomized Block Design and had eight replications. The net plot size was one ridge x 1.8 m long; the distance between

Time	Radiation in cal./cm²/min.			Ratio to total radiation	
	Screen (a)	Screen (b)	Total (c)	Screen (a)	Screen (b)
07.30–08.00	0.24	0.24	0.24	100	100
08.00–08.30	0.40	0.42	0.44	91	95
08.30–09.00	0.52	0.55	0.57	91	96
09.00–09.30	0.64	0.69	0.74	86	93
09.30–10.00	0.40*	0.44*	0.89	45*	49*
10.00–10.30	0.57	0.63	.096	59	66
10.30–11.00	0.72	0.80	1.14	63	70
11.00–11.30	0.80	0.89	1.26	63	71
11.30–12.00	0.82	0.91	1.28	64	71
average	0.57	0.62	0.84	68	74

* Low figures caused by shade of frame on solarimeter.

the ridges was 91 cm. Fertilizers were applied at a rate of 250 kg nitrochalk and 125 kg single superphosphate per ha. Plant spacing was 15 cm on the ridges and thinning was to one plant per stand. Sowing dates were 14–6 and 12–9–1971.

Observations were made on the following characters:

1. Number of days from sowing to the opening of the first flower (first flowering) and to flowering of 50 per cent of the plants (50 per cent flowering).
2. Position of the lowest flower on the stem recorded as number of nodes between the cotyledons and the first flower.
3. Length of the stem in cm.
4. Girth of the stem between the 2nd and 3rd or 5th and 6th node in cm for sowing dates 14–6 and 12–9 respectively, and number of leaf pairs on the stem.
5. Capsule length in cm, number of capsules per plant and seed yield in g per plant.

5.8.2. *Results*

The results of the experiments are summarized in Table 40.

The shaded treatments flowered a little later than the control. Differences in the position of the lowest flower and the length of the stem were small. Stem girth and capsule length of the control slightly exceeded those of the shaded treatments. The number of leaf pairs on the stem was significantly more for the control than for the treatments with screen. At a first glance and confirmed by counting, shading reduced the number of capsules per plant and also the seed yield.

5.8.3. *Discussion and conclusions*

Shading with screens, that intercepted about 25–30 per cent of the radiation, considerably reduced the yield of Dulce, a short, virtually unbranched cultivar, with little mutual shading of the plants in a plot, if the spacing is 15 cm × 91 cm. The cultivar Yandev 55 is much more vigorous (5.4.2.), consequently the

TABLE 40. Effect of shade on flowering, stem length and girth, number of leaf pairs of the stem, length and number of capsules and seed yield of cultivar Dulce during 1971.

Character	Date of sowing 14–6 Treatment screen (a)	screen (b)	control (c)	S.E.D.	12–9 Treatment screen (a)	screen (b)	control (c)	S.E.D.
Days to first flowering	30.1	30.6	29.0	0.6	32.3	32.8	31.9	0.5
Days to 50 per cent flowering	34.5	34.3	32.5	1.0	35.6	35.6	33.6	0.6
Position lowest flower	3.4	3.6	3.6	1.6	2.5	2.7	2.7	0.2
length of stem (cm)	49.1	50.1	54.5	2.8	45.4	44.3	45.4	3.1
Girth of stem (cm)	2.03	2.04	2.34	0.11	2.45	2.33	2.60	3.2
Capsule length (cm)	–	–	–	–	2.78	2.76	2.88	0.05
Number of leaf pairs	13.4	14.0	17.5	1.0	16.8	15.0	18.9	1.0
Number of capsules	27.8	25.6	38.1	3.3	37.9	35.8	46.3	2.2
Seed yield (g)	25.0	20.8	30.0	4.1	29.0	32.0	43.6	3.7

mutual shading and therefore the effect of artificial shading is expected to be more substantial than for Dulce.

With further reference to 3.1.3. and 5.3. it is concluded that the reduction of radiation due to heavier cloud cover after the onset of the rains (3.1.4.) is likely a factor of importance in connection with the observed sowing date effect.

5.9. GENERAL DISCUSSION AND CONCLUSIONS

The results of the experiments discussed in this chapter can be summarised as follows:

1. Delay of sowing after the onset of the rains reduced the yield of sesame at Mokwa and at Provincial experimental stations. Sowing in late August – early September tended to show yield improvement as compared with July sowing (5.1., 5.2. and 5.4.).
2. Delay of sowing date further caused some delay of flowering till about July. Thereafter flowering was somewhat advanced (5.3. and 5.4.).
3. The period from sowing to harvesting varied little for different sowing dates, except if sowing was very late (5.3. and 5.4.).
4. The position of the lowest flower on the stem raised from April to May, dropped during June and July and raised a little again during late August and September sowings (5.3. and 5.4.).
5. The extent of leaf incision decreased with delay of sowing and increased again with sowing at the end of August and September (5.3. and 5.4.).
6. Plant length, branch length, capsule production and seed yield tended to

decline with delay of sowing and to increase in August and September (5.3.).

7. Plants grown in a screened house with 58 per cent light interception yielded considerably less capsules and seed than plants grown in the open (5.3.).
8. The treatment with a movable cage to reduce the daylength caused earlier flowering, earlier harvesting, a lower position of the first flower on the stem, reduced leaf incision, a little less vigour and less capsules, although seed yield was not reduced. The treatment with a light box to extend the daylength had the opposite effect and also increased the seed yield (5.3.).
9. Delay of sowing after the onset of the rains caused a decrease of total dry matter production, crop growth rate and leaf area development, which in turn improved a little with sowing in August – September (5.4.).
10. Net assimilation rates of the first sowing date exceeded those of the middle sowing date for the first 5–7 weeks after sowing. The last sowing date in August–September exceeded for a while the other sowing dates in respect of N.A.R. as from 3–7 weeks after sowing (5.4.).
11. During 1971 no interaction was observed between *N* application and time of sowing regarding crop growth and yield, and no evidence was found of an effect of increased leaching during the course of the season (5.4.).
12. Chemical analyses of leaves and whole plants for *N*, *P*, *K*, *Zn*, *Ca* and *Mg* content offered no indications for possible causes of observed sowing date effects (5.4.).
13. Results of soil analyses for sowing date and crop growth experiment 3 in 1971 suggested the occurrence of a certain degree of *N* leaching caused by rain (5.4.).
14. Top cutting of plants to stimulate the branching failed to result in yield improvement (5.5.).
15. Disturbing the soil surface after rains found no response in yield increase (5.6.).
16. The hypothesis that yield reduction due to delay of sowing is caused by *N* leaching, found no support in the experimental results with plastic soil cover (5.7.).
17. The treatment with wire gauze to intercept light to 25–30 per cent significantly affected capsule number and seed yield (5.8.).

With the above information available and referring to the data in 3.1.3. we turn back to the introduction for a discussion of the possible factors involved in the observed sowing date effects.

(a) *General ecology*

The main sesame growing areas of Nigeria are all well within the belt of the Tropics, but with a rainfall of 1,000–1,500 mm over a period of about six months, these regions cannot be classified as dry and hot tropics during that part of the year. Nearest to a dry climate are the months preceding and following the dry season ... in which farmers actually grow sesame. Most soils are well drained. At low sited places waterlogging has been observed with a harmful effect on crop growth.

(b) *Daylength*

The maximum daylength on 21 June amounts to 12.43 hours. Longer daylengths favour growth and yield. Before 21st June the effect of an increasing daylength is opposite to that of the delay of sowing. An improvement in yield later during the season can also not be explained by daylength changes. Concluded is that daylength is not the factor responsible for the typical sowing date delay effect. However, daylength differences will have contributed to the delay of flowering till about July-sowing, and the advancement of flowering for sowing later during the season; to the differences in position of the lowest flower; and to the differences in incision of the leaves, which for varying photoperiods have been observed by others too (GHOSH, 1955).

(c) *Light intensity*

Light interception caused a considerable decrease of capsule number and seed yield in the experiments at Mokwa.

Light is intercepted naturally by clouds and the extent of interception is reflected in records of daily sunshine hours and solar radiation data.

Table 41 shows average Gunn Bellani radiation figures for periods corresponding with those between the various sampling dates in Sowing date and crop growth experiments 1, 2 and 3.

TABLE 41. Mean Gunn Bellani radiation figures in ml per day for periods between subsequent sampling dates in Sowing date and crop growth experiments 1, 2 and 3; average per cent based on first sowing date.

Experiment 1 (1967)				
Days from sowing	Sowing date 20–4	Days from sowing	Sowing date 31–5	Sowing date 31–8
0–33	17.5	0–21	16.7	14.3
		21–35	12.9	15.8
33–47	17.1	35–49	14.0	17.3
47–61	16.1	49–63	12.4	19.2
61–75	13.2	63–77	12.7	18.6
75–89	14.9	77–91	11.8	19.4
average	16.1	average	13.7	17.2
average (per cent)	100	average (per cent)	87	107

Experiment 2 (1968)			
Days from sowing	Sowing date 15–4	Sowing date 15–7	Sowing date 2–9
0–21	17.7	13.3	15.4
21–42	17.4	15.1	17.3
42–63	15.4	15.5	17.5
63–84	15.4	16.4	18.4
average	16.5	15.1	17.2
average (per cent)	100	92	104

TABLE 41 (continued)

Experiment 3 (1971)			
Days from sowing	Sowing date		
	21–5	9–7	27–8
0– 7	19.0	13.1	13.4
7–14	15.8	12.2	11.3
14–21	17.5	16.8	14.6
21–28	16.1	14.6	15.4
28–35	16.4	9.9	18.4
35–42	16.6	13.4	17.0
42–49	16.1	13.8	17.2
49–56	13.1	13.8	17.0
56–63	12.2	11.4	19.1
63–70	16.8	15.0	19.3
average	16.0	13.4	16.3
average (per cent)	100	84	102

Average differences between the first and middle sowing date varied between 8 and 16 per cent, and average radiation figures for the last sowing date exceeded those of the first sowing date.

Differences in light intensity will have contributed during early and later growth stages to cause differences in growth and yield between the first and middle sowing dates. During the early growth stages light intensities for the first sowing dates exceeded those of the last sowing dates, but later during the growth period this changed in favour of the latter. The differences in Net Assimilation Rate values found in Sowing date and crop growth experiments 1, 2 and 3 seem to show a response to the light intensity differences.

It is of interest to mention here the results of work on maize in Nigeria. STOCKINGER (1970) states that 'the importance of early planting of maize and sorghum is well established throughout Africa. Why this is so important is difficult to explain. Planting cereals early allows them to escape insect attacks and plant diseases which plague late plantings. Early planting gives them a chance to use the first flush of nitrogen released when dry soils are first moistened by the rains. However, these factors can be corrected with chemicals and there is still a large date of planting effect remaining.'

DE WOLFF (1970) observed in a planting dates trial with maize at Mokwa that yields gradually decreased from 3,360–4,480 kg per ha to less than 2,240 kg per ha, when planting was delayed from April to August. He further found a positive correlation between the angle of the third highest leaf with the stem, and yield which indicated that at Mokwa, despite the rather low yield level of the crop, light is already a limiting factor in maize production (DE WOLFF, 1972). This observation agrees with results from an analysis of plant growth in some West African species, including maize, at Ibadan by NJOKU (1960), which suggested that even at full daylight, growth is limited by light.

The experimental results and data from the literature suggest that the heavy cloud formation during July–September is responsible for a good deal of the planting date effect. The decreased cloudiness during October would explain the temporary improvement for late sowing.

(d) *Temperature*

Average maximum and minimum screen temperatures and earth temperatures at 30 cm are presented in Table 42 for periods corresponding with those between the various sampling dates in Sowing date and crop growth experiments 1, 2 and 3.

TABLE 42. Average maximum and minimum screen temperatures and earth temperatures at 30 cm in °C for periods between subsequent sampling dates in Sowing date and crop growth experiments 1, 2 and 3.

Experiment 1 (1967)

Days from sowing	Sowing date 20–4 temperature			Days from sowing	Sowing date 31–5 temperature			Sowing date 31–8 temperature		
	max	min	earth		max	min	earth	max	min	earth
				0–21	31.7	21.7	29.2	29.4	21.1	27.4
0–33	34.4	23.3	31.9	21–35	30.0	21.1	27.9	30.6	21.1	27.6
33–47	33.9	22.2	31.6	35–49	30.0	21.7	27.9	30.6	21.1	28.3
47–61	31.1	21.7	29.0	49–63	29.4	21.7	27.8	31.7	20.6	28.7
61–75	30.0	21.1	28.1	63–77	30.0	21.7	27.6	33.3	17.2	28.6
75–89	30.0	21.7	27.8	77–91	28.3	21.1	26.8	33.9	14.4	27.9
average	32.4	22.3	30.2	average	30.0	21.5	28.0	31.4	19.4	28.0

Experiment 2 (1968)

Days from sowing	Sowing date 15–4 temperature			Sowing date 15–7 temperature			Sowing date 2–9 temperature		
	max	min	earth	max	min	earth	max	min	earth
0–21	32.8	23.3	30.0	30.0	21.7	28.5	31.1	21.1	28.5
21–42	31.7	22.2	29.6	30.6	21.7	28.6	31.7	20.6	28.5
42–63	29.4	22.2	28.6	30.0	21.7	28.7	33.3	20.6	29.3
63–84	30.0	21.7	28.6	31.1	21.1	28.5	34.4	18.3	29.8
average	31.0	22.4	29.2	30.4	21.6	28.6	32.9	20.2	29.0

TABLE 42 (continued)

Days from sowing	Experiment 3 (1971)								
	Sowing date								
	21–5 temperature			9–7 temperature			27–8 temperature		
	max	min	earth	max	min	earth	max	min	earth
0–7	33.9	22.2	31.6	29.4	21.1	28.8	30.0	21.1	27.9
7–14	34.4	23.3	32.0	28.9	21.7	28.2	29.4	21.1	27.7
14–21	33.3	22.8	31.6	30.0	21.1	28.1	30.0	20.6	27.7
21–28	32.2	22.2	31.8	29.4	21.7	28.2	30.6	20.6	27.6
28–35	31.1	21.7	29.4	27.8	21.1	27.8	31.7	21.1	28.6
35–42	31.1	22.2	29.3	29.4	21.7	27.9	32.8	21.1	28.8
42–49	31.1	22.2	29.3	29.4	21.7	27.9	31.7	21.1	28.7
49–56	29.4	21.1	28.8	30.0	21.7	27.9	31.7	20.6	28.6
56–63	28.9	21.7	28.2	29.4	21.1	27.8	32.8	17.8	28.2
63–70	30.0	21.1	28.1	30.6	20.6	27.6	33.3	16.7	28.0
average	31.5	22.1	30.0	29.4	21.4	28.0	31.4	20.2	28.2

Average maximum temperatures of the first sowing dates were 0.6–2.4 °C higher than those of the middle sowing dates, and compared with the last sowing dates 0.1–1.0 °C higher during 1967 and 1971, but 1.9 °C lower during 1968. During the first 6–7 weeks after sowing, average maximum temperatures for the first, middle and last sowing dates of the three experiments in °C were:

Year	Sowing		
	first	middle	late
1967	34.3	30.7	30.1
1968	32.3	30.3	31.4
1971	32.4	29.2	30.9

Average minimum temperatures of the first sowing dates were 0.7–0.8 °C higher than those of the middle sowing dates and 1.9–2.9 °C higher than those of the last sowing date, and during the first 6–7 weeks after sowing these amounted to:

Year	Sowing		
	first	middle	late
1967	23.0	21.5	21.1
1968	22.8	21.7	20.9
1969	22.4	21.4	21.0

For the last sowing date low values were recorded after the commencement of the dry season. The lowest minimum temperature shown in Table 42 is as low as 14.4°C.

Average earth temperatures of the first sowing dates were 0.6–2.2°C higher than those of the middle sowing dates and 0.2–2.2°C higher than those of the last sowing dates, and during the first 6–7 weeks after sowing these amounted to:

Year	Sowing		
	first	middle	late
1967	31.8	28.5	27.7
1968	29.8	28.6	28.5
1971	30.7	28.1	28.1

Literature data regarding the effect of temperature on growth of sesame are sparse. SMILDE (1960) applied treatments of different day and night temperature combinations, among which 33–33, 33–21, 27–27 and 27–21°C, and found considerable differences in plant growth, the higher temperatures giving better results than the lower ones. It may be concluded that temperature differences likely have played a role of some importance in connection with the observed planting date differences. Early sowing has been favoured by higher temperatures and the low minimum temperatures during November may have adversely affected crops of the last sowing date.

(e) *Rainfall*

Table 43 presents rainfall figures for the periods corresponding with those between the various sampling dates in Sowing date and crop growth experiments 1, 2 and 3, and shows totals for periods of 100 days from sowing.

TABLE 43. Rainfall in mm for periods between subsequent sampling dates and rainfall totals for longer periods in Sowing date and crop growth experiments 1, 2 and 3.

