DICTAAT CAPUTCOLLEGE NUTTIGE PALMEN 1977

(J.D. Ferwerda)

Tomlinson 199?

2700

1 INLEIDING

1.1 Gebruikswaarde

Van de ongeveer ~~3500~~ palmensoorten (LANJOUW et al., 1968) kunnen ten hoogste een tiental als echte cultuurgewassen worden beschouwd. Van dit tiental zijn alleen de dadelpalm, de kokospalm en de oliepalm van belang als leverancier van wereldmarktprodukten. Vele palmen leveren echter nuttige produkten. Deze worden meestal in wilde populaties verzameld. Sommige soorten worden voor dit doel als erfgewas of in kleine commerciële tuinen aangeplant. De bekendste produkten zijn:

P r o d u k t	D e e l v a n d e p l a n t
Dakbedekkingsmateriaal, vlechtwerk	Bladen en blaadjes van de meeste palmen
Bezems	Nerven van de blaadjes van vele palmen
Rotanstokken, vlechtriet, pitriet	Stengel van klimmende Lepidocaryoideae, vooral van Calamus spp. en Daemonorops spp.
Palmwijn, arak, azijn, suiker	Sap uit de steel van de bloeiwijze of uit het groeipunt van vele palmen
Palmkool	Zachte weefsel om het groeipunt van vele palmen
Olie	Zaad van vele palmen, soms vruchtvlees
Zetmeel	Stam van Metroxylon spp., Eugeisssona utilis, Arenga pinnata, Caryota urens, Phoenix spp., vruchtvlees van Guilielma gasipaes, Hyphaene thebaica
Eetbare vrucht	Salacca edulis, Mauritia flexuosa, Phoenix dactylifera, e.a.
Plantaardig ivoor	Metroxylon amicarum, Phytelephas macrocarpa.

1.2 Taxonomie

De familie van de Arecaceae (= Palmae) wordt onderverdeeld in negen subfamilies. Het aantal geldige geslachten bedraagt volgens de lijst van BURRET & POTZTAL (1956) 235. Deze zijn beschreven in het populair wetenschappelijk boek van McCURRACH (1960). De onderverdeling in subfamilies berust op de vorm van de blaadjes (op doorsnede V of Λ-vormig), de vorm van de samengestelde bladeren (geveerd of handvormig), de verdeling van de mannelijke en vrouwelijke bloemen (eenhuizig of tweehuizig), de aan- of afwezigheid van schubben op de vrucht, de vorm van de vrouwelijke bloeiwijze (hoofdje of met duidelijke hoofdas) en de aan- of afwezigheid van een hard endocarp. Een sleutel voor deze onderverdeling wordt gegeven in het boek van CORNER (1966). Dezelfde auteur geeft ook een eenvoudige determinatietabel voor de meest bekende palmen.

De negen subfamilies en enige nuttige of bekende vertegenwoordigers zijn:

Subfamilia	Species
Phoenicoideae	Phoenix dactylifera L.
Coryphoideae	Corypha umbraculifera L.
Borassoideae	Hyphaene thebaica (L.) Mart.,
	Borassus aethiopicum Mart.
	Borassus flabellifer L.
	Lodoicea maldivica (Gmel.) Pers.
Caryotoideae	Caryota urens L.
	Arenga pinnata (Wurmb.) Merr.
Lepidocaryoideae	Eugeissona utilis Becc.
	Metroxylon spp.
	Raphia spp.
	Calamus spp.
	Salacca edulis Reinw.
Cocoideae	Arecastrum romanzoffianum
	Astrocaryum murumuru Mart.
	Attalea funifera Mart.
	Cocos nucifera L.
	Elaeis guineensis Jacq.
	Elaeis oleifera
	Guilielma gasipaes (HBK) Bailey
	Orbygnia spp.
Arecoideae	Areca catechu L.
	Ceroxylon andicola Humb. & Bonpl.
	Leopoldinia piassaba Wallace
	Pinanga spp.
	Roystonea regia (Kunth.) O.F. Cook
Nipoideae	Nypa fructicans Wurmb.
Phytelephantoideae	Phytelephas macrocarpa Ruiz & Pav.

Voor verdere bijzonderheden over deze palmen wordt verwezen naar PURSEGLOVE (1972) en McCURRACH (1960).

1.3 Morfologie van de palmen (CORNER, 1966)

1.3.1 De kroon

De kroon van een palm met een zichtbare stam telt, behoudens periodiek door ongunstige omstandigheden veroorzaakte schommelingen, steeds hetzelfde aantal

volgroeide groene bladeren. Dit komt omdat er gemiddeld één oud blad afsterft
als één nieuw blad open gaat. Als de tijd tussen het opengaan van twee opeen-
volgende bladeren p dagen bedraagt en de kroon n groene bladeren telt, bedraagt
de levensduur van een geopend blad np dagen. Om dit mogelijk te maken moeten
aan het groeipunt met gemiddeld dezelfde tussenpozen nieuwe bladprimordia
worden afgesplitst. Bovendien is bij talrijke soorten gebleken, dat het aantal
onvolgroeide bladeren van het 1e bladprimordium aan het groeipunt tot en met
de oudste ongeopende bladspeer eveneens n bedraagt, zodat er 2 np dagen verlopen
tussen de eerste aanleg van een blad aan het groeipunt en de dood van dat blad.
Enige voorbeelden zijn:

	Onvolgroeide bladeren	Volgroeide bladeren	Tijd tussen twee opeenvolgende groene bladeren
Pinanga simplicifrons	4-5	4-5	?
Pinanga furfuracea	5-6	5-6	?
Pinanga kuhlii	6-8	6-8	?
Actinorhytis calapparia	12	12	27-29
Cocos nucifera	22-30	22-30	28-42
Elaeis guineënsis	40-60	40-60	10-15
Phoenix dactylifera	?	100-125	15-20

Als s het rangnummer van een geopend blad in de kroon gerekend vanaf het
oudste gesloten blad (speerblad) is, dan is de ouderdom van dat blad $(m+s)p$.
Op overeenkomstige wijze is de leeftijd van een onvolgroeid blad sp. De leef-
tijd van de hele palm is gelijk aan de leeftijd van de kroon (2 np) + de
leeftijd van de stam + de duur van de rozetfase (= stamloze fase). De leeftijd
van de stam kan geschat worden door het aantal oude bladvoeten of littekens
van oude bladvoeten te tellen en met p te vermenigvuldigen. De duur van de
stamloze fase kan alleen door waarneming worden vastgesteld. Hij varieert van
6-12 maanden bij palmen met dunne stammen tot meerdere jaren bij palmen met
dikke stammen. De stam wordt pas zichtbaar als de stamvoet zijn grootste omvang
bereikt heeft.

De vorm en de afmetingen van palmen verschillen al naar gelang de soort
en de groeifase. Als alle palmbladeren met dezelfde snelheid zouden groeien,
zal een groot blad er langer over doen dan een klein blad om zijn finale
afmetingen te verkrijgen, en in overeenstemming met deze langere groeitijd
langer actief zijn. Een groter blad heeft een dikkere stam nodig om het te
dragen en meer voeding om te groeien. Een dikke stam correspondeert met een
dikke groeitop, en een dikke groeitop is door meer onvolgroeide bladeren
ingesloten dan een kleine. Daarom zouden palmen met dikke stammen grote kronen
met talrijke grote en langlevende bladeren moeten hebben, terwijl palmen met
dunnere stammen kleinere kronen met een geringer aantal kleinere en korter
levende bladeren.

Deze vuistregel lijkt bij een aantal soortenrijke geslachten zoals
Areca, Phoenix en Pinanga goed op te gaan. Het is echter ook duidelijk dat niet
alle palmen dezelfde groeicurve volgen (vb. curva A, fig. 13, blz. 47). Een
Raphia palm heeft een stam die even dik is als die van een kokospalm, maar
heeft minder en langere bladeren. De bladlengte is een eerste maatstaf voor de
bladgrootte en de groeiduur. Er zijn andere factoren die een rol spelen en de

apices van verschillende soorten gedragen zich verschillend. Variatie in (p) kan invloed hebben op de grootte van de bladeren, maar hoeft geen invloed te hebben op het aantal bladeren bij dezelfde diameter van de stam. Bij een grotere groeisnelheid ontstaat een palm met een groter aantal bladeren op een stam van dezelfde dikte, of hetzelfde aantal bladeren op een dunnere stam. Omgekeerd ontstaat bij een geringere groeisnelheid een palmtype met een kleiner aantal bladeren op een stam van dezelfde dikte of hetzelfde aantal bladeren op een dikkere stam.

De phyllotaxis varieert bij de palmen van soort tot soort tussen ½ en 13/34. Meestal heeft elke soort een specifieke bladstand, maar deze is niet altijd even duidelijk en geeft daarom soms aanleiding tot meningsverschillen, zoals bij de oliepalm (normaal 5/8, soms 5/13, volgens HENRY 8/21).

1.3.2 Stam

De meeste palmen hebben een onvertakte stam. De enige echte uitzonderingen op deze regel zijn de dichotoom vertakte Hyphaena spp. van de subfamilie Borassoideae, waarvan de Egyptische doum- of gemberbroodpalm (H. thebaica) het meest bekende voorbeeld is. Vele palmen vertakken zich bij uitzondering wel eens als het groeipunt onherstelbaar beschadigd wordt. In dat geval komen in twee of meer van de jongste bladprimordia vegetatieve spruiten in plaats van bloeiwijzen tot ontwikkeling. Dit verschijnsel is bekend bij oliepalm en kokospalm. Ik heb eenmaal een oliepalm met 8 kronen gezien. Talrijke palmen (vb. Metroxylon spp., Pinanga spp., Caryota spp., Phoenix spp.), hebben stammen die aan de voet dicht tegen elkaar staan. Deze zijn ontstaan uit dikwijls ondergrondse zijscheuten uit slapende okselknoppen van reeds lang afgestorven bladeren. Deze wijze van vertakking is identiek aan die van bv. banaan, bamboe en vele grassen. Soms groeien zijspruiten enige tijd horizontaal, evenals bij de Zingiberaceae en de grassen met stolonen of rhizomen. De meeste natuurlijke groepen van palmen zijn echter uit zaad ontstaan, doordat twee of drie kiem- planten uit één meerzadige vrucht tot ontwikkeling kwamen of omdat meerdere kiemplanten uit twee of meer dicht bijeenliggende vruchten tot ontwikkeling kwamen. Soms ontstaat uit de kiemplant een rozet (Calamus sp.), waarvan de okselknoppen uitlopen tot "stammen".

De groeiwijze van de palmenstam verschilt fundamenteel van die van de stengels van bamboe en grassen. De laatste groeien tot ze bloeirijp zijn. De palmenstam ontstaat uit de stam van de kiemplant. De groeirichting is meestal verticaal, soms aan de basis horizontaal (vb. Elaeis oleïfera). Enkele Amerikaanse geslachten hebben onderaardse stammen. Deze bieden grotere overlevingskansen tegen savannebranden. De palmenstam groeit uitsluitend aan de apex. Deze bestaat uit een zeer klein groeipunt of apicaal meristeem, dat geheel is ingesloten door het zachte weefsel van de primordia van de onvol- groeide bladeren en de voeten van de volgroeide bladeren. Bij dunstammige palmen is de apex conisch, maar bij dikkere komvormig door de grotere ontwik- keling van het subapicale weefsel. In het centrum van deze holte ligt het kegelvormige apicale meristeem. De doorsnede van dit groeipunt varieert van 70-550 nm van soort tot soort. Bij Phoenix canariensis groeit het van 75 nm bij de kiem tot 550 nm bij volwassen palmen, die een stamdiameter van 45 cm hebben. Dit is veel groter dan bij de dicotylen (30-100 nm). Bij sommige palmen is de diktegroei van de stam voltooid in de apicale knop, andere gaan hiermee door tot enige tijd, nadat het blad is afgevallen. Dit is uitsluitend primaire verdikking door celdeling en celgroei. De internodiën blijven meristematisch en groeien vaak door nadat blad en knop volledig uitgegroeid zijn. Hierdoor is lengtegroei van de stam mogelijk zonder interventie van de

apex en zonder vorming van nieuwe bladeren. Dit kan niet bij palmen met blad-standen die overeenkomen met hogere termen van de hoofdreeks van FIBONACCI (zie REINDERS & PRAKKEN, 1964), omdat de bladbases en hun vaatbundels elkaar over-lappen en de stengeldelen niet gescheiden kunnen worden. Daardoor eindigt de stam bij deze palmen in een compact bladrozet.

De kroon van palmen met hellende stammen (vb. kokospalm) blijft horizontaal, ten dele door verlenging van de bladvoeten en de internodiën aan de onderzijde van de stam.

Opgezwollen, fles- of tonvormige stammen komen bij verschillende geslachten voor, bv. bij het Amerikaanse geslacht Acrocomia. De oorzaak is voortgezette diktegroei gedurende de periode van maximale groei. Verschillen in stamdikte hangen echter ook duidelijk samen met het welzijn van de apex. Extreme droogte, gebrek aan nutrienten of sterke bladsnoei veroorzaken bij vele palmen met dikke stammen insnoeringen.

De hoogtegroei van de stam is bij dunstammige palmen groter dan bij dik-stammige, maar vertoont bij dikstammige palmen veel overeenkomst. Enige voorbeelden zijn :

Dadel	25-50 cm/jaar
Kokospalm	30-40 cm/jaar
Oliepalm	30-60 cm/jaar
Rotan	200-250 cm/jaar

De dwarse doorsnede vertoont de palmenstam talrijke vaatbundels verspreid in een massa van dunwandig parenchymatisch weefsel. De vaatbundels hebben aan de naar de buitenzijde van de stam gekeerde kant een schede van harde, donker-bruine of zwarte vezels. Soms bevinden de meeste vaatbundels zich dicht bij de buitenzijde van de stam (Mauritia), soms zijn ze regelmatig over de hele doorsnede verdeeld. Vaatbundels groeien naar boven. Als een vaatbundel dicht bij de buitenzijde van de stam ontstaan is, groeit hij geleidelijk naar binnen tot hij het centrum onder de plaats van een bladprimordium bereikt heeft. Daarna ontwikkelt hij zich naar buiten in het primordium. In de stam van een volwassen kokospalm met een diameter van 30 cm kan men wel 18.000 vaatbundels tellen. Het is niet zeker dat elke vaatbundel correspondeert met een blad.

1.3.3 Wortels

Palmen en Pandanaceae hebben de dikste en taaiste primaire wortels zonder secundaire diktegroei van het plantenrijk. De kiemwortel heeft een korte levensduur. De eerste bijwortels ontstaan in een ring vlak boven de overgang van de kiemwortel naar de hypocotyl, reeds voor het eerste loofblad zich ont-plooid heeft, maar het wortelstelsel van volwassen palmen wordt geheel gevormd door duizenden dikkere bijwortels, die aan de onderaardse stamvoet en het basale deel van de stam ontstaan. Deze primaire bijwortels worden vele meters lang en zijn over het grootste deel van hun lengte omgeven door een sterke, vezelige, verhoute schors. Vlak onder het wortelmutsje bevindt zich het onver-houte deel van de wortel. Hierop bevinden zich meestal geen wortelharen. Door deze bouw zijn de primaire wortels over het grootste deel van hun lengte min of meer ondoorlatend voor water, maar ook uitstekend beschermd tegen uitdroging.

Bij vele palmen groeit een deel van de primaire bijwortels ongeveer horizontaal op enige diepte beneden het oppervlak. Aan deze wortels ontstaan aan de onder- en bovenzijde zijwortels, die zich nog 1-3 x vertakken. De kleinste zijworteltjes zijn ongeveer 1 mm dik. Merkwaardig is, dat de aan de bovenzijde

ontstane zijwortels naar boven groeien tot het bodemoppervlak, alvorens sterk
te vertakken, waardoor een dichte mat van wortels vlak onder het oppervlak
ontstaat. Door deze bouw zijn palmen in staat zowel overstromingen met stromend
water als uitdroging van de bovengrond te overleven.