Experiment 1 (1967)				
Days from sowing	Sowing date 20–4	Days from sowing	Sowing date	
			31–5	31–8
		0–21	82.3	237.2
0–33	38.4	21–35	157.7	51.8
33–47	102.6	35–49	76.7	55.4
47–61	69.1	49–63	15.5	0.0
61–75	157.7	63–77	105.9	0.0
75–89	67.1	77–91	37.9	0.0
0–89	434.9	0–91	476.0	344.4
0–100	444.6	0–100	504.2	344.4

TABLE 43 (continued)

Experiment 2 (1968)			
Days from sowing	Sowing date		
	15–4	15–7	2–9
0–21	187.7*	207.3	208.5
21–42	146.1	190.2	38.1
42–63	105.2	144.0	6.4
63–84	141.2	117.3	0.0
0–84	580.2	658.8	253.0
0–100	687.1	676.6	253.0

Experiment 3 (1971)			
Days from sowing	Sowing date		
	21–5	9–7	27–8
0– 7	11.2	52.1	52.6
7–14	14.7	75.2	44.7
14–21	5.1	80.0	24.1
21–28	45.2	45.2	39.9
28–35	84.1	81.3	17.0
35–42	5.8	27.9	51.8
42–49	71.6	27.7	10.9
49–56	52.1	52.6	0.0
56–63	75.2	15.5	0.0
63–70	80.0	53.3	0.0
0–70	445.0	500.8	241.0
0–100	647.1	620.4	241.0

* = Rainfall on second and third day after sowing totalled to 117.1 mm.

For the first sowing date dry conditions prevailed at the onset of the rains and the rainfall was relatively low during the first 1–2 months after sowing. Water stress occurred at times. Later during the growing season the rainfall increased and the total precipitation over 100 days exceeded that of the middle sowing date during 1968 and 1971.

For the middle sowing date wet conditions prevailed at the time of sowing and relatively heavy rainfall occurred during most of the growing season.

For the last sowing date wet conditions prevailed at the time of sowing, the rainfall remained relatively heavy during September, after which a sudden drop was observed during October, followed by the onset of the dry season.

Growing of sesame was on ridges and the drainage at Mokwa was excellent. Water excess in the soil as a possible cause of growth and yield differences between different sowing dates can therefore be discarded.

Two consequences of heavy rains were supposed to be important in connection with planting date differences:

1. the formation of a surface cap (BOLHUIS, personal communications).
2. the leaching of nutrients, nitrogen in particular.

No evidence was obtained from experiments at Mokwa to support these hypotheses.

Increase of pest attack and disease incidence when sowing is delayed was also thought to be important. In fact an increase of disease incidence was observed several times, e.g. for leaf-curl (7.2.1.5.). In this respect two aspects can be distinguished:

I. After the onset of the rains the potential of the disease inoculum increases.
II. Conditions prevailing when sowing is delayed make plants more susceptible to disease infection.

However, from observations it was concluded that leaf-curl and insect attack were satisfactorily controlled by frequent spraying of insecticides in Effect of sowing date observations 2 and Sowing date and crop growth experiments 1, 2 and 3. The leaf spot disease complex was more difficult to control and its effect on crop growth and yield was hard to estimate (7.1.). Observations suggested that the growth and yield reduction experienced during 1964 and 1967, when sowing was delayed, was intensified by disease incidence, but during 1968 and 1971 the disease complex was rather well controlled.

In conclusion:

a. optimal for the cultivation of sesame are the dry and hot tropics; the crop therefore would be expected to do best in the Middle Belt of Nigeria during the time of year when conditions are as near to optimum as possible; this would be early or late in the rainy season.
b. The factors daylength, water excess in the soil, the formation of a surface cap and leaching of nitrogen do not explain the steep decline in growth and yield when sowing is delayed, and their recovery to some extent when sowing is during the end of August or early September.
c. Light intensity was found to be important in experiments with shading to 25–30 per cent.
d. Temperature differences between different sowing dates favour early sowing. Sowing in August–September has the advantage of rising day temperatures during October–November.
e. Rainfall tailing off during October and stopping at the end of the month causes water stress for the late sown crop, resulting in a reduced yield.
f. Disease incidence increases after the onset of the rains and decreases for sowing late during the rainy season.

Finally, the experimental results of this chapter together with literature data and field observations suggest the following comparative pictures for crops of different dates of sowing:

Early sesame, sown immediately after the onset of the rainy season, e.g. in April, receives initially plenty of sunlight, the temperature is high and consequently, plants grow vigorously. Water stress sometimes occurs, but sesame is fairly drought resistant. The potential of the disease inoculum is still small and the well developing plants resist disease damage. Later during the growing season rainfall, cloudiness and disease infection increase, the temperature decreases and at the time the crop matures harvesting conditions are usually adverse.

Middle late sesame, sown e.g. in June, grows under more cloudy conditions, the temperature is lower and consequently plants grow less vigorously than those sown early. The potential of the disease inoculum has increased, plants are more susceptible and more crop damage is incurred. At maturity harvesting conditions may have improved.

Late sesame, sown e.g. in the middle of August, grows initially under most cloudy conditions, temperatures are low and plant growth is not vigorous. The potential of diseases is high. At the end of September the number of sunshine hours per day increases, so does the temperature, plants improve in growth and disease damage is less than for middle late sowing. The rainfall ends during October, and although heavy dew as a result of the low night temperatures moistens the plants during November, gradually plants become retarded in growth because of drought, look dark-green and shiny and their yield is reduced. Harvesting conditions are ideal and seed of excellent quality is obtained.

6. HARVESTING AND THRESHING SESAME AND THE INDEHISCENT CAPSULE CHARACTER

When Alibaba and the forty thieves used the charm 'sesame open' to get entrance to the cave with treasures, the magic words possibly found their origin in the sesame plant with its characteristically opening capsules. This character of opening or dehiscent capsules has been adventageous and disadventageous for sesame growers. Adventageous as it simplifies threshing; disadventageous as it enhances seed loss.

In 1943 LANGHAM (1946) found in Venezuela in a sesame propagation plot of the F5 generation of a hybrid between the cultivars Criollo and Selection 5 one plant that differed from all other plants in the population in that the leaves were cupped upwards and when mature the capsules remained closed. The discovery caused a revolution in the sesame production in the United States for two reasons: 1. Handling of the dehiscent sesame crop when mature, wind and rain and birds sitting down on plant stooks cause easily seed losses and the newly found character was thought to reduce these, and 2. Indehiscent sesame would enable full mechanisation of harvesting and threshing with combines. Mechanical harvesting and threshing in two separate operations was practiced with dehiscent sesame and caused 13 and 2 per cent more seed loss respectively than the manual operations (MONTILLA and MAZZANI, 1966).

It appeared that the indehiscence character was not caused by a virus disease, it was not graft transmissable and its inheritance was monogenic: Two recessive alleles control indehiscence by influencing the pattern of mesocarp development (MAZZANI, 1960; ASHRI and LADIJNSKI, 1964 and 1965; MAZZANI, 1964).

Unfortunately the plant found by LANGHAM and its non-shattering off-spring showed a great degree of sterility probably caused by the curved shape of the style. The multiple cross method was employed by the Texas and South Carolina Agricultural Experiment Stations to produce improved sesame cultivars with indehiscent capsules and the co-operation resulted in the release of the non-shattering cultivars Rio and Palmetto for commercial planting in 1955 (Texas Agricultural Experiment Station, 1955; United States Department of Agriculture, 1958; MARTIN and CRAWFORD, 1955; KINMAN, 1953).

The indehiscence character however introduced a new problem: Machine threshing was difficult and incomplete and seed damage occurred due to high cylinder speeds and close spacing of cylinder and concave necessary to break up the tough pods (MARTIN, 1954). An improvement was made when the simple recessive character papershell capsules was combined with indehiscence in such cultivars as Delco and Baco, and also an increase in the number of concave bars or cylinder bars together with a lower cylinder speed has brought about a reduction in seed damage and seed loss (CULP, 1960; COLLISTER, 1955; Texas Agricultural Experiment Station, 1957; Texas Agricultural Experiment Station, 1965), but extremely careful adjustment and in some cases extensive modifications of commercial combines are still required to avoid injury to the seed (KINMAN, personal communications; CULP, 1963).

Shattering of seed because of partial dehiscence occurs to percentages ranging from 3.8–31.7 per cent (CULP, 1963).

In the United States farmers grow mainly indehiscent sesame and harvesting and threshing is done with combines, but from a questionnaire sent out to various countries (VAN RHEENEN, 1970, unpublished report) and from literature it became obvious that all main sesame growing countries as India, China, Venezuela, the Sudan and others grow dehiscent sesame and harvest and thresh by hand, although interest in the character indehiscence exists (TAHIR, 1964; VAN RHEENEN, 1969; GERAKIS and TSANGARAKIS, 1969; KHIDIR, 1969).

Shattering of seed in dehiscent sesame cultivars occurs during the period of drying and at the time of threshing. The actual amount of seed loss experienced by Nigerian farmers, using different harvesting methods, is not known, but estimates of 25–50 per cent have been quoted by officials of the Ministry of Agriculture. Such estimates possibly caused a Mission, organised by the International Bank for Reconstruction and Development (1955) to recommend research to be directed towards methods of harvest that will minimise loss by shattering.

Whether the character of indehiscent capsules will be used in a country as Nigeria, where sesame is grown by small farmers and labour costs are relatively low, depends on the following factors:

a. The actual amount of seed loss when the present farmers' practices are applied.
b. The possibilities of improvement of the harvesting methods.
c. The possibility of threshing indehiscent sesame by hand.
d. The possibility of introducing the indehiscence character in an acceptable cultivar.

The following paragraphs will deal in more detail with the factors mentioned.

6.1. HARVESTING OF SHATTERING SESAME: SEED LOSSES AND METHODS OF IMPROVEMENT

A number of field experiments was carried out during the years 1963, 1964 and 1966 to estimate the extent of seed loss for different harvesting methods presently applied and newly designed for seed loss reduction. One of the methods adopted for a little while for harvesting experimental plots was picking of the capsules by hand and it became of interest therefore to know the effect of picking on seed yield and the possibility of artificial drying. The experiments in these fields and their results are discussed in the next sections.

6.1.1. Harvesting methods and seed losses

The farmers' practices of harvesting by placing the plant bundles in shocks or to racks were compared with other methods of harvesting in respect of seed loss.

6.1.1.1. Materials and methods

The vigorous and well-branched cultivar Yandev 55 was used in all experiments. Plots consisted of eight ridges, 91 cm apart and 7.3 m long, and sowing was on the ridges at 15 cm spacing. Thinning was to one plant per stand.

The first series of four experiments investigated the effect of different harvesting methods on yield and so indirectly on seed loss as the actual yield is the potential yield minus seed loss during drying and threshing, or in a formula:

$y = Y - l_1 - l_2 = Y - L$

y = Actual yield

Y = Potential yield

l_1 = Seed loss during drying

l_2 = Seed loss during threshing

L = Total seed loss

The second series of three experiments was to find the actual amount of seed loss for different harvesting methods by spreading polyethylene sheets and jute sacks under the plant bundles after the harvest so that all shattering seed was caught.

Table 44 lists further details of the experiments.

TABLE 44. Information on planting dates, harvesting dates and designs of harvesting experiments at Mokwa.

Experiment	Year	Dates of		Design	Number of	
		planting	harvesting		Treatments	Replicates
1	1963	10/9	16/12	R.B.	4	4
2	1963	19/9	24/12	R.B.	3	4
3	1964	3/5	11/8	R.B.	2	10
4	1964	3/5	10/8 –11/8	L.S.	6	6
5	1964	1/9	30/11– 2/12	L.S.	6	6
6	1966	15/5	18/8 –19/8	R.B.	7	6
7	1966	20/8	9/11–10/11	L.S.	6	6

R.B. = Randomized Block L.S. = Latin Square

The following harvesting methods were tested:

1. Rack A: Plants were cut and bundled and the bundles were placed slantwise against a rack 2.7–3 m long, and about 0.9–1.2 m high, consisting of one horizontal pole supported by two or three forksticks. At threshing three or four jute sacks were spread under the rack and two or three close to the rack. The plant bundles were taken to the sacks close to the rack, turned over and threshed (Fig. 19a).
2. Rack B: As Rack A but the bundles were tied upright to the rack and threshing was on sacks spread around the treatment in abundance.
3. Rack C: As Rack A but the bases of the bundles were kept off the ground at both sides of the rack and rested on two 3 m long horizontal poles in two

small fork-sticks of 25 cm height. The distance between the two horizontal poles and the rack was 46 and 61 cm respectively. Shattered seed could be collected daily (Fig. 19b).

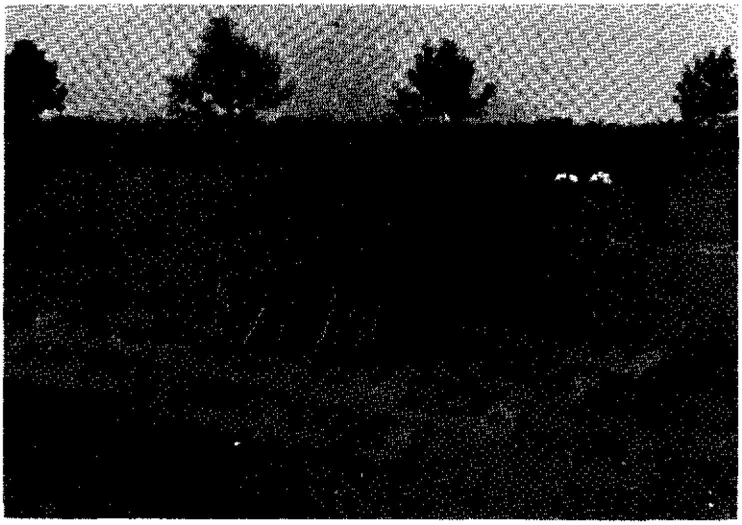
4. Pole A: Plants were cut and bundled and the bundles were tied to a pole 0.9 to 1.2 m high. At threshing two or three iute sacks were spread close to the pole. The plant bundles were taken from the pole to the sacks, turned over and threshed.
5. Pole B: As Pole A, but the pole was fitted and could move in a metal pipe in the soil and could be lifted, with the plants as a whole, at threshing when jute sacks were spread quickly underneath and around the pole.
6. Pole C: As Pole A, but the plant bundles were lifted as a whole shoving them up along the pole, which therefore had to be smooth. Sacks were spread immediately after lifting underneath and around the bundles.
7. Pole D: As Pole A, but with the bundles resting on cross-sticks nailed to the pole 20 cm above the soil. Shattered seed could be collected daily. At threshing, sacks were spread underneath and around the bundles (Fig. 19c).
8. Fence A: Plants were cut and bundled and the bundles were tied upside down to a fence of 3 m long and 1.8 m high, made of two vertical poles and three horizontal poles at 0.5, 0.8 and 1.2 m above the ground respectively. Plant bundles were beaten and seeds were collected daily.
9. Fence B: As Fence A, but with plants upright; the fence was 1.5 m high and had two horizontal poles at 0.6 and 1.5 m above the ground respectively. Shattered seeds could be collected daily (Fig. 19d).
10. Shock: Plants were cut and bundled and the four bundles of a plot were placed in a shock and tied together at the top. At threshing the bundles were taken to three jute sacks close to the shock, turned over and threshed.
11. Under-roof: Plants were cut and bundled and transported to a place where they could dry in the wind under a roof on polyethylene or sacks without any seed loss.
12. Picking: Capsules were picked from the plants by hand, dried and threshed on polyethylene or sacks without seed loss.

Rack C made it possible to determine seed loss during drying (l_1) and seed loss during threshing (l_2) separately; pole D and Fence B gave only seed loss during drying, and for the other methods only the total seed loss could be found provided that polyethylene or sacks were used under the treatments to catch the shattered seeds as in the second series of experiments.

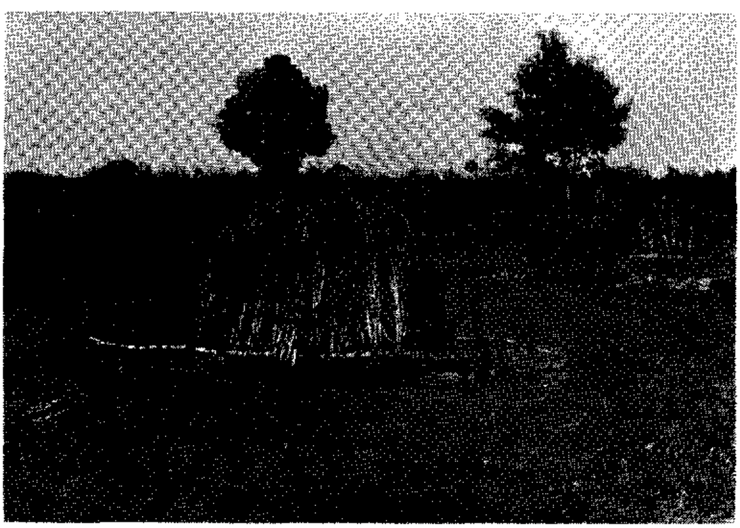
Special measures had to be taken against ants which often carry away sesame seeds to places of storage and against birds. In the former case insecticide was used, and a guard watched the experiment for bird hazard. Groundnut pods and traps were used to check the presence of mice and rats.