Sommige palmen hebben pneumatoden aan wortels die vlak onder of boven
het bodemoppervlak groeien. Door de losse bouw van de cortexcellen van deze
pneumatoden kan O_2 worden opgenomen en CO_2 worden afgegeven. Merkwaardig is,
dat een typische moeraspalm als Nypa fructicans geen pneumatoden heeft, maar
wortels met luchtholten in de cortex, die in verbinding staan met de grote
luchtholten in de bladvoeten.

1.3.4 Bloeiwijze, bloem

De meer of minder sterk vertakte bloeiwijzen hebben meestal een vlezige as.
De bloemen zijn actinomorf, zittend of zeer kort gesteeld en hebben meestal
twee kransen van 6 vrije of vergroeide tepalen. Gewoonlijk zijn er 6 meeldraden,
zelden drie of zeer veel, in twee kransen, vrij of met vergroeide filamenten.
Het vruchtbeginsel is bovenstandig, 1-3 hokkig (zelden meerhokkig) met 1
zaadknop per hok. De bloeiwijze is vóór de bloei ingehuld in één of meer bloem-
scheden. De vertakking van de hoogste orde is de aar, die de afzonderlijke
bloemen draagt. (CORNER (1966) spreekt van een pluim met aren, anderen van een
samengestelde kolf (spadix).

De meeste palmen hebben zijdelingse en okselstandige bloeiwijzen. Elke
bloeiwijze ontstaat uit de knop in de oksel van een loofblad. Deze knoppen
brengen in de regel uitsluitend bloeiwijzen voort. Uitzonderingen zijn de
uitstoelende palmen en abnormaliteiten bij de niet-uitstoelende palmen, die
in plaats van een zijdelingse, okselstandige bloeiwijze een vegetatieve scheut
voortbrengen. Meestal wordt een bloeiwijze zichtbaar aan de bovenzijde van de
bladsteel van het blad, waarbij zij behoort.

Bij palmen met sterke, buisvormige bladscheden kan de jonge bloeiwijze
niet naar buiten treden voor de bladschede gespleten is en het blad in de
toestand gekomen is waarbij het spoedig zal worden afgestoten. Bij de talrijke
palmen van de subfamilie Arecoideae verschijnen de bloeiwijzen enige weken tot
maanden nadat de corresponderende bladeren zijn afgevallen onder de kroon. Men
noemt dit infrafoliaire bloei, in tegenstelling tot de eerder genoemde inter-
foliaire bloei. Soms groeit de bloeiwijze dwars door het driehoekige gat, dat
door splijting van de bladvoet van een nog levend blad ontstaat.

Enkele geslachten hebben een terminale bloeiwijze, t.w. twee waaierpalmen
van de subfamilie Coryphoideae (Corypha en Nannorhops) en zeven vederpalmen
van de subfamilie Lepydocaryoidae (Eugeissona, Metroxylon, Korthalsia,
Myrialepis, Plectocomia, Plectocomiopsis en Ancistrophyllum). Hierbij verschijnt
de bloeiwijze als de stam zijn vegetatieve groei voltooid heeft en de eindknop
generatief wordt. Dit zijn dus echte méérjarige, d.w.z. éénmaal bloeiende
planten. Deze palmen slaan zetmeel en eiwit op in het weefsel van de stam, dat
t.z.t. de energie moet leveren voor de vorming van de bloeiwijze. Terminale
bloeiwijzen zijn bij de Monocotylen regel, laterale uitzondering. Bij dicotylen
zien we vaak eerst een eindstandige bloeiwijze. Hierdoor komt de lengtegroei
van de stengel tot stilstand. Vervolgens groeien zijknoppen uit tot bloeiwijzen
en wel van boven naar beneden, tot de reserves zijn uitgeput. Bij de palmen
komt dit voor bij de subfamilie Caryotoideae. Deze krijgen eerst een eind-
standige bloeiwijze en daarna van boven naar beneden zijdelingse. Als de laatste
uitgebloeid is, sterft de palm. Een bekende vertegenwoordiger van deze
subfamilie is Arenga pinnata (syn. A. saccharifa), waarvan het uit de bloem-
stengels getapte sap verwerkt wordt tot suiker. Voorts de voor hetzelfde doel
gebruikte Caryota urens. Caryota is het enige palmgeslacht met dubbelgeveerde

bladeren. Waarschijnlijk gaat bij deze palmen het groeipunt te gronde en begint
de bloei door het uitgroeien van de generatieve knop in de oksel van het bovenste
blad. Dit is misschien ook het geval bij Metroxylon, maar deze zaken zijn
anatomisch nooit uitputtend onderzocht.

De individuele bloemen zijn meestal eenslachtig, soms tweeslachtig. De
meeste waaierpalmen van de subfamilie Coryphoideae hebben tweeslachtige
bloemen in hun terminale bloeiwijze. Verder komen tweeslachtige bloemen slechts
bij vier geslachten van de vederpalmen voor, alle behorende tot de
Lepidocaryoideae, waaronder Metroxylon. Deze hebben eveneens terminale bloei-
wijzen.
Eenslachtige bloemen hebben soms nog steriele sporophyllen, maar deze kunnen
ook geheel afwezig zijn. Steriele ovaria scheiden meestal de nectar af voor
het insect, dat een rol speelt bij de bestuiving, en komen meer voor dan
steriele meeldraden.
Overgangsvormen met tweeslachtige èn eenslachtige bloemen komen voor bij de
eerder genoemde Coryphoideae, bv. bij Metroxylon. Meestal ontstaan de mannelijke
bloemen eerst aan het apicale en distale deel van de aar, de tweeslachtige bij
de basis. Bij Metroxylon staan de mannelijke en tweeslachtige bloemen echter
om en om langs de aren van zijn enorme bloeiwijze. Bij volledige scheiding van
mannelijke en vrouwelijke bloemen bevinden de mannelijke zich in de regel aan
het topeinde en de vrouwelijke aan het basiseinde van de aard. De Nipa palm
is een uitzondering op deze regel. Deze bloeiwijzen zijn in de regel protandrisch.

De meeste palmen zijn eenhuizig, maar tweehuidigheid is geenszins zeldzaam.
Sommige tweehuizige geslachten (vb. Phoenix en Borassus) hebben geslachts-
chromosomen; XY bij mannelijke en XX bij vrouwelijke individuen). Dit is merk-
waardig, omdat beide palmen als tetraploïden beschouwd worden (2n=36). De
eerder genoemde Coryphoideae zijn uiteraard polygaam, en wel andromonoecisch.
Bij de eenhuizige palmen kunnen de mannelijke en vrouwelijke bloemen zich in
dezelfde bloeiwijze bevinden (vb. kokospalm) of in verschillende bloeiwijzen
(vb. oliepalm). In het laatste geval komen ook wel gemengde bloeiwijzen voor.

Over de bestuiving van wilde palmen is weinig bekend. De bloemen worden
door vele kevers, vliegen en bijen bezocht voor nectar en pollen. Tropische
honing is vaak voor een groot deel afkomstig van palmen en smaakt dan flauw en
erg zoet. Bij de meeste palmen gaan de mannelijke bloemen open bij zonsopkomst
en vallen enkele uren later af. De in de regel veel grotere vrouwelijke bloemen
blijven enige dagen ontvankelijk. Dit is te zien aan de dagelijkse afscheiding
van een druppeltje nectar bij zonsopgang en de uitstekende stempels. De bloem-
dekbladeren blijven het ovarium echter dicht omsluiten.

De meeste palmen hebben een driehokkig vruchtbeginsel met één zaadknop
per hok. Dit kan worden gereduceerd tot één hok met één zaadknop. Er zijn
echter vormen bekend met meerhokkige vruchtbeginsels (5-10), elk met één
zaadknop.

1.3.5 Vrucht en zaad

De vruchten van de palmen verschillen enorm van soort tot soort, in bouw en
afmetingen. Ze hebben echter altijd drie eigenschappen gemeen:

> (1) ze zijn vrij groot;
>
> (2) ze bevatten meestal één zaad;
>
> (3) ze springen niet open.

Hieruit volgt dat de vruchten als zaden functioneren. De meeste vruchten hebben
een vlezig mesocarp, waarvan de samenstelling van soort tot soort zeer

verschillend is.

Sommige palmen (vb. Phoenix) hebben een vlezige vrucht met een niet door een steenschaal omgeven zaad, bij andere heeft het zaad bij uitzondering geen steenschaal (vb. oliepalm). Bij vele geslachten wordt het zaad of worden de zaden omsloten door een verhout endocarp. Drie Borassoideae, waaronder het geslacht Borassus, waartoe de bekende palmyra palm (B. flabellifer) en zijn Afrikaanse verwant B. aethiopium behoren, hebben echter drie "stenen" per vrucht, die wel "olifantsbes" genoemd wordt. Bij de kokospalm droogt de buitenste vruchtwand uit tot een taaie, vezelige bolster. Dit is ook het geval bij de zg. dubbele kokosnoot Lodoicea maldivica (Borassoideae) van de Seychellen.

Bij de Lepidocaryoideae zijn de vruchten geheel door harde, glimmende gele of bruine schubben bedekt. Hieronder ligt een vlezige of vezelige laag, die het al dan niet door een steenschaal omringde zaad omsluit. Bekende vertegenwoordigers van deze subfamilie, waarvan de vruchten gegeten worden, zijn Salacca edulis uit Indonesië en Mauritia flexuosa uit het laagland van tropisch Zuid-Amerika.

De vruchten van de meeste palmen worden door dieren gegeten. Deze dragen bij tot hun verspreiding. De Aziatische en Afrikaanse palmyra palmen komen voor binnen het verspreidingsgebied van de Indische en Afrikaanse olifanten.

De meeste palmzaden hebben een homogeen, hard wit of gelig endosperm. Als de zaden hun uiteindelijke afmetingen bijna bereikt hebben verharden de endosperm cellen zich vanaf de zaadhuid naar binnen. De celwanden worden verdikt met cellulose of hemicellulose tot ze de helft of meer van de celinhoud vullen. De cellen lijken op de cellen van het harde endocarp van de vrucht; door de dikke wanden lopen cytoplasmastrengen, die de verbindingen vormen tussen naast elkaar liggende cellen, maar de wanden zijn niet verhout. De textuur van het rijpe endosperm is hard, en hoornachtig of beenachtig. Uit het endosperm van de grootste en hardste zaden wordt het plantaardige ivoor gemaakt, bv. uit de zaden van Metroxylon amicarum (herkomst Carolinen) en van Phytelephas macrocarpa (herkomst Columbia, Ecuador). Het endosperm van vele palmzaden is oliehoudend.

1.4 Groei en ontwikkeling

De ontwikkeling van de meeste palmen doorloopt een aantal duidelijke verschillende stadia, t.w. embryonaal, kiemplant, rozet en stam.

1.4.1 Embryonale stadium

Dit is morfologisch voltooid als de vrucht rijp is. Het embryo is dan enkele mm lang en in het midden iets ingesnoerd, maar verder nog weinig gedifferentieerd. In het naar buiten gekeerde deel worden het kiemworteltje en de stengeltop gevormd; het naar binnen gekeerde deel is de cotyl.

1.4.2 Kiemplantstadium

Bij de kieming treedt het aanvankelijk nog afgeplatte uiteinde van de kiem door de kiemopening naar buiten en zwelt enigszins op. Aan dit opgezwollen deel ontstaat een knobbeltje, waardoor het kiemworteltje te voorschijn komt. Vervolgens breekt het pluimpje door aan de tegenover het worteltje liggende zijde, maar dit gebeurt pas als het worteltje ongeveer 10 mm lang is. Reeds voor het eerste vliezige en schubvormige blad zich geopend heeft ontstaat de eerder genoemde krans van adventiefwortels vlak boven de overgang van de kiemwortel naar de hypocotyl. Hierna volgen nog een of meer schubvormige

bladeren zonder bladgroen. Daarna komen de eerste loofbladeren, waarvan de vorm
meestal belangrijk afwijkt van die van de volwassen palm. Intussen is de zaad-
lob uitgegroeid tot een haustorium, dat het endosperm geleidelijk verteert. Bij
de oliepalm is het endosperm geheel verteerd als de kiemplant 2-3 groene lancet-
vormige bladeren heeft. Aan de intussen verdikte basis van de kiemplant verschijnt
dan de eerste dikke adventiefwortel. Bij de olieplam duurt dit ongeveer 12
weken, bij de kokospalm 24 weken. Dit is het eind van het kiemplantstadium.

1.4.3 Rozetstadium

Gedurende dit stadium krijgt de palm geleidelijk de volledig geveerde of hand-
vormige bladeren, die karakteristiek zijn voor de volwassen palm. De eerste
loofbladeren hebben afhankelijk van de soort een van de volgende vormen:

(1) lancetvormig (oliepalm, dadelpalm);

(2) omgekeerd eirond (Arenga);

(3) aan de top gespleten – (Caryota, vele Arecoideae, kokospalm, oliepalm);

(4) direct handvormig;

(5) direct geveerd.

Elk volgend blad is groter dan het voorgaande. Het eind van dit stadium wordt
bereikt als de verborgen stam zijn uiteindelijke dikte bereikt heeft en de
stamvorming begint. Bij palmen met laterale bloeiwijzen verschijnen de eerste
bloeiwijzen dikwijls reeds gedurende dit stadium.

1.4.4 Jaarlijkse bladproduktie.

Deze is vrijwel constant en de hoogtegroei gaat door zolang er bladeren
geproduceerd worden. Bij zeer hoge palmen neemt het tempo van de bladproduktie
geleidelijk af. Bij sommige palmen worden dode bladeren afgestoten, bij andere
blijven de bladvoeten aan de stam zitten. Vaak stoten laatstgenoemde palmen hun
bladvoeten op den duur ook af, zodat de gladde stam te voorschijn komt. Bij
palmen met laterale bloeiwijzen gaat de hoogtegroei door tot het groeipunt te
gronde gaat, bij palmen met een terminale bloeiwijze tot de bloei.

1.5 Geografie

Het verspreidingsgebied van de palmen ligt tussen 44° N.B. in Europa en 44°Z.B.
in de Chatham Eilanden van Nieuw Zeeland. Sommige kunnen gedurende korte tijd
temperaturen van -7° verdragen (vb. dadelpalm), maar in grote lijnen komt de
palmengrens ongeveer overeen met de isotherm van 10°C van de koudste maand op
het N. en Z. halfrond. De meeste palmen komen echter binnen het verspreidings-
gebied van de kokospalm voor (tussen 20° N.- en Z.B.) en de grootste dichtheid
wordt aangetroffen in de zône van het equatoriale ombrofiele bos tussen 5° N.
en Z.B. Het is merkwaardig dat geen enkel geslacht, met mogelijk één uitzon-
dering (Cocos) pantropisch is. Met twee uitzonderingen (Elaeis en Raphia)
behoren de geslachten tot de oude óf tot de nieuwe wereld, en met vier
uitzonderingen (Phoenix, Hyphaene, Borassus, Calamus) zijn de geslachten van
de oude wereld Afrikaans óf Aziatisch.

De meeste soorten hebben hun natuurlijke groeiplaats op de alluviale
vlakten van grote rivieren, maar men treft ook palmen aan in bergland, gras-
land, woestijnen, zeekusten. De Z.Amerikaanse waspalm Ceroxylon groeit in de
Andes tot een hoogte van 4000 m.