6.1.1.2. Results

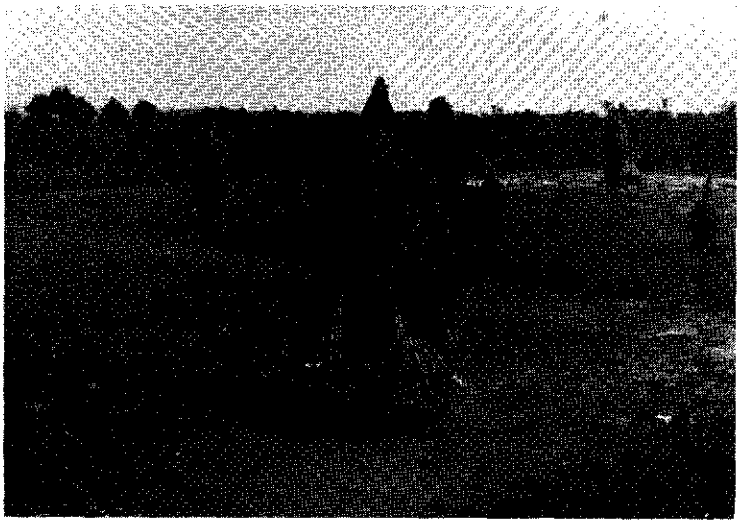
Table 45 presents the actual yield figures (y) for all experiments; the analyses of variance of the yield figures showed that the observed differences were statistically not significant at $P = 0.05$ level.



(a)



(b)



(c)

(d)

FIG. 19. Methods of harvesting. (a) Rack A (b) Rack C (c) Pole D (d) Fence B.

TABLE 45. Actual yields (y) in kg per ha for harvesting experiments at Mokwa during 1963, 1964 and 1966.

Harvesting method	Experiment						
	1963		1964			1966	
	1	2	3	4	5	6	7
Rack A	213	172	340	344	577	220	437
Rack B	–	–	–	352	–	–	–
Rack C	–	–	–	–	587	248	435
Pole A	231	–	–	352	–	–	–
Pole B	–	–	403	396	–	–	–
Pole C	–	–	–	–	588	220	432
Pole D	–	–	–	–	–	272	476
Fence A	–	–	–	–	645	–	–
Fence B	–	–	–	–	–	293	485
Shock	–	–	–	–	–	–	403
Under-roof	256	205	–	416	605	193	–
Picking	231	209	–	382	627	265	–

The total seed loss (L) in percentage of the potential yield (Y) for the second series of experiments, in which seed was caught with polyethylene and jute sacks, is shown in Table 46.

TABLE 46. Total seed loss (L) in percentage of potential yield(Y) for harvesting experiments at Mokwa during 1964 and 1966.

Harvesting method	Experiment		
	1964	1966	
	5	6	7
Rack A	8.0	4.4	8.9
Rack C	6.2	7.8	9.3
Pole C	2.6	4.8	5.3
Pole D	–	2.8	1.7
Fence B	–	1.6	1.1
Shock	–	–	9.0
S.E.D.	1.5	0.7	2.5

In Experiment 6 (1966), planted in May, the harvest was still in the rainy season and total seed loss (L) for Rack A and Pole C was in fact the total of seed loss at threshing plus a little of seed loss during drying as most of the seed, that dropped before threshing, decayed.

The seed loss during drying (l_1) and during threshing (l_2), expressed as percentage of the total seed loss (L) were for Rack C in Experiments 5 (1964) and 6 and 7 (1966) 15.5 and 84.5, 60.4 and 39.6, and 33.5 and 66.5 respectively.

The amounts of seed threshed daily from Fence A in Experiment 5 (1964) are shown in Table 47.

TABLE 47. Percentage of seed collected daily for Fence A in harvesting Experiment 5 (1964) at Mokwa.

Days after harvest	Percentage of seed collected	Days after harvest	Percentage of seed collected
3	2.4	13	3.5
4	4.6	14	2.9
5	8.5	15	1.6
6	12.0	16	1.1
7	17.1	17	0.6
8	14.5	18	0.8
9	10.7	19	0.6
10	8.8	20	0.4
11	4.2	21	0.5
12	4.0	22-onwards	1.2

6.1.1.3. Discussion and conclusions

In the first series of four experiments the actual amount of seed loss was not determined directly but by measuring the potential yield (Y) for the under-roof and picking method, and the actual yield (y) for the other methods. The difference (Y-y) would be an estimate of the seed loss, but it appeared that the difference between the treatments was not significant (Table 45). Apparently seed loss, observed as many scattered small white seeds, looks worse than it is. The normal farmers' harvesting practices of placing the sesame bundles in a shock or tying them to a rack may be compared with the methods involving a shock and Racks A and C in the experiments, which gave seed losses of about 8 to 9 per cent. A recommended method is Fence B (Fig. 19b) with seed loss less than 2 per cent. Methods Pole C and D are not so suitable when harvesting is done during the rainy season as plants and capsules do not dry well when tied tightly to a pole, but the methods are good for small experimental plots, especially when planting is in August–September and harvesting in the dry season.

Seed loss for Rack C may be compared with that for Rack A. In Experiment 5 (1964) seed loss during drying (l_1) was only 15.5 per cent of the total seed loss (L) for Rack C; in Experiment 7 (1966) it was 33.5 per cent, the much higher percentage probably being due to lodging of the crop shortly before harvesting; it amounted to 60.4 per cent in Experiment 6 (1966), the increase being caused by rain and hard wind during drying.

The amount of seed threshed out daily from Fence A increased till seven days after harvest and decreased to less than 1 per cent seventeen days after harvest. About 93 per cent had been collected two weeks after harvesting (Table 47). The adopted practice is to thresh for the first time two weeks after harvesting and to do a second and final threshing one week later.

The experiments show that seed loss can be considerably reduced and there is no advantage in using machinery for harvesting and threshing and planting non-shattering sesame only in order to reduce seed loss.

6.1.2. *Picking of capsules*

The method of harvesting by picking was suggested by officers of the Ministry of Agriculture for sesame experiments at Provincial Experimental Stations and it was also applied once, while the possibility of making the method suitable for farmers by using a sort of comb or stripper to remove the capsules from the plants was thought of (BOLHUIS, and Ministry of Agriculture, personal communications).

It was more or less assumed that the picking of the capsules as such would not affect the seed yield, but at the same time an observation was carried out to verify the assumption as will be described in the next section. It was also realized and experienced that drying of the capsules after picking or stripping was a problem during the rainy season similar to that of groundnuts after lifting and picking of the pods and the use of a cheap artificial drier as developed and described by A'BROOK (1963) or a grain drier, as in our case, could be tried for quick and efficient drying as described in 6.1.2.2.

6.1.2.1. Picking of capsules and seed yield

The following experiments were carried out during the early and the late cropping seasons of 1964 and 1967.

6.1.2.1.1. Materials and methods

Ten plants of the cultivar Yandev 55 were cut when mature, and from each leaf pair one capsule was picked off and one capsule was left on the plant. Where only one capsule was met in a leaf axil, it was removed and discarded, and where the two capsules in a leaf axil were clearly different in size or otherwise, both capsules were removed and discarded. The picked capsules were bulked, the plants were bundled, and all were dried in the sun. Each experiment had ten replications. After drying the seeds were collected and the weight, moisture content and 1000-seed weight determined. Oil contents of the seeds as received were analysed at Shika Agricultural Research Station.

6.1.2.1.2. Results

Table 48 shows the results of the four experiments.

6.1.2.1.3. Discussion

Seed yields and 1000-seeds weights were somewhat higher when the capsules were left on the plant than when the capsules were picked off, while the oil content figures showed an opposite trend; the differences were larger for the early season experiments than for the late season experiments. The figures therefore suggest that there is a negative effect from the picking on the seed development and that the effect is less significant during the late season, possibly because of the low relative humidity and the rapid drying of all plant material.

TABLE 48. Seed weight per ten plants in grams, 1000-seeds weight in milligrams, moisture and oil content in percentages of seed from capsules picked off or left on the plants in experiments during 1964 and 1967, early and late cropping season.

Year and season of Experiment	Treatment of Capsules	Seed Weight	1000-seeds Weight	Moisture Content	Oil Content*
	Picked	61.0	2324	7.1	–
	Left	72.7	2415	7.3	–
1964 Early	L.S.D. (0.05)	6.0	38	N.S.	–
	L.S.D. (0.01)	8.6	54	N.S.	–
	Picked	61.8	2182	4.2	55.57
	Left	65.4	2257	4.2	52.84
1964 Late	L.S.D. (0.05)	1.8	47	N.S.	–
	L.S.D. (0.01)	2.6	68	N.S.	–
	Picked	36.8	1619	d	49.55
	Left	45.9	1767	d	47.00
1967 Early	L.S.D. (0.05)	7.7	127	–	–
	L.S.D. (0.01)	N.S.	N.S.	–	–
	Picked	37.7	2425	d	45.80
1967 Late	Left	40.4	2477	d	45.50
	L.S.D. (0.05)	N.S.	N.S.	–	–

d: during dry season; no difference assumed.
*: oil content of seed as received.

6.1.2.2. Drying of picked capsules

Observations on the use of artificial drying of sesame capsules were carried out as follows.

6.1.2.2.1. Materials and methods

Sesame capsules on a mature crop were stripped off by hand and put in a layer of about 25 cm in an Airwoods grain drier with a floor capacity of about 3.7 × 2.1 m. The cultivar used was 57/244/11B. The temperature of the drier varied between 43–49 °C. Samples were taken from the middle of the layer of capsules at different places every hour and moisture content determinations were carried out for which a ventilated heat oven was used. At the end of the drying period samples were taken from different places in the drier and the number of green, brown, closed, a little opened and well opened capsules was recorded. The air temperature and humidity were recorded by a Casella thermohygrograph.

6.1.2.2.2. Results

The moisture content of the material in the drier decreased from about 75 per cent to 19 per cent over a period of 30 hours of drying (Fig. 20); moisture content of seed samples 22.5 hours after the drying started was 7.3 per cent. The air humidity and temperature graphs were normal for that time of the year; the air humidity decreased from 100 per cent during the night to approximately 60 per cent in the day time, and the temperature varied between about 23 and 31 °C.

After 30 hours of drying many capsules, though dry, were still closed and many showed only small openings. The classification was as follows:

Nature of capsules	Number	Percentage
Well open, brown	269	21.3
Well open, green	208	16.4
A little open, brown or green	341	27.0
Closed, green or brown	447	35.3

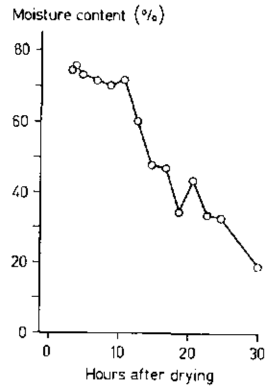


FIG. 20. Drying of picked capsules. Moisture content at different times during period of drying in grain drier.

6.1.2.2.3. Discussion and conclusions

The artificial drying of sesame was not satisfactory. It was a rather long process and the final result was disappointing in that too many capsules had remained closed which would cause seed damage at threshing.

Picking or stripping of capsules is a tedious work and a priori not an attractive method of harvesting. Sun drying of the capsules is also troublesome and risky if it rains frequently. The method may therefore be discarded for practical use; it may however be useful for experimental purposes.

6.2. Harvesting of non-shattering sesame

The question has been raised: if harvesting and threshing of sesame is not mechanized, would hand-threshing of indehiscent sesame be practical, and useful to reduce seed loss? Two experiments were carried out to answer the question.

6.2.1. *Materials and methods*

Three different indehiscent sesame cultivars were compared with the dehiscent cultivar Yandev 55 in 1966, and four in 1967 in small observation plots of 13–26 square m. Table 49 in the next section shows capsule characters of the cultivars. Ib.No. 15, Baco and Paloma are introductions from the United States (1964–1967); 57-6-116BI-56B and 57-6-116B-35 are local selections; Morada indehiscent was introduced from Venezuela.

Mature plants were cut, bundled, stacked and tied to a pole; jute sacks were spread underneath to catch all seed from shattering capsules. Threshing was done two to three weeks after harvesting as follows:

a. First threshing..... normal method by turning over the bundles and beating gently with a stick.
b. Second threshing... hard beating with a stick to crack the unopened capsules.
c. Final threshing..... opening the capsules by hand and collecting the remaining seeds.

For the 1967 experiment seeds were sorted after threshing in groups of damaged and undamaged seeds.

6.2.2. *Results*

Yield figures obtained for the different treatments in the two experiments are listed below.

TABLE 49. Hand threshing of indehiscent sesame. Characters of cultivars, year of experiment, seed yield for different threshing treatments as percentage of total seed yield, and total seed yield in grams.

Variety	Characters		Year	Yield as percentage				yield
				Sh.	(a)	(b)	(c)	
Ib. No. 15	id	p	1966	0.3	0.3	42.7	56.7	136
57-6-116BI-56B	id	P	1966	0.0	7.6	65.2	27.3	60
57-6-116B-35	id	P	1966	0.0	8.3	83.3	8.4	5
Yandev 55	Id	P	1966	0.5	91.7	6.1	1.7	581
Ib. No. 15	id	p	1967	0.0	4.9	68.3	26.8	235
Baco	id	p	1967	0.0	1.2	77.8	21.0	290
Paloma	id	p	1967	0.1	7.1	85.3	7.5	119
Morada indehisc.	id	P	1967	1.2	29.6	31.3	37.9	168
Yandev 55	Id	P	1967	0.5	86.9	123.	0.3	1221

Id = dehiscent, id = indehiscent; P = normal carpel, p = papershell carpel; Sh = shattering, (a) = first threshing, (b) = second threshing and (c) = final threshing.

The percentage of seed damage is shown in Table 50.

TABLE 50. Hand threshing of indehiscent sesame. Percentage of seed damage by weight in 1967.

cultivar	Percentage of seed damage			
	Sh.	(a)	(b)	(c)
Ib. No. 15	–	0.0	14.7	12.4
Baco	–	4.1	6.8	5.1
Paloma	0.0	1.4	11.8	4.7
Morada indehisc.	0.0	0.0	7.0	1.1
Yandev 55	0.0	0.0	1.2	0.1

Sh. = shattering, (a) = first threshing, (b) = second threshing and (c) = final threshing.

6.2.3. *Discussion and conclusions*

A simple method of hand-threshing left between 7 and 57 per cent of the seed behind in the capsules of indehiscent cultivars. Not only is hand-threshing tedious, it also causes a good deal of damage to the seed, whatever the method might be, and this results again in poor quality of oil. Effective threshing of indehiscent sesame will require good and expensive machinery.

6.3. USE OF THE CHARACTER INDEHISCENT CAPSULES

The previous chapters show that the indehiscence character is of no immediate use on farms where mechanization has not been adopted. It may become of use when mechanization is introduced, or when larger projects with mechanized farming are initiated.

To meet possible future demands for indehiscent cultivars, the character was introduced in a breeding programme at Mokwa, and the best line selected was back crossed several times to the cultivar Yandev 5, after which mass selection and line selection gave rise to the cultivar B.C.5.

The latest programme, which was started in 1971, makes use of the long, papershell and indehiscent capsule characters of the cultivar Baco by crossing it to the cultivars Cross. no. 3, X30/115, 65A-36, 65B-61 and Yandev 55, followed by alternating generations of open-pollination in isolation and backcrossing of the plants with the Baco capsule characters to the cultivars mentioned.

7. DISEASES AND INSECT PESTS

Sesame is very sensitive to many different diseases under the conditions prevailing in the main sesame growing areas of Nigeria and depending on weather and time of the year it can be severely attacked by different insect pests. The next sections will only briefly discuss main diseases and pests observed in Nigeria and will conclude with dealing in more detail with sesame leaf-curl.

7.1. Diseases other than leaf-curl and insect pests

Identification work and observations done at Mokwa on fungal and bacterial foliage diseases of sesame in Nigeria, have revealed (Fatmi, McDonald and Stonebridge, unpublished reports):

a. that the following organisms could be isolated from leaves of diseased plants:
Alternaria sesami
Cercospora sesami
Curvularia lunata
Cylindrosporium sesami
Fusarium semitectum
Helminthosporium halodes
Macrophomina phaseoli
Oidium sp.
Pestalotiopsis mayumbensis *Pseudomonas sesami* (?)

b. that the foliage diseases occurred normally as a complex and not as individual diseases and that it was difficult therefore to decide, which individual diseases were the most important ones; this was even more complicated as the picture of the symptoms changed from year to year.

c. that the pathogens *Cylindrosporium sesami*, *Cercospora sesami*, *Alternaria sesami* and *Pseudomonas sesami* are possibly the main members of the disease complex. Symptoms evoked by these pathogens individually are:

1. *Cylindrosporium sesami:* The lesions on the leaves are angular in shape, 4–10 mm across and of a greyish brown colour in the centre with lighter grey margin. The leaf spots may coalesce, covering sections of the lamina. Later during the development many minute, dark spots can be seen scattered over the lesions, indicating the sites of acervuli.

2. *Cercospora sesami:* The pathogen can attack all above ground parts of the plant and it commonly produces lesions on leaves, petioles, stems and capsules. The leaf spots have a brown centre with a more dark brown margin, are roughly circular in shape and from 2 to 4 mm in diameter, but they may coalesce to form lesions of about 8 mm in diameter. The petioles and the stems tend to have more elongated spots than the leaves. The lesions on the capsules are round in shape, slightly sunken in the tissue and at first of a brown colour which later becomes dark brown to black.

3. *Alternaria sesami:* Brown spots of about 5 mm diameter occur on stems, petioles and leaves. Typical is the brown colouring of the vein pattern and the drooping of the leaves.
4. *Pseudomonas sesami* (?): On the leaves angular, dark brown to black spots develop and marginal necrosis occurs. The individual lesions coalesce and the necrotic area rapidly spreads down the leaf blade to the petiole from which discoloured streaks may be seen passing down the stem and causing rotting and lodging.