Fe/vB

3 ECOFYSIOLOGIE VAN DE KOKOSPALM (COCOS NUCIFERA L.)

3.1 Inleiding

Voor recente overzichten van de teeltkunde van de kokospalm wordt verwezen naar de handboeken van CHILD (1964) en FREMOND et al. (1966) en de sectie over dit gewas in het hoofdstuk Palmae van het boek Monocotyledons 2 (PURSEGLOVE, 1972). Een kort overzicht staat in het oude collegedictaat Voedingsgewassen (1971). Aan de ecofysiologie van de kokospalm wordt een door D.B.MURRAY geschreven hoofdstuk gewijd in het in 1977 of 1978 bij Academic Press, New York, te verschijnen boek onder redactie van ALVIM en KOZLOWSKI over de ecofysiologie van tropische gewassen. De colleges berusten in hoofdzaak op de inhoud van dit hoofdstuk, dat als preprint in Hdb 2 aanwezig is.

Voor een goed begrip van zijn ecofysiologie zijn de volgende gegevens over de groei en ontwikkeling van de kokospalm van belang.

	var. typica	var. nana
Tijd tussen aanleg en ontplooiing blad	30 maanden	?
Tijd tussen ontplooiing (=aanleg) van twee opeenvolgende bladeren	30 dagen	21 dagen
Levensduur blad na ontplooiing	3 - 3½ jaar	id.
Aantal groene bladeren per kroon	30 - 40	
Aantal bloeiwijzen per jaar	12	18
Aantal bloemen/bloeiwijze	30 - 40	
Val van pas gezette vruchten en onbevruchte bloemen	70%	
Val van 3-5 maanden oude vruchten	Sterk afhankelijk van milieufactoren.	

3.2 Geografie

De teeltgebieden van de kokospalm bevinden zich in hoofdzaak langs tropische kusten tussen 23° N.B. en Z.B. Hij gedijt echter uitstekend op grote afstand van de kust als de groeivoorwaarden gunstig zijn. Voorbeelden van belangrijke continentale teeltgebieden zijn Mysore in India en Mozambique. Natuurlijke verspreiding van kokospalm door op stranden aangespoelde vruchten is niet uitgesloten, maar vermoedelijk kwantitatief niet belangrijk. Het zaad van een in zee drijvende vrucht bewaart zijn kiemkracht gedurende 110 dagen, maar ondergedompelde vruchten verrotten spoedig. De meeste natuurlijk lijkende palmbossen zijn verwilderde aanplantingen. De grootst mogelijke hoogte boven de zeespiegel

neemt af met de geografische breedte. Enige voorbeelden zijn:

Tabora (Tanzania)	$5^{\circ}02'$ Z.B.	1300 m
Sri Lanka	$6^{\circ}- 9^{\circ}$ N.B.	750 m
Mysore (India)	$12^{\circ}-18^{\circ}$ N.B.	600-900 m
Jamaica	18° N.B.	150 m

3.3 Weer en klimaat

Licht, warmte, water en lucht, de voornaamste elementen van weer en klimaat, worden besproken. De meeste commerciële kokostuinen bevinden zich in streken met perhumide tot nat subhumide, megathermale klimaten met geen, weinig of matig watergebrek gedurende het droge seizoen en een gelijkmatig over het jaar verdeelde potentiële evapotranspiratie, dus volgens THORNTWAITE:

Klimaattype A, B_4, B_3, B_2, B_1, C_2

Ariditeitsindex   r, s of w

TE-type   A'

Zomerconcentratie   a'

Volgens de indeling van KÖPPEN-TREWARTHA behoren deze klimaten tot het Af, Am of Aw type, volgens WALTER tot de klimaten van de Equatoriale Zone.

3.3.1 Licht

Palmen, die onder de schaduw van andere palmen of bomen opgroeien vertonen etoilement. In West Afrika hangt de opbrengst aan kopra samen met het aantal uren zonneschijn tijdens de periode van rijping. Per jaar zouden ten minste 2000 en per maand ten minste 120 zonneschijn-uren (gemeten met de solarimeter van Campbell Stokes) nodig zijn voor normale kopraprodukties. MURRAY heeft er echter op gewezen, dat het aantal uren zonneschijn een onbetrouwbare maatstaf is voor de lichthoeveelheid. In Ecuador bedraagt het aantal uren heldere zonneschijn slechts 35% van dat in Trinidad, maar de werkelijke zonnestraling (Kipp Solarimeter) is veel hoger (75%).

3.3.2 Warmte

De optimale gemiddelde jaartemperatuur is ongeveer $27^{\circ}C$ met een dagelijkse amplitudo van $6-7^{\circ}C$. Deze omstandigheden heersen in de regel bij tropische zeekusten. De gemiddelde temperatuur van de koudste maand mag niet lager zijn dan $20^{\circ}C$ en als de dagelijkse minimum temperaturen vaak beneden 15° dalen worden groei en ontwikkeling, in het bijzonder de bloei en de vruchtzetting, in ongunstige zin beinvloed (FREMOND et al., 1966). In Florida (25°Z.B.) gaan de palmen in koude winters dood. De hoge eisen die de kokospalm aan het warmteklimaat stelt bepaalt de grootste hoogte, waarop hij nog met succes verbouwd kan worden. Bij de evenaar is de jaarlijkse amplitudo van de temperatuur zeer gering; de gemiddelde jaartemperatuur bedraagt op 1210 m (Tabora) $22,5^{\circ}C$ met als uiterste maandgemiddelden $21,2^{\circ}C$ (juni) en $25,4^{\circ}C$ (okt.)

3.3.3 Water

Het optimale jaartotaal van de regenval ligt tussen 1300 en 2300 mm, maar op goed ontwaterde bodems zijn hogere jaartotalen niet nadelig. De ecofysiologische betekenis van deze jaartotalen hangt uiteraard samen met de verdeling van de regenval en de evapotranspiratie. Zo heeft Port-Bouet (Ivoorkust) bij een jaartotaal van 1746 mm vijf maanden met een watertekort en vier met een wateroverschot, waardoor de klimaatsformule volgens THORNTHWAITE $C_2A'w\ a'$ wordt. De op dit station verkregen kopra-opbrengsten behoren niettemin tot de hoogste ter wereld. Soms worden watertekorten gedurende droge seizoenen gecompenseerd door grondwater. In langs de zeekusten geplante kokostuinen wordt het grondwater vaak aangevuld uit iets hoger gelegen zoetwater moerassen en lagunen. Langdurige perioden van watertekort hebben $2\frac{1}{2}$ jaar later invloed op het aantal vruchten en één jaar later op de hoeveelheid kopra/vrucht.

Bij de kokospalm verloopt ongeveer 16 maanden tussen de aanleg van de bloeiwijze en het opengaan van de bloemschede, zodat 28-30 maanden verlopen tussen de aanleg van de bloeiwijze en de oogst van de in deze bloeiwijze gevormde vruchten. Door ernstig watertekort kan de jonge bloeiwijze aborteren. Dit verklaart, waarom langdurige perioden van watertekort tot $2\frac{1}{2}$ jaar later merkbaar zijn in het aantal vruchten/ha en één jaar later in de hoeveelheid kopra/vrucht. Elders is geconstateerd dat de watervoorziening gedurende de eerste drie maanden van de ontwikkeling van de jonge vrucht bepalend zijn voor de opbrengst. In dit stadium is watertekort waarschijnlijk de oorzaak van "vroege val" van onvolgroeide vruchten.

F.HARDY (MURRAY, 1975) heeft een interessante hypothese over de inwendige waterbalans van een kokospalm, die op andere palmen eveneens van toepassing zou kunnen zijn:

(1) De omvang van de kroon is bijna onafhankelijk van de leeftijd, zodat de transpiratie in een atmosfeer met vrijwel constante temperatuur, vochtigheid en luchtbeweging weinig variatie vertoont met de leeftijd.

(2) De lengte van de waterkolom in de vaatbundels neemt toe met de hoogte van de stam, dus met de leeftijd van de boom.

(3) De opwaartse waterbeweging ondervindt meer weerstand naarmate een palm hoger, d.i. ouder is.

(4) Tengevolge van (1) en (2) verwelken palmen reeds bij een hoger vochtgehalte van de grond dan andere boomgewassen.

(5) Schommelende grondwaterspiegels beperken de wortelontwikkeling in slecht ontwaterde bodems, omdat de wortels door zuurstofgebrek te gronde gaan.

(6) Verwelking begint in kokostuinen op bodems met een gering wortelvolume eerder dan op bodems met een groot wortelvolume.

(7) De leeftijd waarop een kokospalm aan verwelking sterft is een maatstaf voor de ariditeit van een regio, in het bijzonder als die door een ongunstige waterhuishouding van de bodem wordt veroorzaakt, zoals slechte ontwatering en hoge grondwaterstanden die fysiologische droogte veroorzaken.

3.3.4 Lucht

Hoge windsnelheden versterken de transpiratie en leiden bij water-
tekort in de bodem eerder tot opbrengstdalingen. De het meest
naar de windzijde gekeerde palmen in een tuin groeien vaak slechter
en hebben lagere opbrengsten. Soms kan dit misschien samenhangen
met afzetting van cyclisch zout op de bladeren.
Veel belangrijker is de schade door tropische stormen en orkanen,
die in sommige delen van de tropen zeer veel voorkomen. Hierdoor
kan de kroon worden afgescheurd en de stam plat op de grond komen
te liggen.

3.3.5 Bliksem

Blikseminslag is een belangrijke oorzaak van vaak onherstelbare
beschadiging van kokospalmen. Door de sterke interne verhitting
barst het vaatbundelstelsel, waardoor vloeistof in de stam stroomt.
Bovendien breken bladeren af en vallen vruchten.

3.4 Bodem

De kokospalm groeit op zeer verschillende bodems, maar de
opbrengsten kunnen eveneens sterk verschillen. Er is niet veel
systematisch onderzoek naar de invloed van bodemeigenschappen
verricht. Het meeste werk heeft betrekking op verbetering van de
bodemvruchtbaarheid door middel van bemesting.

(1) A r e n o s o l s . In de meeste landen groeien kokospalmen
op zandige zeestranden boven de vloedlijn. Deze zanden bevatten
vrijwel geen minerale nutriënten en kokos kan er alleen op groeien
als er mineraalhoudend zoet water uit hoger gelegen zoetwater-
moerassen en lagunes door sijpelt.
Op koraalzandbodems is de diepte van groot belang als het klimaat
gekenmerkt wordt door droge perioden.

(2) F l u v i s o l s . Chemisch vruchtbare rivierafzettingen
zijn goede kokosbodems als hun interne drainage voldoende is. In
India en Sri Lanka staan de beste tuinen op uit leem en fijn zand
bestaande rivierdeltas. In de Filippijnen zijn vruchtbare bodems
gevormd op alluviaal kalksteen.

(3) F e r r a l s o l s . Veel tuinen in India en Sri Lanka zijn
geplant op P- en K-arme ferralsols. Goede groei is alleen mogelijk
op voldoende diepe en voldoende ontwaterde bodems.

(4) A n d o s o l s . Bodems gevormd op vulkanische as en tuf
zijn vruchtbaar en hebben een goede ontwatering. In Indonesia, de
Filippijnen en Nieuw Guinea zijn vele kokostuinen op deze bodems
geplant.

(5) V e r t i s o l s . In Malaysia zijn veel kokostuinen op deze
bodems geplant. Ze zijn chemisch vruchtbaar, maar gedurende het
regenseizoen laat de ontwatering te wensen over en gedurende de
droge tijd vormen ze diepe scheuren.

3.4.2 Fysische eigenschappen.

De textuur van kokosbodems varieert van 100% zand tot 70% klei met 80% organische stof. Goede ontwatering is belangrijk, omdat kokos- wortels geen langdurige inundatie verdragen. Verder belemmeren compacte bodems de groei van de wortels. De diepte van de bodem is belangrijk om een voldoende diepe beworteling mogelijk te maken. Dikwijls wordt de bewortelingsdiepte beperkt door harde bodemlagen of hoge grondwaterstanden.

3.4.3 Chemische eigenschappen.

Kokospalm is weinig gevoelig voor de pH, want koraalzanden hebben een pH in de buurt van 8 en zure kleien 5 of zelfs minder. Bij pH 8 kan Fe-gebrek optreden, bij zeer lage pH's Al- en Mn-vergiftiging. Chemisch grondonderzoek is tot dusver niet veel toegepast. De chemische samenstelling van de strandzanden heeft geen betekenis voor groei en ontwikkeling, maar die van alluviale bodems en kleihoudende bodems zouden aanwijzingen voor K- en P-gebrek kunnen geven. De behoefte aan minerale nutriënten is echter in hoofdzaak benaderd door analyse van de blaadjes en van het vruchtwater, en door middel van bemestingsproeven.

Rijpe vruchten bevatten aanzienlijke hoeveelheden N, P en K. Bijna de helft van de K bevindt zich in de bolsters. Als deze niet voor vezelbereiding wordt benut, moet men ze in de tuin laten verrotten. Veldproeven bij een gewas als kokosnoot hebben in ver- gelijking met die bij andere gewassen verschillende problemen:

(1) Het plantmateriaal is zeer heterogeen.

(2) Hierdoor zijn grote vakken nodig, waardoor de kans op bodem- verschillen toeneemt.

(3) Het verrichten van waarnemingen en het toezicht hierop is moeilijk; het ideaal is elke boom individueel te oogsten door de palm te beklimmen.

(4) Individuele bomen reageren verschillend op bemesting.

(5) Er verloopt een lange tijd tussen de toediening van de meststof en zijn invloed op de nuttige opbrengst.

(6) Langdurige veldproeven zijn nodig om de invloeden van seizoen- effecten en hun interacties op te sporen.

Bladanalyse geeft bij enkelvoudige deficienties goede aanwij- zingen. Er is een duidelijke samenhang van het K-gehalte van de blaadjes van het 14e ontplooide blad met het aantal vruchten/boom, en met de hoeveelheid kopra per vrucht. De kritische gehalten zijn volgens de I.R.H.O.:

N	1,8 - 2,0
P	0,12
K	0,8 - 1,0
Ca	0,5
Mg	0,3.

Analyse van het vruchtwater gaf goede aanwijzingen over K-gebrek in Sri Lanka. Er bleek een duidelijke samenhang te zijn tussen het K-gehalte van het vruchtwater en de opbrengst aan kopra. In Trinidad werd gevonden dat de samenstelling van het vruchtwater aanwijzingen gaf inzake de K-, Ca- en Mg-niveaus van de grond, maar onbruikbaar was als indicatie voor de nitraat-N niveaus.

LITERATUUR

CHILD, R., 1974. Coconuts. Longman, London, 2nd ed., pp. 335.

CORNER, E.J.H., 1966. The natural history of palms. Weidefeld and Nicolson, London, 393 pp.

FREMOND, Y., ZILLER, R. & NUCE de LAMOTHE, M. de, 1966. Le cocotier. Maisonneuve & Larose, Paris, 267 pp.

McCURRACH, J., 1960. Palms of the world. Harpers & Broters, New York, 290 pp.

PURSEGLOVE, J.W., 1972. Oil Palm. Tropical Crops, Monocotyledons 2: 479-510. Longman, London, pp. 607.

Fe/vB

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1. INTRODUCTION

Since the publication of the second edition of the volume on oil crops
by BALLY et al. in 1962 (20), of SPRECHER VON BERNEGG's classical
textbook on tropical and subtropical economic crops of the world,
several monographs and textbooks containing information on the
cultivation of the African oil palm have come out (1 ,22 ,20 ,44 ,
53 ,60 ,62 ,64 ,). Most of the current research work on oil palm
cultivation is published and reviewed in the Malayan Agricultural
Journal, the Journal of the Nigerian Institute for Oil Palm Research
and Oléagineux.

Specific information on the eco-physiology of the oil palm may be
found in review articles by PRÉVOT (1961), HARTLEY (1970) and CORLEY
(1973). In the present paper growth and development of the oil palm
are discussed as affected by the environment. Most emphasis is given
to some controversial views following from HARTLEY's and CORLEY's
papers and new developments since the publication of these papers.
Unpublished results of some investigations carried out on the eco-
physiology of the oil palm at the Agricultural University of
Wageningen are included. For the benefit of those who are not
familiar with the African oil palm, a condensed review is given of
the botany and the cultivation of this crop.

1.1 Botany

The African oil palm, _Elaeis guineensis_ Jacq. belongs to the
family of the _Arecaceae_ (formerly called _Palmae_). Its nearest relative
is the American oil palm, commonly known as _Corozo oleifera_ (HBK)
Bailey or _Elaeis melanococca_ Gaertn., but according to WESSELS BOER
(1965) more correctly _Elaeis oleifera_ with which it can be readily
crossed. It has a columnar well developed, unbranched stem, 25-75 cm
in diameter, which continues to increase in height as long as the
palm lives. This may be more than 127 years, the age of two planted
palms in the botanical garden of Bogor, Indonesia, but the life of
plantation palms is usually terminated for economic reasons when the
stems have attained a height of 10-11 m at an age of 25-35 years. The
root system of adult palms consists of some 8.000 - 10.000 adventitious

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primary roots, 4-10 mm in diameter, emerging mainly from the
subterranean basal bole of the stem. The bulk of these roots grows
more or less horizontally between 20 and 60 cm below the soil
surface; individual roots may attain a length of 15-20 m. Some
roots grow vertically downward. In deep, well-drained soils of
good structure they commonly attain depths of 3 m and have
occasionally been observed as deep as 9 m. Secondary roots, 2-4 mm
in diameter and up to 150 cm long, emerge from the primary roots.
Slightly more than half of them are ascending and almost reach the
surface of the soil. Tertiary roots, 1-2 mm in diameter and 10-15
cm long, grow almost horizontally from the secondaries. They are
most abundant on the secondary roots near the soil surface. Numerous
quaternary roots, 0.5 mm in diameter and up to 2 cm long, are
produced on the tertiaries. The tertiary and quaternary roots near
the soil surface form a thick mat in the top 10 cm of the soil.

The crown of adult palms under favourable conditions consists
of 40-50 opened, green parapinnate leaves, produced at a rate of
approximately two per month. Hence the functional life of an opened
leaf is about two years. The number of juvenile leaves in various
stages of development between the apical meristem and the youngest
opened leaf is approximately the same, sothat some four years elapse
between the initiation of a leaf at the growing point and its death.
Individual leaves are 5-7 m long and are composed of a rachis with
100-160 pairs of linear leaflets and a petiole with spines.

The length of the individual leaflets in the middle of the
rachis is about 100 cm; they are shorter near the top and much
reduced in size near the petiole. On planted palms the basis of
dead leaves remain attached to the stem until the palm is 15-17
years old, on semi-wild and wild palms much longer. The influence of
the age of the palm on the area of its individual leaves and on the
leaf area index (L.A.I.) of a plantation is illustrated in figure 1
(WILLIAMS & HSU, 1970). The leaf area index is an important criterion
for the condition of the oil palm plantations. It is closely related
with the dry matter production (CORLEY et al., 1973), as may be seen
in figure 2. From this it is apparent that the optimum leaf area for
total dry matter production is not the same as that for the production
of palm oil. The amount of dry matter used per palm for the production
of vegetative tissues is fairly constant; when the requirements for
vegetative growth are satisfied, the excess dry matter is used for
the production of fruit bunches.

The palm is monoecious. The inflorescence, which is either
male or female and only rarely hermaphrodite, is a spadix. One
inflorescense is formed in the axil of each leaf shortly after its
differentiation from the stem apex. The sex of an inflorescence on
an adult palm is determined about nine months after its initiation,
but it will take another 24 months before it is ready to flower.
Not all inflorescences will reach this stage, however. During the
period of rapid elongation, 5-6 months before anthesis, some of
them abort. The number of individual flowers per inflorescence varies
between cultivars, and increases with the age of the palm. The
individual flowers of a female inflorescence usually open within
three days and remain receptive during three to four days. The
flowers of the male inflorescences shed their pollen within five
days. Although selfing is not excluded, cross-pollination is the rule.
The fruit is a sessile drupe with a fleshy mesocarp and a hard
endocarp surrounding usually one, occasionally two and rarely three
seeds. The mesocarp of ripe fruits contains 45-50 % of an orange-red
coloured edible oil, containing approximately equal parts of saturated
and unsaturated fatty acids. The ripe seed, commonly called kernel,
contains 48-52 % of an almost colourless oil, predominantly composed
of saturated fatty acids. Fruit bunches develop from fertilized
inflorescences in 5-6 months.

1.2 Propagation

Up to the present time oil palms are exclusively propagated by
means of seed. In plantation practice a "seed" is the proper seed
surrounded by the hard endocarp. Methods of vegetative propagation
are unknown, but the possibilities of propagation by means of tissue
culture are being investigated in several research centres (JONES,
1974; STARITSKY, 1970). When seed is planted in moist sand, germination
will be irregular and may take 6-12 months. Various techniques to
improve the rate of germination by means of heat treatments have
been developed, both in Africa and in the Far East. At present only
two methods are commonly in use, viz. the wet and the dry heat
germination. The first technique consists of exposing previously
soaked "seeds" placed in closed polythene bags to 38° - $40^{o}C$ in
incubators. The seeds, which have germinated, are removed, and planted
directly in the pre-nursery or a nursery. The second technique
consists of heating seed containing about 18 % moisture in the same
way. No germination occurs during this process, but following this

treatment during 30-60 days it is ready for germination at ambient
temperature after bringing up the moisture content to about 22 %.
At present the classic pre-nursery beds have been largely replaced
by polythene bags of about 15 x 20 cm in size when laid flat.
Seedlings may be raised during some 4 months in these polythene bags
before transferring them to a field nursery or to a polythene bag
nursery. The latter consists of heavy quality polythene bags of
size 30-38 cm x 45-60 cm, filled with good soil. Plants raised in
polythene bags are a easier to handle, but they cannot be kept much
longer in these bags than scheduled, and their watering requires more
attention than that of plants raised in field nurseries.

1.3 Field planting

When the palms are 12-14 months old from the germinated seed
stage, they are ready for planting out in the field. Field nursery
palms require some leaf pruning with a view to reducing transpiration
and are lifted with a good ball of earth, which is protected with a
gunny sack or polythene sheet. Polybag nursery palms require little
special care. The spacing in the field is usually about 9 x 9 m
triangular, corresponding with 143 palms per net hectare planted. It
is good plantation practice to keep the land permanently protected
by means of creeping soil cover crops such as Pueraria phaseoloides,
Calopogonium mucunoides and Centrosema pubescens. A vegetable mulch
applied around the young palm after planting out may help to keep
the soil locally moist and cool during prolonged dry spells.

1.4 Field maintenance

This includes ring and path weeding and control of the cover
crop. After planting, a ring with a radius of about 100 cm arount is
kept clean-weeded, which should be increased as the crown expands
with a view to preventing the yet stemless palm from being overgrown
by the cover crop or weeds. Later weeded rings and paths are required
to facilitate harvesting and disease control.
Pruning of young palms, which produce too little to be harvested, is
limited to periodical removal of dead leaves and young inflorescences
just after their emergence. Pruning of producing palms may include
the removal of some green leaves to facilitate harvesting, but it
has been known for many years (TURNER, 1974) that this should be restricted as much
as possible. Although there is no evidence that the presence of
epiphytes on stem and crown reduces bunch yield, it is common practice

to remove them periodically to facilitate harvesting.

1.5 Fertilising

Fertilising has become standard practice in oil palm nurseries
and field plantings and may include both the major nutrients and the
trace elements. The diagnosis of nutritional deficiencies by means
of external symptoms, leaf analysis and to a lesser extent soil analysis
has made much progress during the last 30 years. Although the initial
expectations about the reliability of leaf analysis as a diagnostic
tool proved to be unfounded, analysis of the leaves and other parts
of the palm have undoubtedly contributed to a much better understanding
of its nutritional requirements. Labeled plant nutrients have been
successfully used to study placement and type of fertilisers.

1.6 Plant protection

Control of pests and diseases in nurseries and field plantings
by means of chemical pesticides is common practice in most plantations.
Little progress has been made up to the present time with the development
of effective biological control methods. Mammalian pests are more
important in oil palm cultivation than in most other crops, especially
pigs and rats. The former can be controlled by means of fences and hunting,
but the latter are rather difficult to control without the use of
poison baits.

1.7 Harvesting

Economic harvesting may be commenced during the second half of the
third year from field planting. From young, almost stemless palms the
fruit bunches may be removed by means of a chisel, without removing any
leaves. For rough-stemmed palms, which can be climbed easily without
the use of a ladder, a cutlass or a harvesting-axe is the usual tool.
At present smooth-stemmed palms are often harvested by means of a hooked
knife mounted on a pole, but the traditional way of climbing the palm
by means of a sling and cutting the fruit bunch with a harvesting-axe
or cutlass is still in use in Africa.

1.8 Breeding

The object of oil palm breeding is to increase the yields of oil
per hectare and per annum and to improve the quality of the oil. Most
emphasis is usually given to the yield of palm oil, although the
contribution of the kernels to the economy of a plantation are by no

means negligible. The oil yield per hectare is the product of the
number of palms per hectare x the number of fruit bunches per palm x
the mean bunch weight x the fruit/bunch ratio x the mesocarp/fruit
ratio x oil/mesocarp ratio. The interrelationship and heridity of
these yield components have been the subject of extensive investigations
during recent years. HARDON J.J. et al. (1973). Another important
breeding criterion is the annual height increase of the stems, which
determines the length of the economic life of a plantation to a large
extent. Finally, breeding for resistance against diseases such as the
wilting diseases caused by _Fusarium_ _oxysporum_ and _Ganoderma_ spp.
is receiving more and more attention.

2. GEOGRAPHY

Most geographic factors affect growth and development of plants
through changing other ecological factors, such as solar and terrestial
radiation, heat, water, atmospheric gases and biotic factors. They will
be briefly reviewed and only discussed into greater detail if their
effect is more or less direct.

2.1 Geographic position

The longitude of a habitat is of no eco-physiological significance.
The latitude, however, is very important because it affects the annual
course of the radiation and the temperature. The distance and direction
from the coasts of seas and large lakes work through the climate of the
habitat. A review of the habitats of semi-wild palm groves in Africa was
given by ZEVEN (1967). Outside Africa extensive semi-wild palm groves
only exist in Brazil, where they form a narrow belt along the Atlantic
coast between 13° and 14^OS. Smaller areas may be found further north
in the States of Sergipe, Algoas, Pernambuco and Para (HARTLEY, 1967).
Other small areas and groups of scattered palms may be found in several
other regions of the humid American tropics. It is usually difficult
to trace their origin, but it seems likely that they were introduced at
one time as seed by African slave labour. Commercial oil palm plantations
and experimental plantings have been established in many countries of
the humid tropics between about 16^ON, and 10^OS. In Africa and Asia
commercial planting commenced before the first World War, in America
during and after the second World War.

2.2 Erosion

Erosion by water removes the soil from between the tertiary and quaternary feeding roots near the soil surface, in particular in the clean weeded ring.Exposed roots dry up and die, sothat the capacity of the root system is reduced. Although no experimental evidence is available it is often quite obvious that palms growing under these conditions suffer from shortage of water and nutritional deficiencies. On the other hand the dense mat of tertiary and quaternary roots near the soil surface, the cover crops and the almost closed canopy of the crowns provide a very effective protection for the soil against erosion. Fot this reason soil conservation works are not considered necessary in Malaysia on slopes up to 5°, but slopes between 5° and 10° will usually require some form of conservation if the soils have a tendency to erosion (WILLIAMS & HSU, 1970).
Erosion caused by wind does not occur in the humid tropics and is therefore of no importance for oil palm cultivation.

2.3 Topography

The major topographic elements affecting plant growth and development are the relief, the slope angle, the slope direction and the altitude of the land. They all work through the local climate of the habitat. In addition the relief works through the drainage of the land, the slope angle through the ratio between run-off and infiltration of water and the altitude through many biotic factors. These will be discussed later. Most commercial plantings have been made on land with slopes up to about 20 %, but this has mainly technical and economic reasons (WILLIAMS & HSU, 1970) and only limited eco-physiological significance.

3. WEATHER AND CLIMATE

The effects of weather and climate will be discussed by analysing the effects of the major elements radiation, temperature, water and air. Most commercial plantings have been established in regions where the rainfall is in excess of evapo-transpiration during at least nine months of the year, viz. in regions with climates classified as Af and Am by KÖPPEN, or climates of the Equatorial Zone according to WALTER (1973).

3.1 Radiation

Only solar radiation will be considered under this heading. There is no information on the influence of cosmic radiation, whilst the terrestial radiation works mainly through the temperature of the soil and the air.

3.1.1 Wavelength. Field palms are normally grown under full sunlight, but pre-nursery palms and nursery palms are sometimes shaded, whilst young palms in replantings and young palms in semi-wild groves are usually exposed to more or less shading. Shading may be provided by means of screens made from palm leaves, wooden slats, Saran cloth, or by living trees. Screens reflecting part of the radiation are not likely to affect its composition to a large extent. Light transmitted by living leaves, however, is comparatively poorer in the red and blue wavelengths. This, in addition to the effect of a lower intensity of the solar radiation, may explain the increased size of whole plants and leaves of palms grown under the canopy of living leaves in comparison with palms of comparable morphogenetic age grown under full sunlight. From the results of replanting experiments in Zaïre   (FERWERDA, 1955) it may be deduced that replanted palms growing under the canopy of the old plantation have longer leaves than palms with the same cumulative leaf production growing in full sunlight. It is also clearly shown by the annual height increase of rough-stemmed palms growing under higher smooth-stemmed palms in a Nigerian semi-wild palm grove (ZEVEN, 1967). The mean annual height increase of the rough-stemmed palms was 106 cm, that of the smooth-stemmed palms only 30 cm.

3.1.2 Intensity. Photosynthesis is known to be quantitatively related with the intensity of the photosynthetic active part of the radiation, which corresponds approximately with the visible light. When the sky is clear, light intensity at the equator varies between monthly minima of 1410 Joule $cm^{-2}.day^{-1}$ in June and December to about 1540 Joule $cm^{-2}.day^{-1}$ in March and September. At $10^{o}N.$, however, there is already a distinct minimum of 1218 Joule $cm^{-2}.day^{-1}$ in December and a period of intensities over 1500 Joule $cm^{-2}.day^{-1}$ from March to September. When the sky is clouded, these intensities are reduced to only 20 % of the intensities on clear days, corresponding with a reduction in potential photosynthesis of about 50 % (DE WIT, 1965). It is not surprising, therefore, that the dry matter production of oil palm seedlings during the first 13 weeks after germination is already clearly related with light intensity. If 50 % of the natural daylight is intercepted by means of bamboo slats, the

the reduction of the dry matter production was found to amount to 24 %
for the whole plants, 21 % for the aerial part and 33 % for the roots
(VERMERDA, 1955).