Virus diseases reported for sesame are phyllody and leaf curl (WEISS, 1971).

Phyllody can be very harmful in India and Burma, the attack used to be very light in the Sudan and the U.S.A., and in Nigeria the damage caused by the disease is negligible; the incidence increased a little during the dry season in irrigated plots at Mokwa but it remained of minor importance. (KRISHNAMURTI, 1951; WEISS, 1971; VAN RHEENEN, 1969–'70, unpublished results of a questionnaire).

Leaf-curl can do much damage to sesame in India (JOSHI, 1961; GUPTA et al., 1963). In Nigeria it became a disease of major importance since 1964 and section 7.2. will deal with it in more detail.

Main insect pests in Nigeria are those caused by the moth *Antigastra catalaunalis* Dup. and by the gall midge *Asphondylia sesami* Felt. Larvae of the former are called leaf rolers or leaf webbers, they role and web the leaves together predominantly at the top of the plants and eat the young flower buds, flowers and young fruits. During prolonged periods of drought the damage can be considerable, but the pest can be controlled effectively with insecticides as Didimac and Gammalin (active ingredients D.D.T. and B.H.C.). The gall midge lays eggs in the ovaries and galls develop before the flowers open. The maggots feed on the surrounding tissue and pupate inside the gall. Capsules may be partly or totally affected and in extreme cases all or nearly all capsules of all plants of a field show galls and no yield is obtained at all. Chemical control is difficult but resistance against the gall fly has been found recently (CHADHA, unpublished reports, Mokwa Agricultural Research Station). Resistance to *Asphondylia* has also been observed in the species *Ceratotheca sesamoides* Endl., which is endemic in Africa and appeared to be cross-compatible with *Sesamum indicum* L. (VAN RHEENEN, 1970).

7.2. LEAF-CURL

JOSHI (1961) described the symptoms of a virus disease called leaf-curl which is responsible for heavy yield losses in India. The causal virus is *Nicotiana Virus 10* or *Tobacco Leaf-curl Virus*, which causes leaf-curl in tobacco, tomato, zinnia and other plants (SMITH, 1957). The vector is *Bemisia tabaci* Gen., an insect belonging to the order of the *Homoptera*, to the suborder of the *Aleyrodina* and to the family of the *Aleyrodidae* or white flies, a group of insects with wings and body dusted with a white powdery wax (WYNIGER, 1962; CASWELL, 1962).

Leaf-curl or similar diseases of sesame and sesamum species have been reported to occur in Tanzania and Sierra Leone (WALLACE, 1933; DEIGHTON, 1932 and 1940).

The disease was not mentioned in the list of plant virus diseases of Nigeria made up in 1963 (ROBERTSON, 1963), but it appeared with a question mark in the check-list of plant diseases in Nigeria of 1966 when it had been observed at Mokwa (BAILEY, 1966).

In 1964 a disease with symptoms as described by JOSHI (1961) lightly attacked the sesame crop at the Mokwa experimental farm, but it was very harmful in some of the treatments of a small planting dates experiment laid out in a nursery about four miles away from the experimental farm (7.2.3. and 7.2.5.). In 1965 the disease incidence was extremely severe at Mokwa and caused complete crop failures. A study of the disease was then started and continued till 1971.

7.2.1. *Disease symptoms*

At the time the flower buds appear, the top of the plant becomes brownish green and its leaves curl a little. Later the leaves curl downwards along each side of the midvein and at the top, the colour turns dark green or becomes even brownish and the surface looks more shiny than in healthy plants. The leaves also become brittle and their size is reduced.

The flower buds show a light-brownish, unhealthy colour, do not develop to normal size and produce small, poor-looking flowers.

The capsules may be brown, dark brown or even blackish in colour and may split open along the sutures.

Severely attacked plants show very stunted growth, and leaves and flower buds drop off, the brown stem tops being left without capsules.

The disease symptoms may appear on all or on only some aerial parts of the plant. In some cases, for example, only the main stem but not the branches were affected, or not the lower parts but only the top. Sometimes plants can grow away from the disease and produce a new series of shoots without disease symptoms. No disease symptoms have been observed on the roots.

Plants with leaf-curl symptoms were found to be more frequently attacked by sesame gall midge (*Asphondylia sesami* Felt.) than healthy plants (Fig. 21a).

7.2.2. *Distribution of the disease*

Leaf-curl occurs mainly in early and not in late sown sesame. In 1965 leaf-curl symptoms were observed in sesame crops in Tiv Division around Yandev, in Igbirra Division around Osara and in an experiment at Beli. In some fields certain patches showed symptoms of a severe attack.

During the years 1966–1970 the extent of the disease incidence was visually estimated in a number of farms and scored in a leaf-curl index on a scale of 0–5 (0 = no symptoms; 5 = very severe attack). In addition the percentage of plants with symptoms was estimated from a sample of twenty plants along a line choosen at random within the field. Table 51 shows details of the survey. The locations are divided in three groups, sited in Igbirra Division, Tiv Division and

Beli area respectively. Each year the same number of fields were inspected in each area but due mainly to reductions in crop acreage this was not always possible in the first group of four locations.

TABLE 51. Visual estimation of leaf-curl attack and percentage of plants with symptoms.

Farms visited		Leaf-curl index						Percentage of plants with disease symptoms					
		Year						Year					
Location between	Number	'66	'67	'68	'69	'70	Average	'66	'67	'68	'69	'70	Average
Osara – Egain	6	2.8	1.1	0.8	0.5	1.4	1.3	71	39	8	6	58	36
Egain – Okene	3	1.8	0.8	0.7	0.1	0.5	0.8	88	12	7	0	12	24
Okene – Osara	3	3.8	1.3	–	0.1	–	1.7	100	40	–	0	–	47
Osara – Lokoja	3	3.3	2.2	3.0	–	–	2.8	98	82	70	–	–	83
Oturkpo – Gboko	2	0.5	1.5	0.0	0.1	0.3	0.5	25	80	0	0	0	21
Yandev – Gburuku	4	0.0	0.5	0.1	0.1	0.6	0.3	0	15	0	3	16	7
Gboko – Ihugh	6	0.0	0.4	0.1	0.2	0.8	0.3	0	9	0	3	26	13
Yandev – Makurdi	5	0.0	0.3	0.1	0.8	0.2	0.3	0	9	0	20	2	6
Yandev – Katsina A.	5	–	–	–	0.5	2.1	1.3	–	–	–	13	59	36
Katsina A. – Tor D.	2	–	–	–	0.1	4.5	2.3	–	–	–	3	100	52
Tor Donga – Takum	2	–	–	–	0.0	3.5	1.8	–	–	–	0	93	47
Takum – Wukari	5	–	–	–	1.2	3.5	2.4	–	–	–	30	92	61
Wukari – Gburuku	5	–	–	–	1.7	3.1	2.4	–	–	–	53	85	69
Takum – Tissa	2	–	–	–	1.3	5.0	3.2	–	–	–	25	100	63
Tissa – Beli	3	–	–	–	3.0	3.8	3.4	–	–	–	92	97	95

The survey results show that leaf-curl is not a serious problem in sesame around Yandev where sowing is early i.e. with the first rains; delay of sowing was observed to cause an increase in disease attack. In Igbirra Division leaf-curl caused heavy losses in 1966, but was less harmful in the subsequent years. As a result of the losses in 1966 farmers grew less sesame in the years following. In eastern Tiv Division, around Takum and Wukari and in Beli area leaf-curl attack was considerable in 1969 and severe in 1970. At Mokwa leaf-curl was a major problem for early sown sesame since 1965 whenever planting was a little delayed.

7.2.3. *Losses caused by the disease*

The damage caused by leaf-curl may vary from negligible to disastrous. The following examples will illustrate the harmful effect of the disease.

a. The 1964 planting dates experiment referred to in the introduction of 7.2. consisted of treatments sprayed with the insecticides Gammalin and Didimac (B.H.C. and D.D.T.) and unsprayed treatments. The sprayed treatments, which were free from leaf-curl, yielded 7.5. times more than the unsprayed ones with severe disease incidence, the yield difference being mainly attributable to the difference in leaf-curl attack.

b. A cultivar trial with six cultivars was sown in May and its duplicate in August, 1965. Average yields of the early-sown crop, which suffered badly from leaf-curl, and of the late crop, which was free or almost free from symptoms, were 28 and 558 kg per ha respectively.

c. A yield trial with sixteen entries and five replications, sown in May 1968, was attacked by leaf-curl. The susceptible cultivar Yandev 55 yielded 237 kg per ha, while the best yielding leaf-curl resistant selection produced more than three times as much.

Obviously leaf-curl is a serious danger to common sesame cultivars, not only at Mokwa but also in Igbirra Division, eastern Tiv Division and Beli area.

7.2.4. *Vector and virus*

Spraying with insecticides controlled leaf-curl (7.2.3.). This suggested that insects rather than fungi or nematodes were involved. The absence of clear insect injuries and the nature of the disease symptoms further suggested that insects causing leaf-curl did so as vector of a virus disease. The description and picture of sesame leaf-curl symptoms by JOSHI (1961) showed a striking similarity with the symptoms observed at Mokwa and suggested that the same causing agents were involved.

On two occasions samples of plants showing leaf-curl symptoms were forwarded to the Virus Research Unit, Cambridge, for further analysis, but the material was received in an unsatisfactory state. Investigations were then initiated at Mokwa to identify vector and virus and to check on possible other ways of disease transmission.

7.2.4.1. Materials and methods

a. Cylindrical isolation cages, 61 cm in diameter and 1.2 m long, made of wire and fitted to contain a polyethylene pot, were used for virus transmission experiments. They were hung on a line off the ground. Muslin cloth, sewed to fit the cage, made it white-fly proof. Water supply to the pot was effected through a rubber tube, closed off with a cork (Fig. 21c).

b. A nursery cage, covered with muslin cloth, 91 cm long × 48 cm wide × 76 cm high, made of metal rods, provided with a wooden floor and standing off the ground, was used to raise plants. Water supply was as described under (a).

c. Small muslin cages made of wire, which could be placed over pots with plants, were used temporarily to provide protection against white flies.

d. Screened houses, 4.5 m long × 2.7 m wide × 2.2 m high, were used for virus transmission with plant sap and grafting.

Black polyethylene pots, 11.4 cm in diameter and 25.4 cm high, filled with a sand and compost mixture, were used to grow plants.

White flies were caught by sucking these off plant leaves by means of glass tubes closed at one end with loose cotton wool.

Carborundum powder used was of 300 mesh.

Two methods of grafting were applied: (1) The wedge graft method with wedges about 10–15 mm long and (2) the chips graft method with stem chips of approximately 15 mm length.

Test plants were of the following species:

Althaea officinalis L.
Capsicum annuum L.
Crotalaria iuncea L.
Nicotiana glauca L.
Nicotiana glutinosa L.
Nicotiana tabacum L.
Petunia hybrida (Hook.) Vilm.
Solanum lycopersicum L.
Solanum melongena L.
Zinnia elegans Jack.

7.2.4.2. Vector of leaf-curl

In 1966, seed of the early-flowering, short sesame cultivar Dulce was sown in four cylindrical isolation cages. When the plants were about 5 cm tall white flies were caught separately from three different places: In a sesame crop with leaf-curl, in tomato and sweet pepper plots showing symptoms similar to sesame leaf-curl, and in an isolated cassava farm. The white flies from the different places were transferred to different isolation cages. A fourth cage, serving as a control, received air from the different places, without white flies.

Where white flies from sesame or tomato and sweet pepper had been introduced, sesame plants developed the characteristic leaf-curl symptoms. They failed to do so in the other two cages.

In 1967, seed of the sesame cultivar Dulce was sown in two cylindrical isolation cages. As from about two weeks after sowing white flies were caught over a sesame crop with leaf-curl symptoms and transferred to one of the two cages. The other cage was used as control. About five weeks after sowing the plants in the cage with the white flies developed typical leaf-curl symptoms, the plants in the control cage remained healthy. Pupal cases and larvae found on the plants in the former cage were forwarded to the Commonwealth Institute of Entomology, London for determination. They appeared to be mainly from *Bemisia tabaci* Gen. and for about 10 per cent from *Trialeurodes desmodii* Corbett.

In 1968, seed of the sesame cultivar Dulce was sown in two cylindrical isolation cages. As from about two weeks after sowing white flies, caught in the centre of an isolated cassava field, were transferred via diseased sesame plants of the cultivar Dulce, growing in a round isolation cage, to one of the two cages. The other cage received, as a control, white flies from cassava but via healthy sesame.

The plants in the cage with white flies from cassave via diseased sesame showed leaf-curl symptoms about five weeks after sowing. The plants in the control cage remained free from symptoms. Pupal cases and larvae from the cassava plants were forwarded to the same address as before for identification and were found to be from *Bemisia tabaci* Gen.

The conclusion is that white flies, and likely *Bemisia tabaci* Gen. transmit the disease characterised by leaf-curl symptoms. The white flies from cassava were clean and free from the disease.

7.2.4.3. Test plants

Plants of the ten species mentioned in 7.2.4.1. were used as test plants, either by keeping them under observation after sowing in pots in a screened house, in which white flies from a sesame crop with leaf-curl were released, or by growing them in cylindrical cages, in which white flies caught over a sesame crop with leaf-curl symptoms were brought, or in to which white flies from cassava via diseased sesame were transferred. Control plants were grown simultaneously.

The following plant species showed no leaf-curl symptoms and developed well and normally under all circumstances: *Althaea officinalis*, *Crotalaria juncea*, *Nicotiana glauca*, *Nicotiana glutinosa*, *Petunia hybrida* and *Solanum melongena*.

Other plant species showed the following disease symptoms:

a. *Capsicum annuum:* The leaves curled down round the midvein and at the top, the leaf stalk bent down, the colour of the leaves turned dark green to brownish and the leaf surface looked more shiny. The veins were thick and so were the leaves and leaf stalks. The leaves were brittle and reduced in size, and dropped off easily (Fig. 21d).

b. *Nicotiana tabacum:* The leaves curled down along each side of the midvein and length-wise, their colour turned light brownish and the veins were thicker than normal.

c. *Solanum lycopersicum:* The leaves curled and twisted, their colour turned dark green or brownisch, the veins became thick and the leaflets thick and brittle.

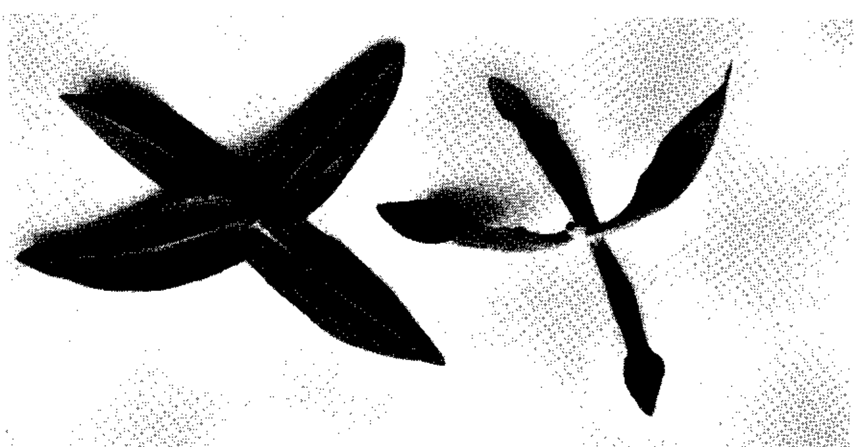
d. *Zinnia elegans:* The leaves curled down round the midvein and length wise, their colour turned dark green to light brownish and they became brittle and remained smaller than normal. The veins were a little thicker and the flowers somewhat smaller than usual (Fig. 21b).

7.2.4.4. Attempt of sap transmission

In 1970, seed of the sesame cultivar Dulce was sown in pots in one of the screened houses. About seven weeks after sowing sap transmission was attempted on 43 plants. Leaves derived from sesame plants with leaf-curl symptoms were ground in a mortar. The inoculum was rubbed gently over the top leaves of the test plants, which had been dusted with carborundum powder. Healthy plants supplied foliar material for the treatment of 43 control plants.

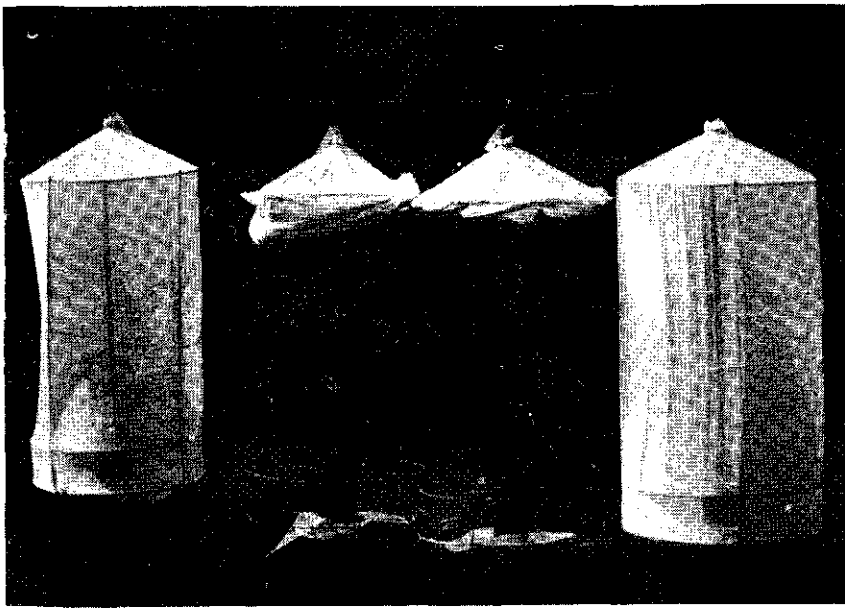
No leaf-curl symptoms developed on any of the plants. The last observation was made five weeks after the treatment.