SPARNAALJ et al. (1963) found a relation between the number of
effective sunshine hours per annum and the yield of fruit bunches. They
defined 'effective' sunshine as the total sunshine received during
periods of moisture sufficiency plus a fraction of the sunshine received
during periods of moisture stress, decreasing with the duration of the
period of moisture stress. Despite a somewhat arbritary estimation of
the influence of the water deficit on the effect of the sunshine, it is
clear that the yields per palm increase with about 5.7 kg per increase
of 100 hours effective sunshine. Extrapolation of these figures to
Malaysian conditions with values of 2400 hours or more 'effective'
sunshine would give mean annual yields of about 125 kg per palm, or
about 18 tons per hectare. These yields are indeed obtained on comparable
sandy soils in Malaysia, but on the coastal clays yields are usually much
higher WILLIAMS & HSU (1970). It is evident, however, that positive or
negative deviations from the calculated mean yield of some 25 kg per
palm are quite within the fiducial limits. It would seem, therefore,
that the influence of moisture stress is underestimated and/or that the
potential yields of the Nigerian planting material is less than that of
the Malaysian. The results obtained with genetically identical planting
material at La Mé, Ivory Coast and at San Alberto, Colombia seem to
confirm the beneficial effect of more sunshine in the absence of water stress
(table 1).

Table 1. Fruit bunches per ha and per annum in various regions

Plantation	Sunshine hours	Planting material	tons/ ha	
La Mé, Ivory Coast	1781	D x P La Mé	14-15	(adult)
San Alberto, Colombia	2070	do.	25-27	(adult)
Turbo, Colombia	1470	DxP Malaysia	16-19	(5th-6th year)
do.	do.	DxP Malaysia	15-18	(4th-5th year)
do.	do.	DxP Surinam	14-21	(4th-6th year)
do.	do.	DxP La Mé	13	(3rd year)
do.	do.	DxP Coldesa (Turbo)	13	(3rd year)

A recent publication on the results obtained at La Arenosa estate near
Turbo in Colombia, however, would seem to cast serious doubts on the
validity of this explanation (COLDESA, 1974). Despite an annual number of
sunshine hours, which is even worse than that at Benin, and a dry season
lasting on an average 75 days, yields of the young palms were suggestive of

potential yield levels comparable with the yield levels obtained at
San Alberto and in Malaysia (table 7). Perhaps the true explanation
of the high correlations found by SPARNAAIJ et al. (l.c.) between
effective sunshine and yield is that their estimation of the
effective sunshine during the dry season is in fact an estimation of
the degree of water stress during that period.

3.1.3 Periodicity. The annual variation in the duration of the daily
solar radiation are sufficiently large within the geographic distribution
of the oil palm to affect growth and development of many annual
tropical plants, such as rice, cowpeas and sesame. At about $16^{o}N$, the
latitude of a commercial plantation in Honduras, the duration of the
shortest day between sunrise and sunset is 11h10' and that of the
longest day 13h05'. The duration of the civil twilight at this latitude
varies only between 21 and 24 minutes. The bunch yield of this plantation
has a very irregular distribution throughout the year. Almost no yield
is obtained during the period January - May as compared with some 90 %
during the period June - December, with a high peak during the period
September - November (HARTLEY, 1957). It is unlikely, however, that
these differences are related with differences in daylength. Young
stemless palms submitted to constant daylengths of 10½, 11½, 12½ and
13½ hours respectively, but receiving the same quantity of photosynthetic
active light, showed no differences in leaf production after 28 weeks
(FERWERDA, 1965). In view of the size of the palms the experiment was
continued with four palms per treatment until the appearance of the first
inflorescences. Then the palms were dissected with a view to examining
the presence of immature inflorescences. The results are summarized in
table 2.

Table 2. Influence of constant daylengths on young stemless palms (mean
initial leaf number 19). Leaves at the conclusion of the experiment
numbered from the spearleaf = +1.

Daylength	New leaves/ palm 9-28th week	New leaves/ palm at conclusion	Inflorescences in axils of leaves -5 to + 15 (20)		
			Absent	Present	Aborted
10h30'	8.37	16.0	2.0	16.0	2.0
11h30'	8.53	16.8	3.1	13.8	3.1
12h30'	8.50	16.0	0.0	16.5	3.5
13h30'	8.33	15.8	3.8	14.2	2.0

Despite the small number of palms, the differences in production of new leaves between individual palms at the end of the experiment varied only between 15 and 17. The inflorescences present in the axils of the 15 youngest leaves including the spear leaf and five immature leaves preceding the spear leaf, however, varied between only 2 well developed + 9 aborted inflorescences and 20 well developed + zero aborted inflorescences, but these large differences were not related with the treatments.

3.2 Temperature

The influence of the temperature on growth and development of the oil palm cannot easily be studied in view of its size. Most information on the temperature requirements has been deduced from the geographic distribution of wild, semi-wild and planted palms. Experimental work has been carried out on the temperature requirements for germination, the regulation of the soil temperature in nurseries (HARTLEY 1967) and the temperature requirements for the growth of seedlings and young stemless palms. Four aspects of the temperature will be considered, viz. the mean temperature, its annual variation, its daily variation and the influence of extreme temperatures.

3.2.1 Mean temperature. The annual mean temperature within the geographic distribution of commercial plantings is between 24° and $28^{\circ}C$, but fruiting semi-wild palm groves occur near the equator at least up to 1300 m and according to older observations even higher (ZEVEN, 1967). This means that the lowest annual mean temperature supported may be close to $20^{\circ}C$. Growth of young seedlings is arrested at $15^{\circ}C$ (HENRY, 1957). FERWERDA & EHRENCRON (1975) studied the growth of young stemless palms with an initial number of about nine leaves at different temperatures in a phytotron. Some of the results are shown in table 3.

Table 3. Growth of young stemless palms at different temperatures in a phytotron. Light (52.500 lux at plant level) provided during 12h15' per day.

Temperature ($^{\circ}C$)			Leaves after four months			
Light (12h15')	Dark(11h45')	Mean	Number	%	Weight(g)	%
32	22	27	6.5	100	19.7	100
27	17	22	6.0	92	17.1	87
22	12	17	3.6	55	12.3	62
17	7	12	0.5	8	1.5	8

From this it is apparent that the rate of leaf production shows an
almost linear increase with the mean temperature in the range 12-22°C.
The increase of the mean dry weight of single leaves gives a similar
picture. Higher temperatures have much less effect on growth. It
seems likely that the annual leaf production of adult palms increases
with the annual mean temperature as well, but direct comparisons of
genetically identical planting material is not available. Although the
highest bunch yields are obtained in regions with annual mean
temperatures between 25 and 27°C, the distribution of the semi-wild
palm groves suggests that the oil palm is well adapted to much lower
temperatures.

3.2.2 Annual variation. The difference between the highest and the
lowest monthly mean temperatures within the geographic distribution
of the commercial oil palm growing regions of the world vary between
only 1.1°C for two sites mentioned by HARTLEY (1967) in Malaysia, 3.8°C
for a plantation at about 16°N in Honduras and 5.8° for the semi-wild
groves at 12-14°S in Bahia, Brazil. The oil palm belt of equatorial
West Africa takes an intermediate place with differences just over
3°C. The highest yielding plantations are found in the regions with
the smallest annual variation of the monthly means. In view of the
relation between the leaf production rate and the mean temperature it
seems unlikely, that the monthly variations in yield are related with
temperature in regions with the largest annual variation of the monthly
mean temperature. The lowest occurring temperatures will hardly slow
down the growth rate and will therefore not increase the time between
the appearance of consecutive inflorescences. Low temperatures may increase
the abortion of inflorescences before anthesis, however, and slow down
the ripening of fruit bunches, high temperatures may have the opposite
effect. This may account for the very irregular distribution of the
bunch yields in Honduras, which has a very pronounced peak in September,
October and November and almost no yield in January - April (HARTLEY,
l.c.). The highest bunch production of the Bahia groves, on the contrary,
seems to be between November and March.

3.2.3 Daily variation. The annual mean of the daily variation of the
temperature in the oil palm regions of the world listed by HARTLEY
(1967) varies between 4.8° and 11.2°C, but 50 % is comprised in the
narrow range 8° - 10°C. The highest yielding plantations are found in
regions with an annual mean daily variation of the temperature within

this range. Although the monthly means of the daily variation of the
temperature tend to be somewhat higher during the driest periods of
the year., the annual variation of these monthly means is surprisingly
small. As the driest periods usually correspond with the coldest
periods, the adverse effects of low temperatures may be strengthened.

3.2.4 Extreme temperatures. Very little is known about the effect
of extreme high or low temperatures on growth and development of the
oil palm. The absolute maximum in the oil palm regions of the world
is about 38°, the absolute minimum 8°, but daily maxima exceeding 34°
and daily minima below 14° are exceptions (FERWERDA, 1962). Brief
exposures to temperatures exceeding $38^{o}C$ and below $8^{o}C$ are not lethal,
however. Palms are occasionally exposed to higher temperatures
during short periods of time in our greenhouses on clear and hot
summerdays without visual damage. Although palms exposed to day
temperatures of $17^{o}C$ and night temperatures of $7^{o}C$ during four months
in a phytotron practically ceased to grow and became very chlorotic,
they were still able to resume growth under normal temperature
conditions.

3.3 Water

The study of the water requirements of the oil palm has been the
subject of several investigations during recent years, including both
experimental work and efforts to analyse the relationship between
water supply and growth and development by means of multifactor
analysis. The results of some of these investigations may seem somewhat
contradictory, but it would appear that this is at least partly due
to their empirical character and to inaccurate and incomplete reproduction
of the conclusions reached by the original authors in some of the
general textbooks. (HARTLEY 1967, SURRE & ZILLER 1963).

3.3.1 Humidity of the atmosphere. All information available on the
relation between growth and development of the oil palm and the
humidity of the atmosphere would seem to be circumstancial evidence.
WORMER & OCHS (1959) demonstrated a parallelism between the aperture
of the stomata and the relative humidity of the atmosphere in the
course of the day, but it is evident that this climatic element is
closely related with other climatic elements showing daily fluctuations,
such as air temperature and the moisture content of the soil. The
same conclusion may be drawn from the observations made by REES (1961)

on the relationship between stomatal opening, air temperature and soil moisture. In one of the general textbooks (SURRE & ZILLER, 1963) a relative humidity of at least 75 per cent is considered as being favourable for growth and development without other evidence than that these humidities obtain in the principal zônes of production. The well known beneficial effects of watering nurseries during prolonged rainless periods and the spectacular effect of irrigation on producing palms under similar conditions suggests that the humidity of the atmosphere is of secondary importance, as these localized applications of water are unlikely to have much effect on the humidity of the atmosphere.

3.3.2 Clouds and Mist. Clouds and mist affect the habitat mainly through their influence on the quantity and the quality of the solar radiation reaching the soil surface, and on the temperature of the air. The influence of these climatic elements has been discussed under 3.1 and 3.2.

3.3.3 Soil Water. The influence of the soil water on growth and development has been the subject of several studies during the last 20 years. Curiously enough the fundamental investigation by RINGOET (1952) on the transpiration and the water balance of cocoa, coffee and oil palm is not even mentioned in the bibliographies of the two leading textbooks (SURRE & ZILLER 1963, HARTLEY 1967), although it was well known to the authors of other publications on related subjects cited in these books.

RINGOET (l.c.) using both direct and indirect methods for the estimation of the transpiration, found a distinct effect of the moisture content of the soil on the transpiration coefficient (table 4). The range of the soil moisture content studied corresponded with the annual range occurring at Yangambi (Zaire) in a local oxysol.

Table 4. Effect of the moisture content of the soil on the transpiration coefficients of young oil palms and young coffee

Soil moisture (%)	Transpiration coefficient	
	Oil Palm	Coffee (Robusta)
11	164	515
15	380	606
19	337	613

Comparison of the mean transpiration coefficients of oil palm and coffee
with those of other plants cultivated or growing in the same region
gave the following result (table 5).

Table 5. Mean transpiration coefficients of various plants at Yangambi
(RINGOET 1952)

Species	Mean transpiration coefficient	Range in per cent of mean for 11-19 % soil moisture
Oil palm (Elaeis guinnensis)	294	115
Upland rice (Oryza sativa)	413	50
Robusta coffee (Coffea canephora)	578	20
Palisotha thyrsiflora (wild plant)	618	10
Cacao (Theobroma cacao)	666	-

From this it may be seen that the oil palm has a relatively low transpiration
coefficient. In addition the large range of the transpiration coefficient
of the oil palm as compared with that of the other plants reveals its
high adaptability to changes in soil moisture, which is characteristic for
xerophytic plants.

WORMER & OCHS (1957, 1959) made extensive studies of the relationship
between the humidity of the soil and various life functions of young oil
palms, which confirm and supplement RINGOET's findings. They found a
relationship between the available moisture content and transpiration,
stomatal aperture, and the N and P content of the leaves. When the moisture
content of the soil decreases, transpiration is unaffected until a
critical moisture level, well above the wilting point, is reached. After
that transpiration decreases and comes practically to a stillstand at
the wilting point. The height of this critical level depends on the
climatic factors determining transpiration. The degree of opening of the
stomata appears to be a reliable measure for the transpiration and may
easily be estimated by an empirical method. The discovery of positive
correlations between the moisture content of the soil and the N and P
content of the leaves is of paramount importance for the interpretation
of the results of leaf analysis.

REES (1961) and REES & CHAPAS (1963) provided complementary evidence
on the relationship between soil moisture and transpiration of nursery
palms, which confirm the results obtained by RINGOET (l.c.) and
WORMER & OCHS (l.c.)

3.3.3 Precipitation. The mean annual rainfall is perhaps the most misused single climatic element in comparitive studies on the ecology of the African oil palm. It is evident that its value as a direct measure for the available water is strictly limited to the site on which the palms are grown. When comparing growth and development of oil palms in different regions, more accurate estimations of the available water will be required, necessitating estimations of the potential evapotranspiration and the available water stored in the soil. The mean annual precipitation in 25 of the 28 oil palm regions of the world listed by HARTLEY (1967) varies between 1531 mm at Sibiti (Congo) and 3634 mm Jarangau (Malaysia). Extremes are 1217mm at Pobé (Dahomey), 5093 mm at Barrancabermaja (Colombia) and 8430 mm at Adenau (Cameroun).
A very important aspect for a continuously growing and fruiting evergreen perennial such as the African oil palm is the distribution of the precipitation. Prolonged virtually rainless periods may cause gradual dessication of the soil penetrated by the roots below the permanent wilting point. Depending on the depth of the soil, its water holding capacity and the height of the ground water table, this may affect growth and development to a greater or lesser extent. The first reaction of the oil palm to water stress is midday closure of the stomata during the hours of maximum potential evapotranspiration, e.g. around 15.00 hours (HARTLEY, 1967). This period gradually extends and eventually the stomata will remain closed during the greater part of the day. Together with the semi-xeromorphic structure of the leaves, this provides an effective protection against dessication. A conspicuous phenomenon resulting from water stress during several months is the failure of spear leaves to open, resulting eventually in a crown with up to six or more elongated unopened leaves. During the same time the oldest leaves continue to die off at a normal or even increased rate, sothat the number of functional green leaves in the crown is reduced. It is not likely, however, that this reduction of some 10 per cent of the leaf area has more influence on the photosynthesis of the palms than corresponds with the reduction in leaf area, because the average age of the functional leaves will be higher. BROEKMANS (1957) has shown that floral abortion about five months before anthesis is related with the intensity of the dry season. This has been confirmed in Malaysia (CORLEY, 1973). CORLEY (l.c.) has also presented

evidence to suggest that this pre-anthesis abortion of inflorescences
may be predominantly female, resulting in an apparent change in
sex ratio not resulting from the sex differentiation shortly after
the initiation of the inflorescence. He is of the opinion that
moisture stress has also a direct effect on the sex differentiation,
resulting in a higher production of male inflorescences 20 months
later, and believes that the results presented by BROEKMANS (1957)
and SPARNAAIJ et al. (1963) after correction for the influence of
the abortion on the apparent sex ratio, confirm these findings. In
my opinion it will be difficult if not impossible to unravel the
direct and indirect effects of moisture stress on sex ratio if
moisture stress is an annually returning phenomenon during the
dry season, as is the case in West Africa.