(a)



(b)

FIG. 21. a. Leaf-curl of sesame b. Leaf-curl of Zinnia.



(c)

(d)

FIG. 21. c. Cylindrical isolation cages d. Leaf-curl of capsicum.

7.2.4.5. Graft transmission trials

In 1966 the wedge graft method was applied for grafting diseased sesame scions, cultivar Yandev 55, on eight healthy tomato plants of the cultivar Money maker. The control consisted of healthy sesame grafted to three healthy tomato plants. The chips graft method was used to graft diseased Dulce and Money maker to five healthy Dulce and five healthy Yandev 55 plants respectively. The control had healthy Dulce and Money Maker grafted to the same number of healthy stock plants.

In 1970, the wedge graft method was applied for grafting diseased Yandev 55 on 22 healthy Dulce plants. The control consisted of healthy Dulce scions grafted to 21 healthy Dulce plants.

The grafting was done four to seven weeks after sowing, either in pots in one of the screened houses or in cylindrical isolation cages.

All wedge grafts with diseased scion material failed except two made in 1970, while in the same year nine grafts with healthy material were succesful. All chips grafts failed to establish. No disease symptoms developed on any of the plants.

7.2.4.6. Seed transmission trial

In 1970 seed was harvested from a sesame plant of the cultivar Dulce, which showed very severe leaf-curl symptoms in all aerial parts including the capsules. Immediately after harvesting the seed was sown in pots in one of the screened houses and in a nearby nursery. There were 25 plants at each place.

About eight weeks after sowing most plants in the nursery showed leaf-curl symptoms, while all plants in the screened house were without symptoms.

7.2.4.7. Discussion and conclusions

None of the sesame diseases described from other parts of the world has symptoms similar to the ones described here except sesame leaf-curl caused by Tobacco Leaf-curl Virus. The only disease reported by SORAUER (1954), SMITH (1957) and CORNUET (1959) as being transmitted by white flies and causing leaf-curl symptoms on tobacco, tomato and zinnia is that caused by Tobacco Leaf-curl Virus.

Description and picture of sesame leaf-curl by JOSHI (1961) suggest that sesame leaf-curl in Nigeria is caused by a virus, that is closely related to the virus causing leaf-curl in India, although it has never been observed here, as it has in India, that 'some diseased plants may also bear enations on the lower surface of the leaves.' THUNG (1932) described three different types of tobacco leaf-curl or kroepoek diseases, two with enations and one without enations. PAL and TANDON (1937) described five different types of tobacco leaf-curl, three with and two without enations along the veins on the dorsal side of the leaves. MCCLEAN (1940), when working with his severe form of tobacco leaf-curl, found that in the course of the transmission of leaf-curl to tobacco by white flies and in the transmission of the disease by grafting between various Solanaceous hosts, two new forms arose, a mild form and a latent form. SMITH (1957) stated that the manifestation of tobacco leaf-curl varies greatly with environment and cultivar. At Mokwa leaf-curl, when transmitted from sesame to tobacco, caused only mild symptoms with no enations nor vein clearing.

Tomato plants infected with tobacco leaf-curl virus may or may not show enations on the undersurface of the leaflets (McCLEAN, 1940; NARIANI, 1968). The leaf-curl symptoms of tomato at Mokwa seem to correspond with those caused by the mild form of the tobacco leaf-curl in McCLEAN's (1940) tomato material. The symptoms induced in zinnia at Mokwa seemed to resemble rather well the leaf-curl symptoms caused by tobacco leaf-curl as described by SMITH (1957). NARIANI (1968) transmitted enation leaf-curl of tomato to *Capsicum annuum*, which then showed mild curling and reduction in size of the leaves and general stunting of the plants. THUNG (1932) induced by virus transmission leaf-curl symptoms in *Nicotiana glauca*, McCLEAN (1940) in *Petunia* and *Nicotiana glutinosa*, plant species which failed to show leaf-curl symptoms at Mokwa. McCLEAN (1940) observed that the reaction of his *Nicotiana glauca* to severe leaf-curl was so slight that it easily escaped detection; his *Solanum melongena* plants, when exposed to infective white flies, developed only a faint yellow network on the upper surface of a few leaves, and thereafter produced normal foliage; he observed that hollyhock plants growing in Durban showed symptoms like leaf-curl, but no attempt was made to transmit the disease and to investigate its relationship to the other forms of leaf-curl. THUNG and HADIWIDJAJA (1953) found in Java plants of *Crotalaria anagyroides* with leaf-curl symptoms which were proved to be of virus origin; also *Crotalaria iuncea* has been reported to show leaf-curl symptoms, but for both *Crotalaria* species the indentity of the virus has not been established. At Mokwa symptoms similar to leaf-curl have been observed on *Vicoa leptoclada* (WEBB) Dandy, *Dahlia* and *Cosmos sulphureus* Cav.

Leaf-curl can be transmitted by grafting (SMITH, 1957), but at Mokwa grafting as such yielded very little success, and transmission of the disease was not observed.

Leaf-curl cannot be transmitted with plant sap (SMITH, 1957), which was confirmed by the sap transmission experiment.

7.2.5. *Sowing date and leaf-curl*

The 1964 planting dates experiment referred to in the introduction of 7.2. showed that the unsprayed treatments sown in April developed less severe leaf-curl symptoms than the treatments sown between May and July; during August leaf-curl attack decreased again, while the treatments sown in September were only very lightly attacked.

From 1965 till 1971 early-sown sesame at Mokwa was severely attacked by leaf-curl, if there was a delay in planting after the onset of the first rains, whereas the late sesame crop, sown in August and September, was practically free from disease symptoms.

The observations that leaf-curl increases, when sowing is delayed after the first rains, and decreases again, when sowing is practiced in August and September, was confirmed in planting dates experiments conducted in 1966 and 1967. During these years an attempt was made to observe the fluctuation in size of the white fly population by means of vertical, yellow, cylindrical, sticky traps as used by A'BROOK (1968) with a trapping area of approximately 9.3 dm^2. Leaf-curl indices were determined as described in 7.2.2.

In 1966, the cultivars Dulce and Yandev 55 were sown weekly in plots of ten ridges, 91 cm apart and 9.1 m long. The intra-row spacing was 15 cm and the date of first sowing was 4th May. The number of stem nodes between the cotyledons and the capsule at the highest position, was counted and recorded; in case no capsule had formed the figures 8 and 2 were recorded being minima for Yandev 55 and Dulce respectively.

In addition, the total number of capsules formed on the stem was counted.

Table 52 shows results of scores and counts of nodes and capsules for the first seven sowing dates.

TABLE 52. Leaf-curl index, node number of highest capsule on the stem, and number of capsules on the stem as averages for twenty plants in the first seven sowing dates during 1966.

Sowing date	Yandev 55 Leaf-curl index	Yandev 55 Nodes	Yandev 55 Capsules	Dulce Leaf-curl index	Dulce Nodes	Dulce Capsules
4th May	2.7 ± 0.1	26.7 ± 1.5	19.1 ± 1.8	0.5 ± 0.0	19.5 ± 0.7	?
15th May	3.6 ± 0.2	24.1 ± 2.7	11.7 ± 2.3	0.8 ± 0.1	16.1 ± 0.4	?
18th May	4.3 ± 0.2	17.6 ± 2.2	7.8 ± 2.1	1.6 ± 0.2	15.7 ± 0.9	35.5 ± 2.6
25th May	5.0 ± 0.0	12.0 ± 1.1	2.0 ± 0.7	2.6 ± 0.2	12.7 ± 1.1	24.6 ± 2.0
1st June	5.0 ± 0.1	9.4 ± 1.0	1.0 ± 0.6	3.7 ± 0.1	13.1 ± 1.6	10.1 ± 1.5
8th June	5.0 ± 0.0	9.2 ± 0.9	0.8 ± 0.5	4.4 ± 1.0	12.7 ± 1.6	6.8 ± 0.8
15th June	5.0 ± 0.0	8.0 ± 0.1	0.1 ± 0.1	4.7 ± 0.8	6.1 ± 0.8	4.0 ± 0.8

When the sowing was delayed, the disease symptoms became more severe. More flowers and flower buds dropped off, which resulted in a lower position of the last-formed capsule and reduced the number of capsules on the stem.

The results of the later sowing dates were somewhat confused by leaf-spot diseases and insect attack, but disease scores, here per plot, show that the attack became less severe at the end of July and in August (Fig. 22).

Fifteen traps around the experimental farm, one in a nursery and one trap per plot in the experiment, were set at 60 cm height to catch white flies.

Fig. 22 shows the average number of white flies caught per trap and per month. During May the number caught was small, it increased during June, decreased again in August, was small during September and October, and then increased rapidly during November and December.

In 1967, a sowing date Split-Plot experiment was laid out in which the cultivars Dulce and Yandev 55 were assigned to the whole plots and seven different sowing dates to the sub-plots. There were three replications, the plot size was ten ridges, 91 cm apart and 9.1 m long, and the spacing between the plants on

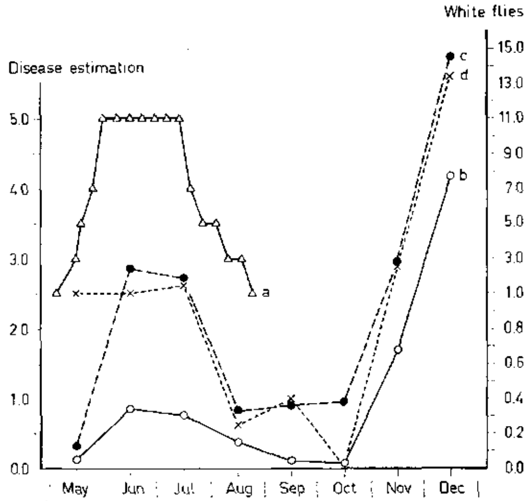


FIG. 22. Estimation of leaf-curl incidence for different sowing dates (a), and average number of white flies caught per trap per month during 24 hours around the experimental farm (b), in the sowing date experiment (c) and in a nursery (d) at Mokwa during 1966.

the ridges was 15 cm. White-fly traps were placed in the middle of the plots, but only in two of the three replications and only for the first, third, fifth and seventh sowing dates. The traps were kept at crop level and used only once a week for 24 hours. For each plot the leaf-curl index was determined shortly before harvest. Average numbers of white flies per trap per 24 hours were calculated for the first, second and third month after planting, and observations on different plant characters were made at or after harvest (Table 53). Again the experience was, that when sowing was delayed after the onset of the rains, the disease symptoms became more severe, the plants remained smaller, less leaves developed on the stem, branching was reduced, the stem girth was smaller, less capsules developed on stem and branches, and the seed yield decreased as well; but as from August a clear improvement occurred in respect of these characters. Average numbers of white flies caught per trap per 24 hours during May till December for each month were 18.6, 25.6, 13.1, 26.4, 7.2, 9.0, 33.0, and 55.4 respectively. They again showed the increase during June, the low level during September and October, and the rapid increase during November and December. The number of white flies trapped during August was relatively higher than in the previous year.

During the period April 1970–April 1971 fortnightly five pots were placed in a circle at three different sites in a nursery where throughout the year tomatoes and sweet peppers were grown. The pots were sown with seed of the cultivar Dulce. In the centre of the circle which had a diameter of about 1.5 m, a trap was placed and kept at crop level. Catching for 24 hours and counting of white flies was done weekly. From the data thus obtained average numbers of white flies,

TABLE 53. Leaf-curl index, number of white flies trapped per 24 hours and plant characters for the sowing dates trial in 1967. Measures in cm and weights in kg.
* = less than 1.

Observation	Yandev 55 Sowing date						
	20–4	31–5	21–6	12–7	2–8	23–8	13–9
Leaf-curl index	2.0	4.5	5.0	5.0	1.0	0.6	0.5
White flies (first month)	24.0	–	11.5	–	30.0	–	9.8
White flies (second month)	30.8	–	22.0	–	5.0	–	20.8
White flies (third month)	4.9	–	5.8	–	7.9	–	39.9
Plant length	142	93	52	39	56	98	94
Total length primary branches	497	209	25	35	92	190	150
Total length secondary branches	215	93	2	3	39	46	22
Leaf pairs on stem	39.6	25.1	18.4	16.2	21.5	27.5	26.6
Girth between 5th and 6th node	4.8	4.1	2.8	1.5	2.8	3.0	3.0
Capsules on stem	18.7	1.8	0.1	0.1	6.4	21.3	21.9
Capsules on primary branches	82.7	10.3	0.1	0.1	23.1	54.5	39.9
Capsules on secondary branches	45.7	11.8	0.2	0.0	7.8	9.6	5.5
Capsules per plant	150.6	25.3	0.2	0.2	37.3	85.5	67.3
Seed yield per plant × 10,000	101	25	*	*	29	104	81

Observation	Dulce Sowing date						
	20–4	31–5	21–6	12–7	2–8	23–8	13–9
Leaf-curl index	0.8	4.0	5.0	5.0	2.7	0.8	0.7
White flies (first month)	21.2	–	13.1	–	27.9	–	10.1
White flies (second month)	33.8	–	26.8	–	7.5	–	22.8
White flies (third month)	6.1	–	8.2	–	4.9	–	44.7
Plant length	58	51	31	33	28	29	42
Total length primary branches	98	14	14	8	2	2	3
Total length secondary branches	14	0	0	1	0	0	0
Leaf pairs on stem	34.3	23.7	12.7	14.1	15.3	13.7	20.1
Girth between 5th and 6th node	2.8	2.8	1.5	1.5	1.5	1.5	2.5
Capsules on stem	54.0	18.2	2.0	1.4	4.9	12.0	41.1
Capsules on primary branches	62.7	2.9	0.5	0.3	0.4	0.8	0.7
Capsules on secondary branches	3.2	0.0	0.0	0.1	0.0	0.0	0.0
Capsules per plant	119.9	21.1	2.5	1.8	5.3	12.8	41.8
Seed yield per plant × 10,000	45	5	*	*	1	19	37

caught per trap per 24 hours during the first and second month after planting, were calculated. About nine weeks after planting, leaf-curl indices were determined for each plant. The results of the observations are shown in Fig. 23.

Different from the experience at the experimental farm, the plants of planting dates 18th April and 2nd May showed severe leaf-curl symptoms; thereafter the disease incidence decreased, and showed an increase again during July, remained severe during August and September, and decreased during October. It

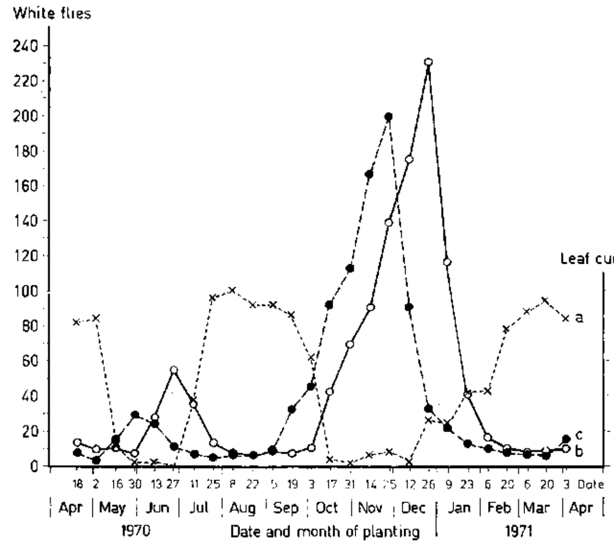


FIG. 23. Estimation of leaf-curl incidence for different sowing dates (a), and average number of white flies caught per trap per 24 hours during the first (b) and second month (c) after sowing at Mokwa during 1970–1971.

remained mild during November and part of December after which the attack became gradually more severe.

The results of the white flies trapping were comparable with those obtained previously. SQUIRE (1960) found that the white fly population at Ibadan was at a minimum during the dry season, increased after the onset of the rains and then showed a decrease from the middle of September onward owing to the appearance of a parasitic fungus. At Mokwa, the white fly population increased after the onset of the rains, showed a decrease during August or September, and increased greatly during November.

Generally it has been found, that planting as early as possible with the onset of the rains, gives a healthy or lightly infected crop; it was observed that the white fly population was relatively small during that part of the year. Delay of planting caused more disease incidence; at the same time the white fly population was observed to increase. Planting about the middle of August also gave rise to a healthy or lightly affected crop; the white fly population then was observed to be relatively small. However the size of the white fly population is not the only factor to influence leaf-curl as Table 53 and Fig. 23 show. One crop may show greater numbers of white flies trapped and at the same time less severe leaf-curl symptoms than another crop. GIHA and NOUR (1969) stated that, in the Sudan, leaf-curl of cotton, varies through the season and from year to year, but that it is not yet known whether these fluctuations are caused by environmental factors affecting the crop, the vector or both. The fact that at Mokwa the fluctuations in disease incidence cannot be fully explained by the magnitude of the white fly population, and the observation that severely attacked plants may recover in August to September, suggest that environmental factors, acting on the plant-virus relationship, contribute to the seasonal fluctuations. The observation that the cultivar Yandev 55, with a longer growing season and later flower initiation than Dulce, showed an earlier decrease of leaf-curl symptoms at later sowing dates, seems to point in the same direction (Table 53).

7.2.6. *Resistance to leaf-curl*

In 1965 leaf-curl was so severe that it caused total or almost total crop failures at Mokwa, and even the maintenance of cultivars and selections was a problem. One of the experiments that failed was a spacing trial with the cultivars Dulce and Yandev 55. The Dulce plants were the first to show the typical leaf-curl symptoms except for a few that looked healthy and green and flowered well. These differed from normal Dulce plants in that they were covered with many hairs.

A similar behaviour of plants was observed in F4 populations of crosses between various parents: All populations were severely attacked except those of the crosses X30/46 × Oro (61/1) and Oro × X30/46, (61/6) which were in general more hairy than the others. Within the two populations plants differed in hairiness and disease symptoms. A visual estimation on a scale of 0 to 5 (0 = character not expressed; 5 = character very clearly expressed) was made for fifty plants of population 61/1 and for twenty-five plants of 61/9 (Cross: X30/46 × V16/U) in respect of the following characters:

Leaf-curl incidence.
Density of stem-hairiness between fifth and sixth node.
Length of stem-hairs between fifth and sixth node.
Density of leaf-hairiness, dorsal side, at fifth node.
Length of leaf-hairs, dorsal side, at fifth node.

For 61/1 correlation coefficients, and for both populations average values of the visual estimations were calculated (Table 54).

TABLE 54. Correlations between characters for population 61/1 and visual estimates (0–5 scale) of characters for 61/1 and 61/9 during 1965, early season.

Character	Correlation coefficient					Visual estimate	
	leaf curl	Stem-hairs		Leaf-hairs		61/	61/9
		density	length	density	length		
Leaf-curl		–0.8	–0.8	–0.4	–0.4	1.6	5.0
Density stem-hairs	–0.8		0.9	0.6	0.5	4.4	0.9
Length stem-hairs	–0.8	0.9		0.4	0.5	4.6	3.3
Density leaf-hairs	–0.4	0.6	0.4		0.2	3.1	1.1
Length leaf-hairs	–0.4	0.5	0.5	0.2		1.9	1.0

There appeared to be a distinct negative correlation between leaf-curl and hairiness.

Within population 61/1 small patches of diseased plants could be recognised at some distance. For ten such patches the plant with the most severe symptoms was chosen for a visual estimation of the characters shown in Table 54 and the average scores were 4.6, 2.1, 3.6, 1.9, and 1.4 respectively, showing again, when compared with the visual estimates for 61/1 in Table 54 that hairiness protected against leaf-curl.

Unfortunately, hairiness was found to be associated with caterpillar attack, mainly of *Antigastra catalaunalis* Dup., especially during dry periods in the growing season. Similar observations as described were made in the late planted crop, growing under dry conditions, with the difference that the visual estimation of leaf-curl was replaced by that of caterpillar attack. Table 55 shows the results.

TABLE 55. Correlation between characters for population 61/1 and visual estimates (0–5 scale) of characters for 61/1 and 61/9 during 1965, late season.

Character	Correlation coefficient					Visual estimate	
	cater-pillar	Stem-hairs		Leaf-hairs		61/1	61/9
		density	length	density	length		
Caterpillar		0.8	0.6	0.6	0.7	2.8	0.6
Density stem-hairs	0.8		0.7	0.6	0.6	3.9	0.9
Length stem-hairs	0.6	0.7		0.5	0.7	4.2	2.6
Density leaf-hairs	0.6	0.6	0.5		0.3	3.2	1.3
Length leaf-hairs	0.7	0.6	0.7	0.3		1.8	1.0

There appeared to be a clear positive correlation between caterpillar attack and hairiness.

Within population 61/1 single plants with only little caterpillar damage could be recognised at some distance. For ten such plants the visual estimates of the characters as shown in Table 55 were 0.6, 1.1, 1.9, 1.5 and 1.0 respectively, demonstrating again that hairiness was associated with caterpillar damage.

In 1965, a total of 148 single plant selections was made for leaf-curl resistance in the cultivar Dulce, the F4 population 61/1 and 61/6 and in progenies of pedigree selections. Most of the plants were well covered with hairs, but some were only slightly hairy. In 1966 seed of the selected plants was sown in progeny rows, while Yandev 55 was sown in control rows. About forty-five progenies showed no or almost no disease symptoms. The average yield of Yandev 55 was 44 kg per ha and the best progeny row yielded 743 kg per ha. In 1967 seed from thirty-five progeny rows was used for sowing a replicated experiment in which Yandev 55 was again utilised as control. The experiment was sown with the onset of the rains, leaf-curl attack was less severe than in 1966, but drought and caterpillars, mainly *Antigastra catalaunalis* Dup, were harmful. Yandev 55 yielded 513 kg per ha and the best selection yielded 768 kg per ha. Seed harvested from twelve selections was used to sow a replicated experiment in 1968. Here Yandev 55 yielded 236 kg per ha, all twelve selections yielded more than Yandev 55, and the best selection yielded 729 kg per ha. Although the resistance to the disease appeared to be not complete, the difference in resistance between Yandev 55 and the selections was most striking in the years that followed.

TANDON and BANERJEE (1968) tested a number of insecticides and found Endrin, sprayed weekly from two weeks after sowing till harvest, the best to control leaf-curl. It reduced the percentage of infection from 32 to 8 per cent. They also screened a collection of 26 different cultivars and found five cultivars moderately resistant. In India SINGH (1963) screened a collection of sesame cultivars for leaf-curl resistance and found that the cultivars N.P.6, B/5, B/14 and B/54 had normal formation of capsules, good setting of seed and could be considered resistant. GEMAWAT and VERMA (1971) however observed that N.P.6 was susceptible to leaf-curl.

At Mokwa the cultivar N.P.6 showed a certain degree of resistance, but at the end of the growing season leaf-curl symptoms appeared and the yield was low. All four cultivars mentioned were tested against Mokwa selections in 1968, using plots of three ridges, 91 cm apart and 5.5 m long, with each introduction and selection being flanked by Yandev 55 control plots. Table 56 presents yields as percentages of th control plots.

TABLE 56. Yields of cultivars and selections as percentages of those of Yandev 55, during 1968.

Cultivar or selection	Origin	Yield
N.P.6	India	36
B/5	Sudan	21
B/14	Sudan	25
B/54	Sudan	184
65A-30	Mokwa	172
65A-36	Mokwa	209
65A-124	Mokwa	139
65A-90	Mokwa	86

The cultivars B/5 and B/14 were susceptible to leaf-curl at Mokwa, N.P.6 was lightly attacked and B/54 was resistant. The latter cultivar has brown seed and is densely covered with long hairs.

From the results reported here it is concluded (a) that leaf-curl resistance exists; (b) that it occurs in plants densely covered with hairs, in which case possibly the hairs keep off the white flies, but (c) that it has also been found in very slightly hairy plants; and (d) that caterpillar damage was more severe in hairy than in glabrous plants.

SUMMARY

Sesame (*Sesamum indicum* L.) is a crop of great antiquity and probably one of the oldest oilseeds under cultivation. No records on sesame outdate those of Babylon in Sumeria where it was known in 2350 B.C. At present the crop is grown in many tropical and subtropical countries, among which India, China, Mexico, the Sudan and Venezuela rank first in production. Since 1967 most published research has been carried out in India and Venezuela.

The total world production which varies considerably from year to year, has shown since 1950/1951 no consistent trend of increase or decrease. It amounted to about 1.8 million ton both in 1950/1951 and 1969/1970. Approximately 10 per cent of the production moves into international trade. In Nigeria purchases of sesame seed by the Marketing Board arrived at 17,459 ton in 1969/1970 and 5,714 ton in 1970/1971. The export is mainly directed towards Italy.

Sesame seed contains about 50 per cent oil and 20 per cent protein, it is a popular constituent of various local dishes and is highly regarded because of the good quality of its oil.

The crop is well established in parts of four provinces of the Northern States of Nigeria. The production areas are characterised by their location between latitudes 6° and 10°, a duration of the dry season of about 4 to 5 months, an annual rainfall of about 1,000–1,500 mm, a vegetation of rather open savannah woodland and a top soil of loamy sand. The cultivation and crop handling follow traditional patterns and the use of machinery is uncommon.

Most of the experimental work reported here has been carried out at the Agricultural Research Station, Mokwa, Nigeria. Section 4 deals with spacing and density experiments. Ways of sowing vary in the different production areas of Nigeria, but basically two methods can be distinguished: (a) The Igbirra method, characterised by sowing on ridges about 4 m apart at a spacing of 145 cm between the stands and with about 16 plants per stand, and (b) the Tiv method, which involves broadcasting, rarely followed by thinning; plant counts per unit area showed considerable variation, the mean plant density value being calculated as 673,000 plants per ha. In view of soil and water conservation, sowing on ridges has been a recommended practice in Nigeria for a long time, the distance between the ridges usually being 91 cm. The experimental results under such conditions were interpreted as to give an optimum for a spacing of about 6 cm on the ridges. Sowing on the flat in 1971 produced a maximum yield at a spacing of about 22 × 13 cm. In this case a formula derived from BLEASDALE and NELDER (1960) was found to describe well the relation between spacing and yield. In both methods, described under (a) and (b), there is room for improvement.

In Nigeria, it is common experience that for a good number of crops early sowing, immediately after the onset of the rains, results in maximum yields and delay of sowing causes yield reduction. Factors thought to affect sowing date

differences in their consequences for crop growth and yield, were: daylength, leaching of nitrogen, capping of the soil by hard rain, saturation of the soil with water, and light intensity, disease and pest incidence and temperature during the growing season. The data in section 5 provide a quantitative evaluation of the effect of sowing date on growth and yield of sesame. They indicate that the first four factors mentioned cannot explain the typical 'sowing date delay effect.' However, changes in light intensity, disease incidence and possibly temperature during the season influence the relation between sowing date and crop growth.

Most of the common sesame cultivars are characterised by opening or dehiscent capsules. This capsule character has the advantage that it simplifies threshing, but the disadvantage that it increases seed loss. The discovery in 1943 of the indehiscence character in Venezuela by Langham was of great significance, as it enabled increased mechanisation of sesame production, and was expected to reduce seed loss. However, the results of experiments described in section 6 showed that losses caused by shattering of seed from opening capsules is less than visually estimated, and that seed loss need not exceed 2 per cent if a good harvesting method is applied (Fence B). It is concluded that the character of indehiscent capsules will become of value only when combines can be employed economically at harvest. Picking or stripping of capsules appeared to be a method of no practical value.

Section 7 mentions the main diseases and pests of sesame and deals in more detail with a virus disease called leaf-curl. Attempts to transmit the disease with plant sap and with seed failed but white flies were observed to act as vectors of leaf-curl. The damage caused by the disease can be disastrous and it embodies an actual or potential threat to sesame cultivation in Nigeria. Sowing date trials showed that delay of sowing after the onset of the rains increases infection and that the disease incidence decreases when sowing is postponed till after the middle of July. Sowing after the middle of August results in disease-free crops. The magnitude of the white fly population, as estimated by counts on yellow, sticky traps, was not always a reliable indicator for the extent of disease infection. Resistance to leaf-curl was correlated with hairiness in an F4 bulk population, but occurred also in glabrous plants and reduced the disease damage considerably.

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SAMENVATTING

Sesam (*Sesamum indicum* L.) is een oliegewas, waarvan de teelt reeds in het verre verleden werd beoefend. Geschriften, daterend uit de bloeitijd van het Babylonische Rijk omstreeks 2350 jaar voor de geboorte van Christus, maken reeds melding van zijn bestaan. Het gewas wordt tegenwoordig verbouwd in vrijwel alle tropische en sub-tropische landen, waarvan India, China, Mexico, de Soedan en Venezuela de voornaamste plaats als producent innemen. Het meeste gepubliceerde onderzoek is verricht in India en Venezuela.

De totale wereldproduktie schommelt aanzienlijk van jaar tot jaar, is sinds 1950 niet van betekenis toegenomen en bedroeg omstreeks 1,8 miljoen ton in 1969/70. De wereldhandel in sesamzaad is van opvallend geringe betekenis; de konsumptie vindt voor ongeveer 90 procent in de producerende landen plaats. De in Nigeria voor export opgekochte produktie bedroeg 17.459 ton in 1969/70 en 5.714 ton in 1970/71 en de uitvoer is hoofdzakelijk gericht op Italië.

Sesamzaad heeft een oliegehalte van omstreeks 50 procent, is in trek als bestanddeel van velerlei volksvoedsel en wordt gewaardeerd vanwege de goede kwaliteiten van de olie. Het eiwitgehalte van het zaad bedraagt ongeveer 20 procent. Analysecijfers voor zaad van Nigeria worden gegeven in 1.5.

De gebieden in Nigeria, waar sesam een belangrijke en gevestigde plaats inneemt onder de geteelde gewassen, komen voor in een viertal provincies van de noordelijke staten en zijn gelegen tussen de 6° en 10° breedtegraad. Deze zijn gekenmerkt door het optreden van een droge tijd van om en nabij 4 tot 5 maanden en een jaarlijkse hoeveelheid neerslag van omstreeks 1.000–1.500 mm. De natuurlijke vegetatie bestaat uit bos-savanne. De grondsoort in de bovenlaag wordt uitgemaakt door lemige zandgrond. Sesam in Nigeria is een typisch gewas van het kleinbedrijf en de huidige teelt- en oogstmethoden verschillen in wezen niet van die toegepast van oudsher.

Het merendeel van de hier beschreven proeven werd verricht aan het Agricultural Research Station te Mokwa. In hoofdstuk 4 wordt onderzoek besproken over zaaiafstanden en gewasopbrengsten. De thans gangbare methoden van zaaien vertonen plaatselijk verschillen, maar laten zich toch kort omschrijven als (a) de Igbirra methode met zaai op ruggen, die ongeveer 4 m uiteen liggen en waarop de plantplaatsen onderling omstreeks 145 cm verwijderd zijn en ongeveer 16 planten tellen en (b) de Tiv methode met breedwerpig zaaien en omstreeks 673.000 planten per ha. Deze aantallen variëren echter sterk.

Bij ruggenzaai met afstanden tussen de ruggen van 91 cm werd onder de voor de proeven geldende omstandigheden een plantafstand van omstreeks 6 cm optimaal bevonden. Daarentegen werd bij zaaien op vlakke grond een plantverband van omstreeks 22 × 13 cm als optimaal aangemerkt. In het laatste geval bleek een formule ontleend aan BLEASDALE en NELDER (1960) en aangepast aan de gebruikte proefopzet een goede beschrijving te geven van het verband tussen plantverband en zaadopbrengst. De gevolgtrekking wordt gemaakt, dat de onder (a) en (b) genoemde methoden voor verbetering vatbaar zijn.

In Nigeria doet zich ten aanzien van een aantal gewassen het opvallende verschijnsel voor, dat vroege zaai, onmiddellijk na het inzetten van de regentijd, de beste opbrengsten oplevert en dat uitstel van zaaien opbrengstderving tot gevolg heeft. Als oorzaken van dit verschijnsel heeft men gedacht aan de factoren: Daglengteverandering, uitspoeling van stikstof, dichtslaan van de grond door harde regen, verzadiging van de bodem met water, afname van lichtintensiteit, toename van schade door ziekten en plagen en daling van de temperatuur. De in hoofdstuk 5 vermelde proefresultaten geven een kwantitatieve waardering van het verschijnsel bij sesam en wel hoofdzakelijk onder de te Mokwa optredende omstandigheden. Voorts tonen deze aan, dat als mogelijke oorzaken de eerste vier vermelde factoren aldaar niet voor een verklaring in aanmerking komen, doch dat afname van lichtintensiteit, toename van ziektenaantasting en wellicht temperatuursdaling factoren van betekenis zijn.

De meest verbouwde sesamrassen zijn gekenmerkt door het bezit van openspringende doosvruchten. Deze eigenschap van de vruchten brengt aan de ene kant een risico van zaadverlies met zich mee, aan de andere kant vereenvoudigt ze het dorsen. De door LANGHAM in Venezuela ontdekte eigenschap van niet openspringende vruchten bleek van grote betekenis voor het mechaniseren van de oogst van het gewas. Onderzoek, beschreven in hoofdstuk 6, toonde echter aan, dat zaadverlies ten gevolge van het openspringen der vruchten aanmerkelijk geringer is dan men vermoedde, dat bij een goede oogstmethode (Fence B) het verlies niet meer dan 2 procent hoeft te bedragen en dat de eigenschap van niet openspringen der vruchten alleen dan pas betekenis krijgt, als maaidorsmachines economisch verantwoord bij de oogst ingezet kunnen worden. De methode van het afplukken der vruchten bleek in de praktijk van geen nut te zijn.