NG & GON showed in 1970 that fruit set, fruit/bunch and oil/
bunch in Malaysia were negatively correlated with rainfall at
anthesis, 160 days earlier (CORLEY, 1973). This is obviously due
to the reduction in atmospheric pollen density caused by rainfall,
as shown by HARDON & TURNER (1967). It seems likely that these
phenomena are positively correlated with the number of rainy days.
It has been suggested that drought may be one of the causes of the
sudden death of adequately pollinated bunches 2-4 months after
anthesis, a condition called bunch failure by TURNER & BULL (1967),
but no conclusive evidence is available to support this statement.

It is useful to re-examen the earlier studies on the relation-
ship between precipitation and the annual yield variation in the
oil palm in the light of the advaced knowledge on the physiology
of the oil palm. SPARNAAIJ, who made a similar effort in 1963,
found 'little or no agreement about the period of time between the
occurrence of a particular climatic condition and its effect on
production, or about the climatic factor or factors responsible
for the major yield fluctuations'. This is hardly surprising. First
because one important point was overlooked, viz. that not the
number of months between the climatic or edaphic condition determining
the sex of the inflorescence and anthesis should be compared, but
the number of leaves produced during that period of time. It is
obvious that the latter equally depends on the sufficiency of the
water supply and in addition on the temperature, the soil fertility,
the age and the genetic origin of the palms. There is ample
evidence to show that this is the case from experimental work and
observations carried out in Afica and the Far East. Annual leaf

production of adult palms in Nigeria is 22-24 (HARTLEY 1967, after
BROEKMANS 1957) as opposed to 25-35 in Malaysia (WILLIAMS & HSU
1970). If the sex of an inflorescence is determined in the axil
of the 18th leaf from the apex, it reaches the stage of anthesis
when this leaf has reached the 66th position (HARTLEY 1967, p. 177).
In the meantime 48 new leaves have been initiated at the apex and
the same number has been unfolded. In HENRY's model of the development
of the leaves and inflorescences (SURRE & ZILLER 1963, p.21) there
is no indication of the leaf number corresponding with the stage
of sex differentiation in the inflorescence, but it seems likely
that this is the 29th leaf ('individualisation de l'inflorescence').
When this leaf has reached the 76th position from the apex, the
inflorescence reaches the stage of anthesis. In the meantime 47
new leaves have been initiated and the same number unfolded. The
time required to produce 47-48 new leaves amounts to 24-26 months
in Nigeria and 16-23 months in Malaysia, almost exactly the time
between sex differentiation and anthesis according to BROEKMANS
(1957) in Nigeria and according to CORLEY (1973) in Malaysia.
Secondly the climatic factor or factors responsible for the major
yield fluctuations are clearly not identical in all oil palm regions
of the world. In West Africa both solar radiation and the
distribution of the precipitation are limiting factors, in West
Malaysia occasionally occurring periods of prolonged severe drought
and excessive rainfall are likely to be important.
DEVUYST (1948) found at La Mé, Ivory Coast, a positive correlation
between the annual yield and the sum of the monthly rainfall up to
300 mm during 12 consecutive months 33 months earlier. His limitation
of the useful rain to a maximum of 300 mm per months may seem rather
artificial at present, but it should be born in mind that PENMAN's
and THORNTHWAITE's estimations of the evapotranspiration were
published in the same year and that RINGOET's fundamental work on
the transpiration of the oil palm was not published before 1952.
The period of 33 months between rainfall and yield suggests a
period of approximately 27 months between sex differentiation and
anthesis, corresponding with an annual leaf production of about
21 according to HARTLEY's and HENRY's models. This is rather low,
but not improbable in view of the occurrence of two relatively
dry seasons and the rather particular palm population of the La Mé
experimental station at that time (SURRE & ZILLER, 1963, p.32).

HEMPTINNE & FERWERDA (1961) studied the regression of the 12

months's totals of the bunch yield on the 12 months' totals of the precipitation in two oil palm plantations in Zaire, Yaligimba situated north of the equator (2°17' N, 22°15' E, altitude 435 m) and Leverville situated south of the equator (4°15' S, 18°44' E, altitude 520 m), by means of a multiple regression analysis. The 12 months' totals of the precipitation varied between approximately 1500 and 2000 mm in the northern plantation and between 1100 and 2000 mm in the southern plantation. They found for the northern plantation a negative regression of bunch yield on the precipitation 31 months earlier and a positive regression on the precipitation 12 months earlier, for the southern plantation a quadratic regression of the bunch yield on the precipitation 33 months earlier and no regression of the bunch yield on the precipitation 12 months earlier. This suggests periods of 25 and 27 months respectively between sex differentiation and anthesis and floral abortion some six months before anthesis in the north. Supposing again that the time between sex differentiation and anthesis equals the time required to produce 47-48 leaves, this would correspond with an annual leaf production of 23 in the northern and of 21 in the southern plantation. These figures are in close agreement with the actual annual leaf productions of palms of this genetic origin (tenera x tenera ex. I.N.E.A.C. Yangambi, planting 1940 and 1941) growing under the abovementioned conditions of rainfall and temperature. SPARNAAIJ (l.c.) misunderstood the explanation given by these authors for these regressions. They suggested that the negative regression of the yield on the rainfall 31 months earlier at Yaligimba was in fact part the right half of a quadratic regression curve, with an optimum between 1500 and 1600 mm, as was found for Leverville. They did not give a valid explanation for the harmful effect of excessive rain fallen 31-33 months earlier on bunch yield, but were able to show that this was not due to insufficient solar radiation. Most of the rain at Yaligimba and Leverville falls in the afternoon and at night, sothat there is no negative regression of solar radiation on rainfall. The most likely explanation in the light of our present knowledge is an increase of the leaching of plant nutrients proportional with the quantity of rainwater percolating through the rooted soil (OLIVIN & OCHS 1974) and/or an increased incidence of waterlogging of the top soil proportional with increasing rainfall.

RINGOET (1952) arrived at the following estimation of the water balance of an 11 years old plantation based on actual measurements (table 6)

Table 6. Water balance (in mm) of an 11 years old oil palm plantation (+ 150 palms/ha) at Yangambi, Zaire (after RINGOET, 1952).

Rain	1875	Retained by the vegetation	131
Dew and mist	75	Transpired by the palms	400
		Transpired by the cover plants	673
		Evaporated from the soil	307
		Run-off and percolation	439
	1950		1950

From this it may be seen that the actual evapotranspiration of this plantation amounts to 1511 mm and that the percolation on flat land may be as much as 439 mm. This would seem to confirm the estimation of the optimum rainfall for Yaligimba by HOFTIJZE & VERHERDA (l.c.), because the climatic conditions of Yaligimba and Yangambi are very similar. It is evident that this figure does not represent an optimum water supply to the palms, because the distribution of the rainfall, although quite regular, is not ideal. Short periods during which the actual evapotranspiration will be lower than the potential evapotranspiration may occur during the driest months.

3.4 Air

Only wind will be considered under this heading. The composition of the air, in particular its CO_2 content, may show ecologically important differences between the oil palm regions of the world, but nothing is known on this point. Oil palm planters make the best use of the local CO_2 content of the air in two different ways (CORLEY, 1973). First by increasing the leaf area index by increasing planting density, the area of the individual leaves and the number of leaves per palm, secondly by increasing the net assimilation rate by improving the water supply, the mineral nutrition or the genetic potention for photosynthesis.

Tropical storms may do much damage, as the speed of the wind they create may exceed 160 km/hour . Some regions are notorious for the frequency of these storms, such as the islands and the coastal zones of the East and South China Sea, the Bay of Bengal, the Arabian Seas, the Caribbean Seas, the Gulf of Mexico, the Indian Ocean east of Madagascar, the Coral Sea and the Pacific east of Australia and west of Mexico. TAILLEZ & VALVERDE (1971) examined the effects of a cyclone that struck an oil palm plantation in the valley of the Magdalena river, Colombia, in March, 1968. Although most trees survived this disaster, many had more or less leaning trunks as a consequence of roots snapping off near the bulb. Growth and bunch production after erection of the trees was closely

related with the degree of inclination of the stems after the cyclone. Trees with inclinations between 0-30° were hardly affected, those with inclinations between 30-60° had shorter and sometimes deformed leaves and produced no bunches during about one year. Thirty months after the cyclone, some of the trees with inclinations of 60-90° still produced deformed leaves and most trees only produced male inflorescences. The inclination was also related with the age of the palms and their genetic origin. They are most susceptible to wind damage between 2½ and 4½ years after field planting, probably because the crown gradually reaches its final dimensions whilst the rooting system is still extending and brittle. The effect of the genetic origin is probably due to differences in height increase. There is a positive correlation between the susceptibility to wind damage and the height of the trunk.

4. SOILS

Semi-wild palm groves and cultivated palms may be found on a wide range of soils, indicating that the oil palm is not an exacting crop in this respect. This is confirmed by the fact that the natural habitats of wild oil palms, such as springs, banks of rivers and lakes, wet valleys and swamps, are too wet for dicotyledonous trees (ZEVEN, 1967). They grow better on fertile, deep, good structured and well-drained soils, but are unable to compete with the trees of the ombrophilous lowland forest and the tropical evergreen seasonal forest without man's intentional or unintentional protection.

4.1 Soil Profile

According to the 7th Approximation of the U.S. System of Soil Classification most oil palm soils belong to the following orders and suborders: Oxisols (Orthox), Ultisols (Udults) and Inceptisols (Aquepts). Although soil maps are available for many oil palm plantations, it is not yet possible to compare them on the common basis of an internationally used classification, such as the abovementioned system or the FAO classification. For the time being the suitability of certain soils for the cultivation of oil palm must be based on known factors limiting growth and development, such as the presence of a hardpan, poor internal and external drainage, insufficient depth, a high water table, poor structure and a low chemical fertility.

4.2 Physical properties

The texture of oil palm soils varies between loamy sand, sandy loam, sandy clay loam, sandy clay and clay. There is perhaps a preference for soils containing 25-30 per cent clay because of their good water holding capacity and usually good structure, but excellent plantations may be found on soils with finer or coarser textures. Modern forest clearing methods with heavy equipment are destructive of soil structure, because they cause compaction. This may locally ~~affect the growth of young palms planted on these sites~~ reduce bulk density to critical levels for root penetration and affect the growth of young palms planted on these sites.

4.3 Chemical properties

Although a considerable amount of information is available on the mineral reserves, the clay minerals, the cation exchange capacity and the exchangeable cations in soils used for the cultivation of oil palms, little is known on the quantitative relationship between each of these factors and growth and development of the oil palm. OLLAGNIER et al. (1970) give an example of chemically fertile montmorilonite clays in Brazil, which have such a poor internal drainage that yields are poor. TINKER (1963) describes chemically poor kaolinite clays giving satisfactory yields with adequate fertilizing. TINKER & SMILDE (1963) estimated for Benin soils a release of some 20 kg K per annum over a depth of 3 m, corresponding with 0.5 p.p.m. from a total content of some 200-300 p.p.m.. This covers approximately 40 per cent of the requirements of adult palms.

/= The effects of nutritional deficiencies, either in an absolute sense or induced, on growth and development are much better understood. The visual symptoms of the major element deficiencies and of some of the minor element deficiencies are known from the results of pot- and field experiments. The first descriptions based on experimental evidence of K- and Mg deficiency symptoms was made by THOMPSON (1941), of B-deficiency by FERWERDA (1954), of N-deficiency by BROESHART (1955), of P- and S-deficiency by BROESHART, FERWERDA & KOVACHICH (1957) and of Fe- and Mn-deficiency by BULL (1961[b]). They were followed by many others. The most thorough and complete studies of this subject were made by BROESHART et al. (1.c.) and BULL (1961). RAJARATNAM (1972) made comprehensive and exhaustive studies of the external and internal symptoms of B-deficiency. The visual symptoms of Cl-, Cu-, Zn- and Mb-deficiency are still unknown, but there is evidence to suggest that Cl is an essential element for the nutrition of the oil palm (OLLAGNIER & OCHS 1971).

Many nutritional deficiencies are known to affect growth, development and bunch yield. A summary of these effects on young and adult plantation palms was given by FERWERDA (1962), based on experimental work carried out in Zaïre. This summary is, slightly supplemented, reproduced in the tables 7 and 8.

/= 4.3.1 Nutritional deficiencies.

Table 7. Effect of nutritional deficiencies on growth, development and the bunch production during the first and second year of harvesting of young palms during six years after field planting (after FERWERDA 1062)

	Deficiency										
	N	P	S	K	Ca	Mg	Cu	Mn	Zn	B	Mo
Leaf production	-	0	-	-	-	-	0	0	0	0	0
Length leaves	-	0	-	-	-	-	0	0	0	-	0
Number pinnae	-	0	-	-	-	-	0	0	0	-	0
Length pinnae	?	?	?	-	?	0	?	?	0	-	0
Width pinnae	?	?	?	-	?	0	?	?	0	-	0
Deficiency symptoms	+	0	+	+	0	+	0	0	0	+	0
First inflorescence	-	0	-	-	-	-	0	0	0	0	0
Male inflorescences	-	-	-	-	-	0	0	-	0	-	-
Female inflorescences	-	-	-	-	-	-	-	-	0	-	-
Fruit bunches (number)	-	-	-	-	-	-	-	-	-	-	-

- = reduced or retarded; 0 = no effect; + = increased or accelerated; ? = effect unknown.

From this it may be seen that nutritional deficiencies may affect bunch production without measurable effect on growth and without visible leaf symptoms.

Table 8. Effect of nutritional deficiencies on bunch number, mean bunch weight and mortality of adult palms (after FERWERDA 1962)

	Deficiency											
	N	P	S	K	Ca	Mg	Cu	Mn	Zn	Fe	B	Mo
Fruit bunches (number)	-	-	-	-	-	-	-	-	?	?	-	-
Mean bunch weight	0	0	?	-	?	-	0	0	?	?	-	?
Mortality	+	0	?	0	?	0	?	?	?	?	+	?

- = reduced or retarded; 0 = no effect; + = increased or accelerated; ? = effect unknown.

Almost all nutritional deficiencies cause a decrease of the number of fruit bunches, either by changing the sex ratio in favour of male inflorescences and/or by increasing the abortion of immature female inflorescences some six months before anthesis. A decrease of the

number of fruit bunches does not always correspond with a decrease
of the mean bunch weight. Reduction of the number of fruit bunches
is apparently the first adaptation of the palm to adverse conditions.

Recently OLLAGNIER & OCHS (1971) have presented evidence to
suggest that chlorine is an essential element for the oil palm.
Their conclusion was based on the existence of a highly significant
correlation between the chlorine content of the leaves and bunch
yield in field experiments including potassium chloride as a
differential treatment, in the absence of a correlation between the
potassium content of the leaves and bunch yield. HEW & KHOO (1972)
could not find conformation for this in three manurial trials on
coastal clay soils in Malaysia, although there were significant
responses to fertilizing with muriate of potash and although the
Cl-contents of the leaves varied between 0.12-0.56% as compared
with 0.81-1.22% for the K-contents. The correlation coefficients
between bunch yield and Cl-content were small and insignificant.
Only in one experiment there was a significant but equally low
correlation of the bunch yield with the K-contents of the leaves.
VAN DIEST & STRUIF BONTKES (1972) studied the influence of Cl in the
nutrient solution on the growth and the chemical composition of
approximately one year old young seedlings.

Table 9. Effect of chlorine on the growth, chemical composition and
organic cation content of young seedlings during four months
(after VAN DIEST & STRUIF BONTKES, 1972) in per cent of Cl-free
nutrition

	%
Dry matter aerial part (last two months)	78
Dry matter roots (do.)	84
K-uptake (do.)	87
Ca-uptake (do.)	110
Mg-uptake (do.)	76
Cl-uptake (do.)	330
NO_3-concentration (last month)	140
SO_4-concentration (last month)	91
H_2PO_4-uptake (last two months)	80
N-uptake	88
Organic cations (cations - anions)	86

Addition of chlorine to the nutrient solution did not improve growth and caused a decrease of the uptake of N, P, S, K and Mg. For these reasons I feel that it is too early to proclaim chlorine as an essential nutrient for the oil palm. Although it is tempting to interpret high correlation coefficients between bunch yield and the Cl-content in the leaf as a causal relationship, it is evident that this is not necessarily the case.

NG SIEW KEE & TAN YAP PAU (1974) and NG SIEW KEE et al. (1974) presented convincing evidence that the symptoms of mid-crown chlorosis of palms planted on deep, acid peat soils are due to Cu-deficiency.

The chemical composition of oil palms, in particular the chemical composition of the leaves, is widely used as a tool for the diagnosis of nutritional disorders. Between the introduction of the plant analysis technique for oil palms by HALE (1947) and CHAPMAN & GRAY (1949) and its present wide use, after having been improved by many other investigators, the confidence in the absolute value of the leaf nutrient contents as norms for deficiency or sufficiency gradually disappeared. FERWERDA (1961) stated on account of COULTER's (1958) and his own investigations that the norms for the interpretation of leaf analysis data can only be established locally by comparison with the results obtained in fertilizer experiments in the same plantation and sampled at the same time. HARTLEY (1967, p. 477) arrived at much the same conclusion and very recently the same opinion has once more been expressed by BOLLE-JONES (1975). The latter pleads for a more quantitative approach of the uptake of plant nutrients by means of simultaneous measurements of growth and dry matter production of the analysed plants. The uptake of a nutrient is likely to be much closer related with bunch yield, than its concentration in the leaf.

4.3.2   pH. The oil palm is not exacting with respect to the pH of the soil. The pH of the soils of good yielding plantations varies between approximately 4.0 and 8.0, but most plantations have been established on more or less acid soils (pH 4.0-6.0).

4.3.3 Salt tolerance. Critical salt concentrations in the soil solution may occur as a consequence of brackish groundwater or cyclic salt in coastal regions. FERWERDA & STRUIF BONTKES (1972)

studied the influence of different salt concentrations on the
growth of 4-leaf seedlings grown during six months
raised in sand culture. Both the nutrient solution and the additional
salt were applied by means of continuous trickle irrigation, so that
nutrient and salt concentrations in the soil solution were constant
throughout the duration of each treatment. Five different salt
concentrations were tested by adding none, 40, 90, 140 and 190
milli-equivalent salt per liter to the nutrient solution as NaCl,
half NaCl and half $CaCl_2$ or half NaCl and half $MgCl_2$. The
concentration
of the nutrient solution was about 10 milli-equivalents per liter,
so that the range obtained was 10-50-100-150 and 200 milli-
equivalents, corresponding with a conductivity of 1-5-10-15 and 20
millimhos per cm. The duration of the exposure of the plants to the
salt solutions was two, four or six months. Plants exposed to salt
solutions during two or six months received a normal nutrient
solution during the remainder of the time.

The time required to produce one new leaf increased from about
2 weeks to nearly 5 weeks for the highest salt concentration, but
solutions with a E.C. up to 10 millimhos per cm appear
to have little effect. The effect of pure NaCl appears to be somewhat
worse than that of the mixtures with $CaCl_2$ or $MgCl_2$. (figure 3).
The first symptom of salt damage are the appearance of pale green
areas on the leaves, which turn into a yellow colour and eventually
become necrotic. The symptoms are proceeding from the oldest leaves
to the youngest leaves. The youngest leaf is always green.
The influence on the dry matter production per plant during six
months is shown in table 10.

Table 10. Influence of the salt concentration of the soil solution, the duration of the exposure to a salt soil solution and the kind of salt on the dry matter production of 4-leaf seedlings raised in sand culture during six months (FERWERDA & STRUIF BONTKES, 1972).

| | Dry weight per palm (g) | |
	Aerial part	Roots
Complete nutrient solution only	125.2	17.3
Electric conductivity 5 mmhos/cm	101.3	16.4
do. 10 mmhos/cm	97.0	15.6
do. 15 mmhos/cm	63.6	11.0
do. 20 mmhos/cm	33.9	6.3
Exposed during two months	108.7	17.9
four months	66.1	11.3
six months	51.9	8.6
100% NaCl	69.0	12.0
50% NaCl + 50% CaCl$_2$	94.6	13.6
50% NaCl + 50% MgCl$_2$	79.6	12.3

From this it may be seen that the dry matter production is affected by all salt concentrations, but up to E.C. values of 10 millimhos per cm the reduction is rather limited. The duration of the exposure is very important. If limited to two months, the growth reduction is only about 10%. The composition of the salt has much influence. Pure NaCl appears to be worse than a mixture of NaCl and MgCl, and the latter worse than a mixture of NaCl and CaCl.
From this it may be concluded that young oil palms are moderately tolerant to salts in the soil solution.

4.4 Biotic properties

High concentrations of active tertiary and quaternary roots are found near sites with accumulations of decaying vegetable matter, such as leaves removed during pruning rounds (TAILLER 1971). The major cause of this concentration is likely to be the locally increased supply of mineral nutrients. The oil palm and its cover crop provide a continuous supply of organic matter to the soil from decaying

leaves and roots, and protect the soil from direct solar radiation
and rain. The total annual production of leaves, stems and fruit
bunches was found to amount to 20-30 ton dry matter per $ha^{-1}.yr^{-1}$.
(REES & TINKER, 1972; CORLEY et al. 1973). This represents some
96% of the total dry matter production (CORLEY et al. l.c.).
The leaves provide 56% of this fraction (REES & TINKER, l.c.), sothat
     the leaves supply 11-16 ton organic matter per $ha^{-1}.yr^{-1}$ to
the soil. To this may be added the 10-14 ton of dry matter produced
annually by the cover crop (ROMBAUT 1974). From this it may be seen
that the primary production of an oil palm   plantation
amounts to 31-44 ton dry matter per $ha^{-1}.yr^{-1}$ and is therefore
of the same magnitude as that of ombrophilous and evergreen seasonal
forests of the tropical lowland.
Even without returning the bunch refuse to the plantation and
neglecting male inflorescences and dead roots, the annual supply
of organic matter to the soil amounts to 21-30 ton per $ha^{-1}.yr^{-1}$,
hence considerably more than required to compensate for the rate of
decomposition of organic matter on similar soils under annual
cropping.

5. BIOTIC FACTORS

     Under this heading only the influence of higher plants will be
discussed. The influence of the other biotic factors such as lower
plants and animals is usually so complex, that conclusions have very
limited general validity. In addition they are often closely related
with the physical environment. The most important biotic factor,
man, is entirely beyond the scope of this paper, because his
influence is primarily of a social, economic or technical nature.

5.1 Plants

5.1.1 Competition. In oil palm plantation there is competition for
environmental sources between neighbouring palms, and between palms
and the interline vegetation including cover crops, weeds or other
annual or perennial crops. The study of the competition between
neighbouring palms is closely related with the study of the optimal
planting density. CORLEY et al. (1973) reviewed the older work on

this subject, except the basic study by MARYNEN (1963). RAMACHANDRAN
et al. (1973) compared wide avenue and triangular planting with
densities varying from 96-183 palms per ha. (CORLEY et al. l.c.)
defined optimal density in three ways, viz.:
(a) the highest current yield in any given year;
(b) the highest cumulative yield over a given period;
(c) the maximum cumulative profit over a given period.
For the purpose of this paper only (a) and (b) will be considered.
PREVOT & DUCHESNE (1955) found a negative linear regression of the
current or cumulative yield per palm on the number of palms per ha.
This may be written as

$$y = a - bx,$$

where y is the yield per palm, x the number of palms per ha and
a and b constants. It is evident that b is the amount by which the
yield per palm decreases with a unit increase in density. This
decrease is both due to a decrease of the mean annual number of
bunches per palm and of the mean annual bunch weight, as may be seen
in the figures 4 and 5 taken from RAMACHANDRAN et al. (l.c.) MARYNEN
(l.c.) confirmed that this linear regression fitted just as well
as two more complicated non-linear functions describing competition
within species. It is evident that this can only be true for medium
densities, as the yield per palm will eventually attain a maximum
at very high and a minimum at very low densities. At medium
densities the regression for the yield per ha on the number of palms
is therefore a quadratic curve

$$Y = x.y = ax - bx^2,$$

where Y is the yield per ha. The optimal density $x_{max.}$ is now given
by

$$x_{max.} = \frac{a}{2b}$$

As could be anticipated, the regression coefficients b (or competition
factors) vary when comparing data from different planting density
experiments.
CORLEY et al. (l.c.) showed that the mean area per leaf may be used
as a standard for the comparison of different sets of data, despite
its close relationship with palm age, soil fertility and genotype.
They arrived at the important conclusion that the mean leaf area
can be used to estimate the current optimal density, independently
of the considerable differences between the actual current yields

corresponding with these densities (figure 6). Similarly the
competition factor may be estimated from the mean leaf area,
independently of the actual leaf level (figure 7). Since leaf area
reaches a maximum at 9-10 year after planting (figure 1) it is likely
that the effects of density are approximately constant after this
age, so that the optimal densities for 10-30 year old plantations
may be estimated by extrapolation.
PREVOT & DUCHESNE (l.c.) presented convincing evidence to show that
for any given density a triangular spacing is superior over a
rectangular spacing. This was confirmed by RAMACHANDRAN et al. (l.c.)
under Malaysian conditions.

The influence of the interline vegetation on the palms is too
complex for general conclusions, perhaps with one exception. DANIEL
& TAFFIN (1974) found in the dry zone of Dahomey, with an annual
water deficit of 600 mm, that removal of the interline vegetation
almost doubled the cumulative bunch yield obtained at the end of the
sixth year after planting. It remains to be seen, however, whether
the physical and chemical fertility of the soils can be maintained
under these conditions. Experience with clean weeding in the Far
East in the thirties was not very promising in this respect, but
the use of inert indestructible mulching materials may be
considered.

6. SUMMARY

Important contributions to the knowledge of the environmental
physiology of the African oil palm, Elaeis guineensis Jacq., were
made during the last ten years. These would seem to suggest that
the satisfactory growth, development and bunch yield may be obtained
under lower light intensities and at lower temperatures than was
rather generally accepted up to the present time. The daylength
is not likely to play an important role. There is much evidence to
suggest that the water supply should be continuously sufficient,
but not excessive, throughout the year for optimal results.
Tropical storms may cause serious and long lasting damage.
The essence of chlorine in the mineral nutrition is questioned, but
there is convincing evidence that copper deficiency may occur under
field conditions. The tolerance to salts in the soil solution is
moderate. The annual supply of organic matter to the soil in

plantations compares favourably with that of forests of the moist
tropical lowland.

The mean leaf area appears to provide a good estimation for the
optimal planting density. In regions with long dry seasons the
desirability of a living interline vegetation may be questioned.

R E F E R E N C E S

1. ANONYMUS (1966)
   The oil palm in Malaya
   Ministry of Agriculture and Co-operatives, Kuala Lumpur, pp. 255.

2. BOLLE-JONES, E.W. (1975)
   Limitations of foliar diagnosis with special reference to the
   oil palm
   Tropical Agriculture (Trinidad) 32:11-19 (1975)

3. BROEKMANS, A.F. (1957)
   Growth, flowering and yield of the oil palm in Nigeria.
   J.W.Afr.Inst.Oil Palm Res. 2:187-220.

4. BROESHART, H. (1955)
   The application of foliar analysis in oil palm cultivation.
   Thesis Wageningen, pp. 114.

5. BROESHART, H., FERWERDA, J.D. & KOVACHICH, W.G. (1957)
   Mineral deficiency symptoms of the oil palm.
   Plant and soil 8:289-300.

6. BULL, R.A. (1961)
   Studies on the deficiency diseases of the oil palm 2. Macronutrient
   deficiency symptoms in oil palm seedlings grown in sand culture.
   J.W.Afr.Inst.Oil Palm Res. 3:254-264.

7. BULL, R.A. (1961)
   Studies on the deficiency diseases of the oil palm 3.
   Micronutrient deficiency symptoms in oil palm seedlings grown in
   sand culture.
   J.W.Afr.Inst.Oil Palm Res. 3:265-272.

8. CHAPMAN, G.W. & GRAY, H.M. (1949)
   Leaf analysis and the nutrition of the oil palm (Elaeis guineensis
   Jacq.)
   Ann. Bot. XIII:415-433.

9. COLDESA (1974)
   Replanting diseased oil palm areas with Elaeis oleifera x E.
   guineensis hybrids at "La Arenosa" estate in Colombia.
   Oil Palm News 18:1-6.

10. CORLEY, R.H.V. (1973)
    Oil palm physiology: a review
    Advances in Oil Palm Cultivation : 37-51, Kuala Lumpur, Malaysia.

11. CORLEY, R.H.V., HEW, C.K., TAM, T.K. & LO, K.K. (1973)
    Optimal spacing for oil palms.
    Advances in oil palm cultivation : 52-71, Kuala Lumpur, Malaysia.

12. COULTER, J.K. (1958)

Mineral nutrition of the oil palm in Malaya.

Malayan Agric. J. 41:131-151.

13. DANIEL, C. & TAFFIN, G. de (1974)

Conduite des jeunes plantations de palmier à huile en zones sèches
au Dahomey.

. Oléagineux 29:227-232.

14. DEVUYST, A. (1948)

Influence des pluies sur le rendements du palmier à huile, enregistrés
à la station de La Mé de 1938 à 1946.

Oléagineux 3:137-144.

15. DIEST, A. van & STRUIF BONTKES, T. (1972).

De invloed van de N-vorm en de toediening van Cl op de groei, de
chemische samenstelling en het C-A-gehalte van de eenjarige olie-
palm (_Elaeis guineensis_ Jacq.)

Internal Research Report, Dept. of Soils and Fertilizers, Agricultural
University, Wageningen.

16. FERWERDA, J.D. (1954)

Boron deficiency in oil palms in the Kasai region of the Belgian
Congo.

Nature, London 173:1097.

17. FERWERDA, J.D. (1955)

Questions relevant to replanting in oil palm cultivation.

Thesis, Wageningen, 101 pp.

18. FERWERDA, J.D. (1956)

Germination of oil palm seeds.

Trop. Agric. (Trinidad) 33:51-66.

19. FERWERDA, J.D. (1961)

Growth, production and leaf composition of the African oil palm
as affected by nutritional deficiencies.

Publ. Am. Inst. Biol. Sci. 8:149-159.

20. FERWERDA, J.D. (1962)

Die Oelpalme.

SPRECHER von BERNEGG (ed.). Tropische und subtropische Weltwirt-
schaftspflanzen, II. Teil Oelpflanzen: 309-378, Enke, Stuttgart.

21. FERWERDA, J.D. (1965)

Unpublished data.

22. FERWERDA, J.D. (1971)
Oelpalme.
P. von Blanckenburg & H.-D. CREMER. Handbuch der Landwirtschaft
und Ernaehrung in den Entwicklungslaendern Band 2:330-340.

23. FERWERDA, J.D. & STRUIF BONTKES, T. (1972)
De zoutresistentie van de jonge oliepalm (*Elaeis guineensis* Jacq.)
Internal Research Report, Dept. of Tropical Crop Science,
Agricultural University, Wageningen.