In het laatste hoofdstuk wordt een korte opsomming gegeven van de voornaamste ziekten en plagen, die in Nigeria sesam schade toebrengen, terwijl uitvoeriger wordt ingegaan op het optreden van de bladkrulziekte. Hetzelfde virus, dat bladkrul bij tabak veroorzaakt, werd aansprakelijk bevonden voor de overeenkomstige ziekte van sesam. Het bleek, dat de ziekte niet met plantensap en met zaad, maar wel met behulp van witte vliegen kan worden overgebracht. De gevolgen van bladkrul kunnen rampzalig zijn voor de opbrengst en de ziekte vormt een al dan niet sluimerend gevaar voor de teelt in de voornaamste produktiegebieden van Nigeria. Zaaidataproeven toonden aan, dat de aangerichte schade groter wordt, als na het inzetten van de regentijd het zaaien wordt uitgesteld, maar dat de aantasting weer afneemt, als de zaaidatum verschoven wordt tot na midden juli. Bij zaaien na midden augustus werden veelal geen ziektesymptomen meer waargenomen.

De grootte van de witte vliegen populatie was niet alleen-bepalend voor de mate van ziekteschade. Resistentie tegen bladkrul, die in een aantal gevallen op de aanwezigheid van beharing berust en aangetroffen is in Nigeria en elders, bleek de schade aanmerkelijk te kunnen beperken.

REFERENCES

A'BROOK, J. (1963). Artificial drying of groundnuts: A method for the small farmer. Trop. Agric. Trin. **40**: 241–245.

A'BROOK, J. (1968). The effect of plant spacing on the numbers of aphids trapped over the groundnut crop. Ann. appl. Biol. **61**: 289–294.

ARROYO, J., ALLIEVI, J. and MAZZANI, B. (1967). Comparison of sesame varieties in the Sabana de Londres, Estado Lara. Agronomia trop. **17**: 123–126.

ARZUMANOVA, A. M. (1958). Utilizing a sesame collection as initial material for breeding indehiscent forms. Byull. vses. Inst. Rasteniev **4**: 40–44.

ARZUMANOVA, A. M. (1963). Influence of different cultural conditions on the oil content of til. Trudy prikl. Bot. Genet. Selek. **35**: 168–172.

ASHRI, A. and LADIJINSKI, G. (1964). Anatomical effect of the capsule dehiscence alleles in sesame. Crop. Sci. **4**: 136–137.

ASHRI, A. and LADIJINSKI, G. (1965). Anatomical manifestations of the indehiscence alleles in sesame. Israel J. agric. Res. **15**: 107.

BAILEY, A. G. (1966). A check-list of plant diseases in Nigeria. Memo. Fedl Dep. agric. Res. Nigeria no 96: 25.

BALDWIN, K. D. S. (1957). The Niger Agricultural Project, an experiment in African development. Blackwell, Oxford.

BALUCH, M. A. and MAJIDANO, B. A. (1966). Botanical collection of sesame (*Sesamum indicum* L.). W. Pakistan J. agric. Res. **4**: 58–67.

BLEASDALE, J. K. A. (1966). Plant growth and crop yield. Ann. appl. Biol. **57**: 173–182.

BLEASDALE, J. K. A. (1967). The relationship between the weight of a plant part and total weight as affected by plant density. J. hort. Sci. **42**: 51–58.

BLEASDALE, J. K. A. and NELDER, J. A. (1960). Plant population and crop yield. Nature **188**: 342.

BRUCE, E. A. (1953). Flora of Tropical East Africa. *Pedaliaceae*. Turill, W. B. and Milne-Redhead, E., Crown Agents, London.

BRUCE, E. A. (1953). Notes on African *Pedaliaceae*. Kew Bull. **67**: 417–429.

CANO, J. and LOPEZ, M. (1950). El ajonjoli y su cultivo. Circ. Dep. Agric. El Salvadore no 12.

CASWELL, G. H. (1962). Agricultural Entomology in the Tropics. Arnold, Maidenhead: 35–37.

CHATFIELD, C. (1934). Sesame seeds have high nutritive value. Yb. U.S. Dep. Agric. 1934: 316–317.

COLLISTER, E. H. (1955). Improvement of sesame. Bull. Hoblitzelle agric. Lab. no 4.

CORNUET, P. (1959). Maladies a virus des plantes cultivees et methodes de lutte.

CULP, T. W. (1960). Inheritance of papershell capsules, capsule number and plant colour in sesame. J. Hered. **51**: 146–148.

CULP, T. W. (1963). Sesame production in the Mississippi Delta. Bull. Miss. agric. Exp. Stn no 674.

DAGHIR, N. J., ULLAH, M. F. and ROTTERSTEN, K. (1967). Lysine supplementation of sesame meal. Trop. Agric. Trin. **44**: 235–242.

DALZIEL, J. H. (1948). The useful plants of West Tropical Africa. Crown Agents, London.

DEIGHTON, F. C. (1932). Mycological work. A. Rep. agric. Dep. Sierra Leone 1931: 20–25.

DEIGHTON, F. C. (1940). Tobacco leaf-curl in Sierra Leone. Pap. 3rd W. Afr. agric. Conf. 1938 **1**: 7–8.

D'HOORE, J. L. (1964). Soil map of Africa, scale 1 to 5,000,000. Explanatory monograph. C.C.T.A., Lagos.

ECKEY, E. W. (1954). Vegetable fats and oils. Reinhold, New York.

EL BARADI, T. A. (1972). Sesame. Trop. Abstr. **27**: 153–160.

Extension Service (1960). Benniseed and soya beans. Ext. Pamph. Min. Agric. Benue Province Nigeria no 2.

Extension Service (1966). Benniseed. Agric. Newsletter Min. Agric. Niger Province **63** and **64**: 2.

Extension Research Liaison Section (1968). Guide to the production of benniseed (sesame). Ext. Guide no 4.

FISHER, R. A. (1921). Some remarks on the methods formulated in a recent article on the quantitative analysis of plant growth. Ann. appl. Biol. **7**: 367–372.

GARCIA, J. B., MAZZANI, B. and SAINZ, J. M. (1971). Relacion entre el balance de agua en el suelo y el rendimento del ajonjoli (*Sesamum indicum*). Agronomia trop. **21**: 49–57.

GEMAWAT, P. D. and VARMA, O. P. (1971). Diseases of sesamum (*Sesamum indicum* D.C.) III – Virus diseases and susceptibility of some important varieties. Manuscript for submission for publication.

GERAKIS, P. A. and TSANGARAKIS, C. Z. (1969). Response of sorghum, sesame and groundnuts, to plant population density in the Central Sudan. Agron. J. **61**: 872–875.

GERAKIS, P. A. and TSANGARAKIS, C. Z. (1969). Sesame variety comparisons and breeding objectives in the sandy soils of the Central Sudan. Crop Sci. **9**: 487–489.

GHOSH, B. N. (1955). Photoperiodic response in til (*Sesamum indicum* L.). Curr. Sci. **24**: 170.

GIHA, O. H. and NOUR, M. A. (1969). Epidemiology of cotton leaf-curl virus in the Sudan. Cott. Gr. Rev. **46**: 105–118.

GREGORY, F. G. (1926). The effect of climatic conditions on the growth of barley. Ann. Bot. **40**: 1–26.

GUPTA, G. P., MATHUR, B. P. and KHAN, A. R. (1963). Studies in the performance of sesamum varieties. Indian Oilseeds J. **7**: 140–143.

HACK, H. R. B. (1970). Emergence of crops in clay soils of the Central Sudan rainlands in relation to soil water and air-filled pore space. Exp. Agric. **6**: 287–302.

HIGGINS, G. M. (1961). Experimental farm coverage in Northern Nigeria. Niger. geogr. J. **4**: 11–25.

HIGGINS, G. M., HOPE, W. A. and CLAYTON, W. D. (1957). A preliminary report on the detailed soil and contour survey of Mokwa Experimental Farm site. Soil Survey Bull. Reg. Res. Stn Samaru no 4.

HIGGINS, G. M. and MOULD, A. W. S. (1962). Progress of soil survey in Northern Nigeria. Proc. 3rd inter-Afr. Soils Conf.

HUTCHINSON, J. and DALZIEL, J. H. (1963). Flora of West Tropical Africa II. Crown Agents, London.

IL'INA, A. I. (1959). Response of sesame to intensity of light. Fiziologiya Rast. **6**: 263–273.

IRVINE, F. R. (1969). West African Crops. W. Afr. Agric. London **2**: 71–74.

International Bank for Reconstruction and Development (1955). The economic development of Nigeria. Hopkins, Baltimore: 222.

ITO, K. and MATSUOKA, K. (1960). Studies on the sesame varieties. II. Varietal difference in drought tolerance of sesame. Bull. Shikoku agric. Exp. Stn **5**: 15–26.

JOHN, C. M., NARAYANA, G. V. and SESHADRI, C. R. (1940). The wild gingelly of Malabar. Madras agric. J. **27**: 47–50.

JOHNSON, R. H. and RAYMOND, W. D. (1964). The chemical composition of some tropical food plants. III. Sesame seed. Trop. Sci. **6**: 173–179.

JOSHI, A. B. (1961). Sesamum. Indian Central Oilseeds Committee, Hyderabad.

KASHI RAM and MADHAVA ROW, R. (1931). Some observations on the growth of *sesamum indicum* D.C. in different soil conditions with special reference to root development. Indian J. agr. Sci. **1**: 715–717.

KEAY, R. W. J. (1953). An outline of Nigerian vegetation. Federal Government Printer, Lagos.

KHATTAB, A. H. and KHIDIR, M. O. (1970). Oil and protein content of local sesame types (*Sesamum orientale* L.) J. Food Sci. Tech. Sudan **2**: 8–9.

KHIDIR, M. O. (1969). Indehiscent sesame (*Sesamum orientale* L.) Sudan Agric. J. **4**: 30–35.

KHIDIR, M. O. (1972). Natural cross-fertilization in sesame under Sudan conditions. Expl. Agric. **8**: 55–59.

KHIDIR, M. O. and KHATTAB, A. H. (1972). Oil, protein and dry matter development in sesame seed. Expl. Agric. **8**: 61–65.

KINMAN, M. L. (1953). Shattering vs non-shattering sesame in Texas. Prog. Rep. Texas agric.

Exp. Stn no 1677: 3.
KINMAN, M. L. and MARTIN, J. A. (1954). Present status of sesame breeding in the United States. Agron. J. **46**: 24–27.
KIRTIKAR, K. R. and BASU, B. D. (1935). Indian medicinal plants **3**: 1857–1861.
KLINKENBERG, K. and HIGGINS, G. M. (1968). An outline of Northern Nigerian soils. Niger. J. Sci. **2**: 91–115.
KOSTRINSKY, Y. (1959). Methods for increasing the production of *Sesamum indicum* in Israel. Bull. agric. Res. Stn Bet-Dagan Israel no 62.
KRISHNAMURTHY, K., RAMAKRISHNAN. F. N., RAJOGOPALAN, R., SWAMINATHAN, M. and SUBRAHMANYAN, V. (1959). The chemical composition and nutritive value of sesame seed (*Sesamum indicum*) and its products. Fd Sci. **8**: 316–320.
KUMAR, K., BHARGAVA, P. D. and UPADHYAYA, S. M. (1967). Classification of Rajasthan sesames (*Sesamum indicum* L.). Indian J. agric. Sci. **37**: 193–199.
LANGHAM, D. G. (1946). Genetics of sesame. III. Open sesame and mottled leaf. J. Hered. **37**: 149–152.
LAVRONOV G. A. (1950). The cultivation of *Sesamum indicum* on the unirrigated soils of Uzbekistan. Selek. Semenovod. **17**: 59–61, from: Fld Crop Abstr. **5** (1952): 163.
LAWES, D. A. (1966). Rainfall conservation and the yields of sorghum and groundnuts in Northern Nigeria. Expl. Agric. **2**: 139–146.
LEAKEY, C. L. A. (1970). Crop improvement in East Africa. Tech. Commun. Commonw. Bur. Pl. Breed. Genet. **19**: 157–177.
LEROY, M., GOURSAUD, J. and LUQUET, F. M. (1970). Dosage du sesamol dans les beurres et huiles de beurres dénaturés. Rev. lait. Fr. **274**: 181–183.
MARIJNEN, T. (1963). Contribution à l'étude de la densité de plantation chez les végétaux. Publs Inst. natn. Étude agron. Congo belge, serie scientifique no 102.
MARKELEY, K. S. (1950). Sesame, a new oilseed crop for the South. Cott. Gin Oil Mill Press **51**: 10–12.
MARTIN, J. A. (1954). A report to the S.9 Regional Plant Introduction Experiment Station, Georgia, on the sesame breeding program; cyclostyled, 12 pp.
MARTIN, J. A. and CRAWFORD, J. H. (1955). Palmetto sesame. A new non-shattering variety. Circ. South Carolina agric. Exp. Stn no 98.
MATSUOKA, K. (1959). Studies on the sesame varieties. 7. Temperature and photoperiodic responses of sesame varieties. Jap. J. Ecol. **9**: 39–45.
MATSUOKA, K. (1960). Studies on the sesame varieties. 9. Effects of the temperature and photoperiod responses on the growth of sesame varieties. Jap. J. Ecol. **10**: 22–28.
MAZZANI, B. (1960). Grafts of indehiscent and dehiscent sesame and reciprocals. Agronomia trop. **10**: 97–105.
MAZZANI, B. (1964). Nuevos datos y observaciones sobre la naturaleza del carácter 'fruto indehiscente' del ajonjoli (*Sesamum indicum* L.). Agronomia trop. **13**: 225–232.
MAZZANI, B. (1964). Sesame improvement in Venezuela. Oleagineux **19**: 775–782.
MAZZANI, B. (1966). El cultivo del ajonjoli. Agronomia. Caracas **3**: 9–18.
MAZZANI, B. and COBO, M. (1956). Effect of different spacings on some characteristics of branched varieties of sesame. Agronomia trop. **6**: 3–14.
MAZZANI, B. and COBO, M. (1958). The effect of different sowing densities on various characteristics of an unbranched variety of sesame. Agronomia trop. **8**: 109–114.
MAZZANI, B. and ALLIEVI, J. (1969). Primera informacion sobre el comportamiento del ajonjoli en un ensayo de rotacion de cultivos en Maracay. Agronomia trop. **19**: 119–123.
MCCLEAN, A. P. D. (1940). Some leaf-curl diseases in South Africa. Sci. Bull. Dep. Agric. For. Un. S. Afr. no 225.
MONEY-KYRLE, A. F. (1957). Agricultural development and research in Turkey. Pub. Am. Univ. Beirut no 1, from: Weiss, E. A. (1971). Castor, sesame and safflower. Hill, London: 447.
MONTILLA, D. and MAZZANI, B. (1966). Estimacion de perdidas de semilla en la cosecha mecanica del ajonjoli (*Sesamum indicum* L.). Agronomia trop. **16**: 209–211.
MOURSI, M. A. and ABD EL GAWAD, A. A. (1965). Shading effect on the growth of sesame plant.

Ann. agric. Sci. Univ. Ain Shams 8: 305–313.
NARAIN, A. and SRIVASTAVA, R. N. (1962). A note on spacing trials of sesame in Bihar. Indian J. Agron. 7: 133–135.
NARIANI, T. K. (1968). Enation leaf-curl of tomato. Pl. Dis. Reptr 52: 595–596.
NJOKU, E. (1960). An analysis of plant growth in some West African species II. The effect of shading. J. West. Afr. Sci. Assn 6: 1–17.
NYE. G. W. (1940). Simsim. Agriculture in Uganda. Tothill, London: 172–175.
OLIVE, F. R. and CANO, J. G. (1954). The influence of various spacings on the yield of different types of sesame. Turrialba 4: 143–146.
PAL, B. P. and TANDON, R. K. (1937). Types of tobacco leaf-curl in Northern India. Indian J. agric. Sci. 7: 363–393.
PARTHASARATHY, N. and KEDHARNATH, S. (1949). The improvement of the sesame crop in India. J. Genet. Pl. Breed. 9: 59–71.
PULLAN, R. A. (1962). The concept of the Middle Belt in Nigeria. An attempt at a climatic definition. J. geogr. Ass. Nigeria 5: 39–52.
PULLE, A. A. (1950). Compendium van de terminologie, nomenclatuur en systematiek der zaadplanten. Oosthoek, Utrecht.
PURSEGLOVE, J. W. (1968). Tropical crops. Dicotyledons 2. Longman, London: 430–435.
RADFORD, P. J. (1967). Growth analysis formulae. Their use and abuse. Crop Sci 7: 171–175.
RANGANATHAN, S., SUNDARARAJAN, A. R. and SWAMINATHAN, M. (1936). Indian J. med. Res. 24: 699, from: Weiss, E. A. (1971). Castor, sesame and safflower. Hill, London: 383.
RHEENEN, H. A. VAN (1969). Hand-threshing of non-shattering sesame. Samaru agric. Newsletter 11: 50–52.
RHEENEN, H. A. VAN (1970). Intergeneric hybridization between *Ceratotheca sesamoides* Endl. and *Sesamum indicum* L. Nigerian J. Sci. 4: 251–254.
RHIND, D. (1935). A note on photoperiodism in Sesamum. Indian J. agric. Sci. 5: 729–736.
ROBERTSON, D. G. (1963). Plant virus diseases in Nigeria. Memo. Fedl. Dep. agric. Res. Nigeria no 47.
RUSSELL, W. J., NEILSON, K. R., MATCHES, A. G. and MALM, N. R. (1967). Sesame performance trials at the South-eastern Branch Station. Res. Rep. New Mex. agric. Exp. Stn no 131.
SESHADRI, C. R., BHAVANISHANKER RAO, M. and SUBBIAH, V. (1956). Spacing trials in gingelly. Paper presented to the 5th Scientific Workers Conference, from: Joshi, A. B. (1961). Sesamum. Indian Central Oilseeds Committee, Hyderabad.
SINGH, B. P., BHARGAVA, P. D., MURTI, C. S. and BHATNAGAR, M. P. (1963). Strains of sesamum resistant to leaf-curl virus. Indian Oilseeds J. 7: 339–340.
SMILDE, K. W. (1960). The influence of some environmental factors on growth and development of *Sesamum indicum* L. Meded. Landbouwhogeschool Wageningen 60–5.
SMITH, K. M. (1957). A textbook of plant virus diseases. Churchill, London.
SORAUER, P. (1954). Die Virus- und Bakterienkrankheiten. Handbuch der Pflanzenkrankheiten II. Parey, Berlin.
SQUIRE, F. A. (1960). White fly studies. A. Rep. Fedl Dep. agric. Res. Nigeria 1958–59: 22–26.
STEELE, W. M. (1960). Sesame and soya bean. Internal report, Mokwa Agricultural Research Station, Nigeria.
STOCKINGER, K. R. (1970). Environmental factors limiting yield of the major cereals in Northern Nigeria. Afr. Soils 15: 481–484.
STONEBRIDGE, W. C. (1963). Benniseed variety and sowing method trials. Tech. Rep. Inst. agr. Res. North. Nigeria 28: 1–9.
Sudan (1954). Agriculture in the Sudan. Tothill, London: 341–345.
TAHIR, W. M. (1964). Sesame improvement for mechanized production in the Central Rainlands of the Sudan. Emp. J. Exp. Agric. 32: 219–224.
TANDON, I. N. and BANERJEE, A. K. (1968). Control of phyllody and leaf-curl of *Sesamum orientale*. Pl. Dis. Reptr 52: 367–369.
Tanganyika (1966). A. Rep. Dep. Agric. Tanzania, Part II.
Texas agric. Exp. Stn (1955). Rio, a new non-shattering sesame. Publ. Leaflet L. 242.

Texas agric. Exp. Stn (1957). Delco, a new non-shattering sesame Publ. Leaflet L. 344.

Texas agric. Exp. Stn (1965). Baco, a new combine sesame. Publ. Leaflet L. 644.

THUNG, T. H. (1932). De krul- en kroepoek-ziekten van tabak en de oorzaken van hare verbreiding. Meded. Proefstn vorstenl. Tabak Klaten no 72.

THUNG, T. H. and HADIWIDJAJA, T. (1953). De krupuk-ziekten van *Crotalaria* en *Arachis hypogaea*. Landbouw **25**: 149–162.

TRIBE, A. J. (1967). Sesame. Fld Crop Abstr. **20**: 189–194.

TSATSARONIS, G. C., BOSKOU, D. and KEHAYOGLOU, A. (1971). Composizione dei semi di sesamo greco. Riv. ital. sostanze grasse **48**: 490–492.

Uganda (1964). Agricultural Production programme. Dep. Agric. Uganda, from: WEISS, E. A. (1971). Castor, sesame and safflower. Hill, London: 448.

U.S. Dep. Agric. (1958). Sesame production. Farmers' Bulletin no 2119.

U.S. Dep. Agric. (1960 and 1967). Soil classification: A comprehensive system. 7th Approximation. And its supplement. U.S. Govt Printer, Washington.

WALLACE, G. B. (1933). Report of the mycologist. A. Rep. Dep. Agric. Tanganyika 1932: 76–80.

WALTER, M. W. (1967). Length of the rainy season in Nigeria. J. geogr. Ass. Nigeria **10**: 123–126.

WEISS, E. A. (1971). Castor, sesame and safflower. Hill, London.

WHITEHEAD, R. A. (1967). Sesame. 7th A. Rep. Res. Dep. Cocon. Industry Board Jamaica: 13–22.

WIT, C. T. DE (1960). On competition. Versl. landb. Onderz. no 66.8.

WOLFF, F. DE (1970). The maize program at Mokwa, Nigeria. Afr. Soils **15**: 433–435.

WOLFF, F. DE (1972). Mass selection in maize composites by means of selection indices. Meded. Landbouwhogeschool Wageningen **72**-1.

WYNIGER, R. (1962). Pests of crops in warm climates and their control. Acta trop., suppl. 7.

ZAGHI, S. DE and BRESSANI, R. (1969). Uso de recursos alimenticios Centro-Americanos para el fomento de la industria animal. II. Composicion quimica de la semilla y de la harina de torta de ajonjoli (*Sesamum indicum*). Turrialba **19**: 34–38.

APPENDICES

APPENDIX 1

Production of sesame seed in 1000 tons for principal countries for the period 1950–1970.

Country	50/51	51/52	52/53	53/54	54/55	55/56	56/57	57/58	58/59	59/60	
India	438	445	464	554	593	460	431	353	499	364	
China	800	785	760	420	420	425	340	305	340	380	
Sudan	166	40	130	70	88	148	151	129	152	176	
Mexico	79	85	89	86	89	90	98	111	115	123	
Burma	39	48	54	44	36	44	55	34	52	66	
Venezuela	5	2	2	7	9	13	12	21	19	16	
Colombia	7	12	10	10	8	8	13	20	21	18	
Pakistan	34	34	36	36	36	37	36	28	34	34	
Turkey	29	28	29	39	47	50	45	43	47	46	
Ethiopia	–	–	–	35	35	35	35	35	32	36	
Uganda	33	26	29	29	33	30	28	28	33	30	
Nigeria	9	10	14	13	16	19	16	16	16	21	
Others	186	202	213	129	139	139	132	136	137	145	
Total	1825	1717	1830	1472	1549	1498	1392	1259	1497	1455	
Country	**60/61**	**61/62**	**62/63**	**63/64**	**64/65**	**65/66**	**66/67**	**67/68**	**68/69**	**69/70**	**Total 50/70**
India	313	366	484	432	485	418	409	415	408	426	8757
China	350	320	335	335	360	360	360	360	360	360	8475
Sudan	125	228	140	171	181	157	132	184	120	199	2887
Mexico	127	144	153	167	168	159	173	177	212	246	2691
Burma	64	75	84	53	99	57	56	106	82	75	1223
Venezuela	24	28	30	46	53	59	79	70	80	124	699
Colombia	20	21	21	48	70	61	45	55	65	70	603
Pakistan	31	37	34	33	31	31	34	39	39	35	689
Turkey	43	43	40	39	33	33	31	39	49	40	793
Ethiopia	37	30	30	30	31	32	35	36	36	37	577
Uganda	29	32	28	30	30	30	30	30	30	30	598
Nigeria	28	21	21	20	24	23	16	12	13	17	345
Others	138	126	142	160	151	150	139	135	141	131	2971
Total	1329	1471	1542	1564	1716	1570	1539	1658	1635	1790	31308

Sources: Commonwealth Secretariat: Vegetable oils and oilseeds. McNERNEY (1971/1972): Personal communications.

APPENDIX II

Estimated yields of sesame seed in kg per ha for principal countries.

	Year									
Country	50/51	51/52	52/53	53/54	54/55	55/56	56/57	57/58	58/59	59/60
India	202	185	198	219	229	204	198	171	225	173
China	558	563	545	480	439	445	371	319	342	367
Sudan	809	591	959	489	563	563	461	615	492	429
Mexico	469	508	532	503	509	510	531	569	584	609
Burma	–	91	102	82	65	77	94	61	93	108
Venezuela	559	–	–	863	2466	1457	558	532	388	362
Colombia	–	–	–	–	–	–	–	–	–	–
Pakistan	425	432	438	418	425	436	417	380	432	405
Turkey	452	482	536	563	612	638	565	548	582	608
Uganda	324	330	345	343	353	291	278	309	339	321
Nigeria	188	228	293	251	297	341	309	287	287	352

	Year										
Country	60/61	61/62	62/63	63/64	64/65	65/66	66/67	67/68	68/69	69/70	Average 50/70
India	147	165	193	182	196	171	149	157	171	187	186
China	374	365	365	365	393	393	393	393	393	393	412
Sudan	436	563	436	350	392	400	345	359	271	352	493
Mexico	636	676	656	678	653	592	625	631	702	1079	613
Burma	110	123	135	83	143	120	74	130	167	136	104
Venezuela	453	502	446	538	720	633	603	669	543	600	731
Colombia	–	507	507	415	587	504	565	553	777	645	562
Pakistan	369	371	417	426	372	401	428	471	492	502	424
Turkey	600	559	574	535	525	559	585	662	621	605	571
Uganda	298	298	343	351	208	279	279	279	279	342	313
Nigeria	352	–	–	306	327	328	285	298	294	314	297

Sources: Commonwealth Secretariat: Vegetable oils and oilseeds. McNERNEY (1971/1972): Personal communications.

Appendix III

Exports of sesame seed in 1000 tons for principal countries during the period 1950–1970.

Country	Year										
	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960
Sudan	–	–	14	23	20	25	30	40	29	44	75
Mexico	–	–	–	–	–	–	–	–	–	–	–
Ethiopia	7	8	12	13	11	2	3	3	2	2	3
Nigeria	14	11	13	12	15	13	22	19	12	18	27
Tanzania	–	–	–	–	3	4	11	8	8	11	11
Hong Kong	10	9	21	23	10	8	11	7	5	4	3
Cambodja	–	–	–	–	–	1	2	5	1	1	3
Nicaragua	7	8	17	12	6	5	3	6	6	9	9
Thailand	–	–	–	–	2	4	8	3	3	3	3
China	18	12	25	80	8	18	13	4	11	10	8
India	–	2	3	–	–	3	–	–	–	–	–
Kenya	–	–	–	–	1	–	–	1	1	1	1
Uganda	–	–	–	–	–	–	–	1	1	–	–
Mozambique	2	1	1	2	3	–	–	–	2	1	1
Guatemala	–	–	–	–	–	–	–	–	–	1	1
Indonesia	3	1	1	2	4	1	–	1	2	1	1
South Yemen	–	–	–	–	–	–	–	–	–	–	–
Others	22	20	17	24	10	14	17	12	9	10	9
Total	83	72	124	191	93	98	120	110	92	116	155

Country	Year										Total 50/70
	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	
Sudan	62	76	69	100	69	73	74	83	111	81	1098
Mexico	–	2	22	2	–	3	22	2	1	–	54
Ethiopia	4	9	8	14	16	20	19	27	30	39	252
Nigeria	21	24	15	18	21	25	4	14	16	12	346
Tanzania	12	8	9	7	10	7	6	7	7	5	134
Hong Kong	4	6	6	5	7	6	5	3	3	3	159
Cambodja	6	8	6	1	9	5	6	1	2	–	57
Nicaragua	8	6	6	6	5	5	7	7	7	7	152
Thailand	3	7	4	3	4	5	4	4	4	5	69
China	4	2	2	3	8	8	1	1	2	1	239
India	–	–	2	–	–	–	–	–	–	–	10
Kenya	1	1	1	1	1	1	1	1	1	1	15
Uganda	1	1	1	1	1	1	4	5	4	3	24
Mozambique	2	4	1	2	1	2	2	2	3	1	33
Guatemala	1	1	1	1	1	1	4	5	3	3	23
Indonesia	2	2	2	2	2	2	2	3	2	–	36
South Yemen	–	2	1	1	1	1	1	–	–	–	7
Others	16	19	13	16	7	2	4	10	11	8	270
Total	147	178	169	183	163	167	166	175	207	169	2978

Sources: Commonwealth Secretariat: Vegetable oils and oilseeds. McNerney (1971/1972): Personal communications.

Appendix IV

Imports of sesame seed in 1000 tons for principal countries during the period 1950–1970.

Country	Year										
	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960
Japan	2	8	5	10	12	16	21	11	17	27	27
Italy	8	7	7	22	4	8	28	16	17	19	25
United States	9	6	5	5	7	5	6	7	7	6	8
Egypt	1	5	2	1	–	6	8	8	6	8	6
Soviet Union	–	–	–	–	–	15	5	2	7	4	6
Hong Kong	11	9	22	23	12	11	10	7	7	4	5
South Yemen	–	–	–	–	–	–	5	4	6	4	4
Belgium	5	1	1	7	5	2	4	6	6	5	4
Jordan	–	–	–	–	–	–	–	–	–	2	2
Lebanon	3	2	1	4	3	1	3	5	4	3	4
W. Malaysia and Singapore	3	3	3	2	4	4	2	3	3	3	4
Portugal	1	1	1	3	1	–	–	–	–	1	1
Venezuela	4	3	9	13	5	12	3	18	11	10	32
Israel	4	–	1	1	–	–	–	–	–	1	1
Denmark	3	1	6	5	6	3	5	5	3	2	2
Poland	–	–	–	–	–	3	3	1	1	3	1
Syria	1	1	1	–	2	1	2	1	2	3	2
France	–	2	–	7	1	1	2	1	–	–	–
Spain	–	–	–	–	–	–	–	–	–	–	13
Czechoslovakia	–	–	–	–	–	–	1	4	3	6	3
Others	29	18	30	76	17	5	10	6	–	2	1
Total	84	67	94	179	79	93	118	105	100	113	151

Country	Year										
	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	Total 50/70
Japan	22	28	32	33	33	37	39	39	34	52	505
Italy	19	20	32	26	31	40	35	44	51	40	499
United States	10	9	11	11	11	13	16	15	17	19	203
Egypt	12	15	9	7	5	7	13	9	10	19	157
Soviet Union	12	8	10	12	8	–	7	9	12	9	126
Hong Kong	4	7	7	5	6	6	6	5	4	8	179
South Yemen	6	6	9	6	6	9	–	–	–	–	65
Belgium	4	4	6	6	7	7	7	7	–	–	94
Jordan	5	4	4	4	3	5	4	4	3	–	40
Lebanon	5	5	5	5	4	5	5	5	–	–	72
W. Malaysia and Singapore	3	4	4	2	2	2	3	2	3	3	62
Portugal	1	1	3	3	6	4	4	4	5	2	42
Venezuela	16	21	14	15	1	3	3	–	–	–	193
Israel	–	–	1	2	2	3	3	4	3	–	26
Denmark	1	2	2	2	–	2	2	1	2	–	55
Poland	1	–	1	2	8	3	2	4	3	1	37
Syria	3	3	4	3	1	3	–	1	1	–	35
France	1	1	1	1	2	1	–	–	1	–	22
Spain	9	16	–	–	1	–	–	–	–	–	39
Czechoslovakia	2	–	–	–	8	–	–	–	–	–	27
Others	2	2	2	2	1	–	–	4	11	7	225
Total	138	156	157	147	146	150	149	157	160	160	2703

Sources: Commonwealth Secretariat: Vegetable oils and oilseeds. McNerney (1971/1972): Personal communications.

Appendix V

Exports of sesame oil in 1000 tons for principal countries for the period 1950–1970.

Country	Year										
	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960
Denmark	–	–	–	–	–	–	0.8	0.5	0.3	0.5	0.4
France	–	–	–	0.1	–	–	–	–	–	–	–
Japan	–	–	–	–	–	–	–	0.1	–	0.1	0.2
Mexico	–	–	–	–	–	–	–	–	–	–	–
South Yemen	–	–	–	–	–	–	–	–	–	–	1.1
Sudan	–	–	–	–	0.1	0.1	0.2	0.2	0.3	0.6	0.8
Total	–	–	–	0.1	0.1	0.1	1.0	0.8	0.6	1.2	2.5

	Year									
Country	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970
Denmark	0.2	0.4	0.3	0.2	0.2	0.4	0.4	0.2	0.3	–
France	–	–	–	–	0.2	0.4	–	–	–	0.3
Japan	0.3	0.4	0.5	0.6	0.7	0.8	0.7	0.7	0.9	0.9
Mexico	–	–	0.2	0.1	–	0.9	0.3	0.1	–	–
South Yemen	0.8	1.0	0.9	1.0	1.3	1.3	–	–	–	–
Sudan	1.0	2.3	0.8	0.8	0.6	0.7	0.6	0.6	0.2	–
Total	2.3	4.1	2.7	2.7	3.0	4.5	2.0	1.6	1.4	1.2

Appendix VI

Quarterly average prices of sesame seed in £.s. per metric ton for the period 1958–1970.

	Year											
Quarter	1958		1959		1960		1961		1962		1963	
January–March	85	0	66	5	66	15	76	10	83	5	79	10
April–June	86	15	69	0	66	0	76	5	87	10	77	5
July–September	81	10	66	15	66	0	71	5	82	0	74	5
October–December	69	15	66	5	64	5	71	15	74	0	72	15
Annual average	80	15	67	0	65	15	74	0	81	15	76	0

	Year													
Quarter	1964		1965		1966		1967		1968		1969		1970	
January–March	70	15	73	15	80	10	95	5	98	5	90	5	118	10
April–June	68	10	72	15	88	10	105	0	97	5	96	5	122	7
July–September	64	5	73	0	92	5	101	5	90	0	100	0	118	13
October–December	73	5	78	15	89	15	86	10	89	0	97	5	113	13
Annual average	67	10	74	10	87	15	97	0	93	12	95	19	118	6

Sources: Commonwealth Secretariat: Vegetable oils and oilseeds. McNerney (1971/1972): Personal communications.