24. FERWERDA, J.D. & EHRENCRON, J. (1973)
Unpublished data.

25. HALE, J.B. (1947)
Mineral composition of leaflets in relation to chlorosis and
browning of oil palms in West Africa.
J. Agric. Sci. 37:236-244.

26. HARDON, J.J., MOKHTAR HASHIM & OOI, S.C. (1973)
Oil palm breeding: a review
Advances in Oil Palm Cultivation: 23-36, Kuala Lumpur, Malaysia.

27. HARDON, J.J. & TURNER, P.D. (1967)
Observations on natural pollination in commercial plantings of
oil palm (*Elaeis guineensis*) in Malaya.
Expl. Agriculture 3:105-116.

28. HARTLEY, C.W.S. (1967)
The oil Palm, Longmans, London, 706 pp.

29. HARTLEY, C.W.S. (1970)
Some environmental factors affecting flowering and fruiting in oil
palm.
In: L.C. LUCKWILL & C.V. CUTTING (ed.). Physiology of tree crops:
169-286. Academic Press, London & New York, pp. 382.

30. HEMPTINNE, J. & FERWERDA, J.D. (1961)
Influence des précipitations sur les productions du palmier à huile.
Oléagineux 16:431-437.

31. HENRY, P. (1957).
Recherches sur la croissance et le développement chez *Elaeis*
guineensis Jacq. et chez *Cocos* *nucifera* L. Comparaison avec quelques
autres palmiers. Thèse Université Paris, 154. pp.

32. HEW, C.K. & POON, Y.C. (1973)
The effects of muriate of potash and bunch ash on yield and uptake
of potassium and chlorine in oil palms on coastal soils.
Advances in Oil Palm Cultivation: 239-247, Kuala Lumpur, Malaysia.

33. JONES, L.H. (1974)

Propagation of clonal oil palms by tissue culture.

Oil Palm News 17:1-8.

34. KNECHT, J.C.X., RAMACHANDRAN, R. & NARAYANAN, R. (1974).

Some variational features of the leaf nutrient contents in oil palm sampling.

Oléagineux 29:287-295.

35. MAILLARD, G., DANIEL, C. & OCHS (1974)

Analyse des effets de la sécheresse sur le palmier à huile.

Oléagineux 29:397-404.

36. MARYNEN, T. (1963)

Contribution à l'étude de la densité de plantation chez les végétaux.

Publ. I.N.E.A.C., Série Scientifique no. 102, pp. 79.

37. NG, SIEW KEE & TAN, YAP PAU (1974)

Nutritional complexes of oil palms planted on peat in Malaysia. I.

Foliar symptoms, nutrient composition and yield.

Oléagineux 29:1-14 (1974).

38. NG S.K., TAN, Y.P., CHAN, E. & CHEONG, S.P. (1974)

Nutritional complexes of oil palms planted on peat soil in Malaysia II.

Preliminary results of copper sulphate treatments.
Oléagineux 29: 445-456.

39. OLLAGNIER, M., OCHS, R. & MARTIN, G. (1970)

The manuring of oil palm in the world.

Fertilité 36:3-63.

40. OLLAGNIER, M. & OCHS, R. (1971)

Le chlore, nouvel élément essentiel dans la nutrition du palmier à huile.

Oléagineux 26:1-15.

41. OLIVIN, J. & OCHS, R. (1974).

Le lessivage du potassium et du magnésium en colonnes de terre.

Premiers résultats expérimentaux.

Oléagineux 29:175-182.

42. PREVOT, P. & DUCHESNE, J. (1955)

Densités de plantation pour le palmier à huile

Oléagineux 10:117-122.

43. PREVOT, P. (1961)

Données récentes sur la physiologie du palmier à huile.

Physiologie des plantes tropicales cultivées 1:11-39.

44. PURSEGLOVE, J.W. (1972)
Oil Palm
Tropical Crops, menocotyledons 2:479-510 (1972)

45. RAJARATNAM, J.A.
Observations on boron-deficient oil palms (Elaeis guineensis).
Expl. Agric. 8:339-348.

46. RAMACHANDRAN, P., NARAYANAN, R. & KNECHT, J.C.X. (1973)
A planting distance experiment on Dura palms.
Advances in Oil Palm Cultivation: 72-88, Kuala Lumpur, Malaysia.

47. REES, A.R. (1961)
Midday closure of stomata in the oil palm.
J. Exp. Bot. 12:129-146.

48. REES, A.R. & CHAPAS, L.C. (1963).
Water availability and consumptive use in oil palm nurseries.
J.W.Afr.Inst.Oil Palm Res. 4:52-65.

49. REES, A.R. & TINKER, P.B.H. (1973)
Dry matter production and nutrient content of plantation oil palms
in Nigeria.
1. Growth and dry matter production.
Pl. Soil 19:19-32.

50. ROMBAUT, D. (1974)
Etude sur l'élevage bovin dans les palmeraies de Côte-d'Ivoire.
Oléagineux 29:121-125 (1974).

51. SPARNAAIJ, L.D., REES, A.R. & CHAPAS, L.C. (1963).
Annual yield variation in the oil palm.
J.W.Afr.Inst. Oil Palm Res. 4:111-125.

52. STARITSKY, G. (1970)
Tissue culture of the oil palm (Elaeis guineensis Jacq.) as a tool
for its vegetative propagation.
Euphytica 19:288-292.

53. SURRE, CH. & R. ZILLER (1963)
Le palmier à huile.
Maisonneuve & Larose, Paris, pp. 243

54. TAILLEZ, B. & VALVERDE, G. (1971)
Sensibilité aux ouragans de différents types de croisements de
palmier à huile.
Oléagineux 26:753-763 (1971).

55. THOMPSON, H. (1941)
Notes on plant diseases
Malayan Agric. J. 29:241-242.

56. TINKER, P.B.H. (1963)
Changes occurring in the sedimentary soils of southern Nigeria
after oil palm plantation establishment.
J.W.Afr.Inst.Oil Palm Res. 4:66-81.

57. TINKER, P.B.H. & SMILDE, K.W. (1963)
Cation relationship and magnesium deficiency in oil palm.
J.W.Afr.Inst.Oil Palm Res. 4:82-100.

58. TURNER, P.D. & BULL, R.A. (1967)
Diseases and disorders of the oil palm in Malaysia.
Incorporated Society of Planters, Kuala Lumpur, pp. 247.

59. TURNER, P.D. (1974)
Oil palm pollination and pruning: some new light on old ideas.
Planter (Malaysia) 50:24-31.

60. TURNER, P.D. & GILLBANKS, R.A. (1974)
Oil palm cultivation and management.
The Incorporated Society of Planters, Kuala Lumpur, Malaysia, pp. 672.

61. WALTER, H. (1973)
Vegetationszonen und Klima. Ulmer, Stuttgart, pp. 253.

62. WASTIE, R.L. & EARP, D.A. (1973)
Advances in oil palm cultivation.
The Incorporated Society of Planters, Kuala Lumpur, Malaysia,
469 pp.

63. WESSELS BOER, J.G. (1965)
The indigenous palms of Surinam. Thesis Utrecht, pp. 172.

64. WILLIAMS, C.N. & Y.C. HSU (1970)
Oil palm cultivation in Malaya.
University of Malaya Press, Kuala Lumpur, Malaysia, pp. 205.

65. WIT, C.T. de (1965)
Photosynthesis of leaf canopies.
Agric. Res. Rep. no. 663, pp. 57.
Institute for Biological and Chemical

66. WORMER, Th.M. & OCHS, R. (1957)
Humidité du sol et comportement du palmier à huile en pépinière.
Oléagineux 12:81-89.

67. WORMER, Th.M. & OCHS, R. (1959)
Humidité du sol, ouverture des stomates et transpiration du
palmier à huile et de l'arachide.
Oléagineux 14:571-580.

68. ZEVEN, A.C. (1967)
The semi-wild oil palm and its industry in Africa.
Thesis, Wageningen, pp. 178.
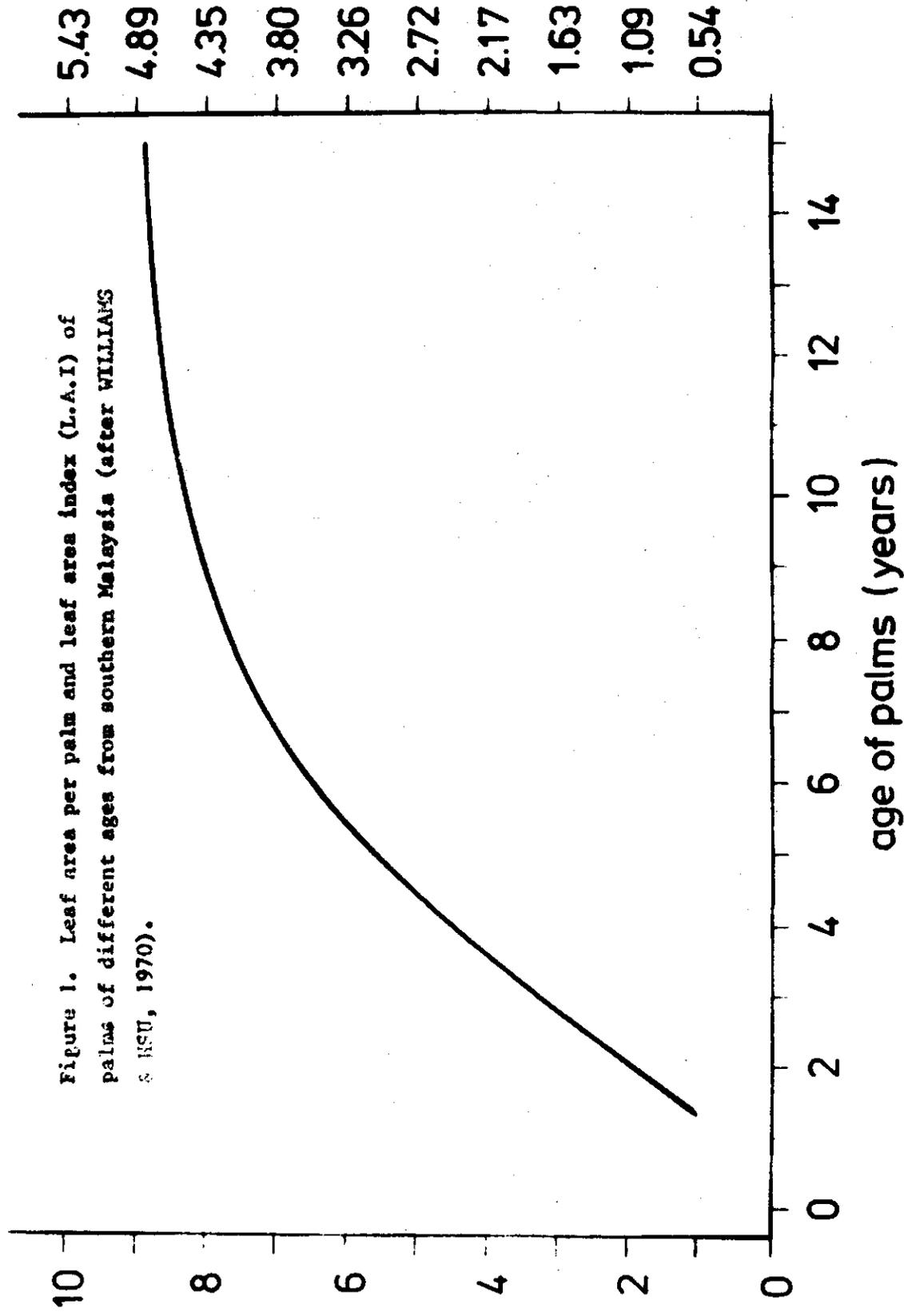
Figure 1. Leaf area per palm and leaf area index (L.A.I) of palms of different ages from southern Malaysia (after WILLIAMS & HSU, 1970).

Figure 2. Relationship between crop growthrate (C.G.R.), yield and leaf area index (after CORLEY, 1973)
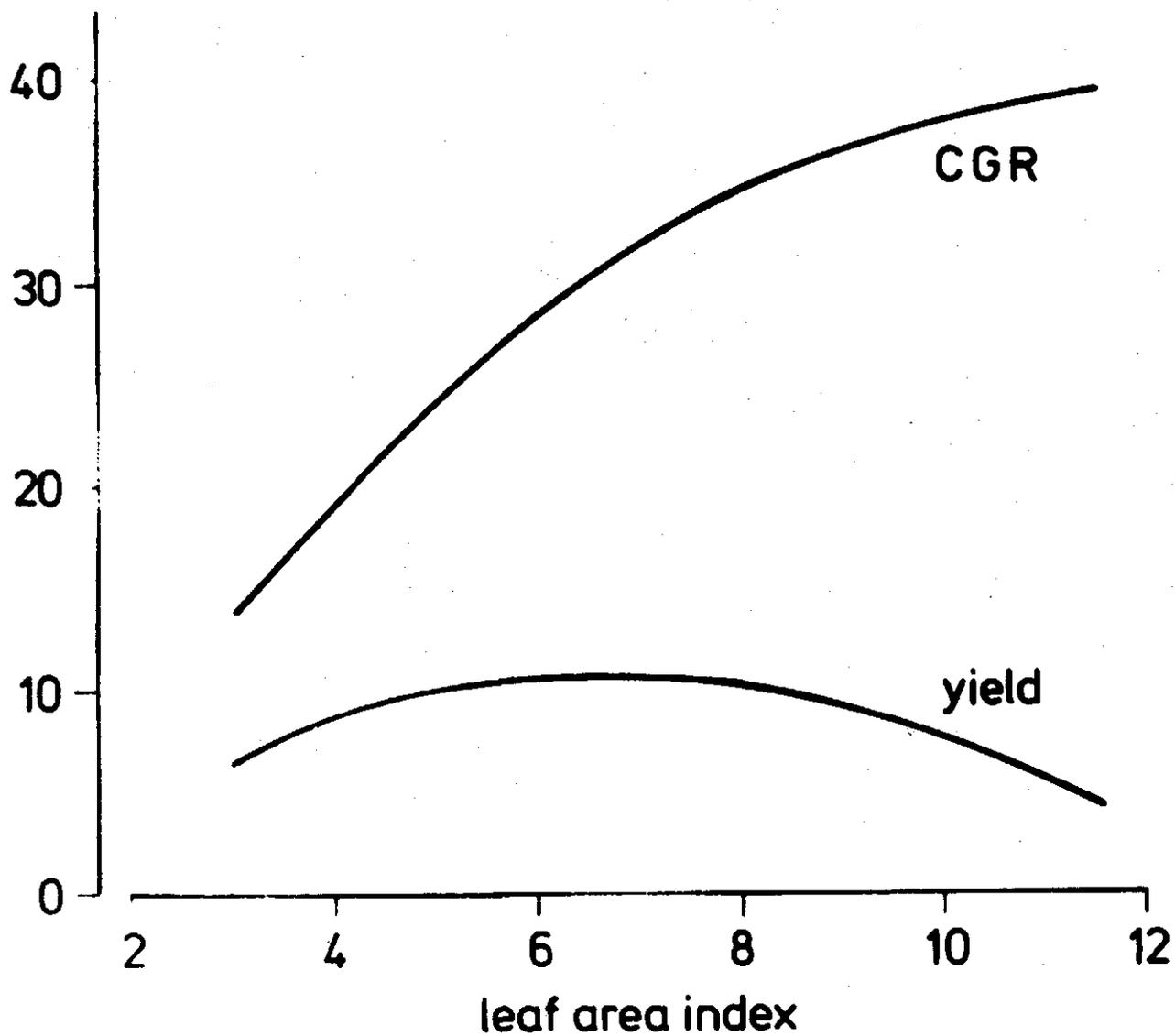
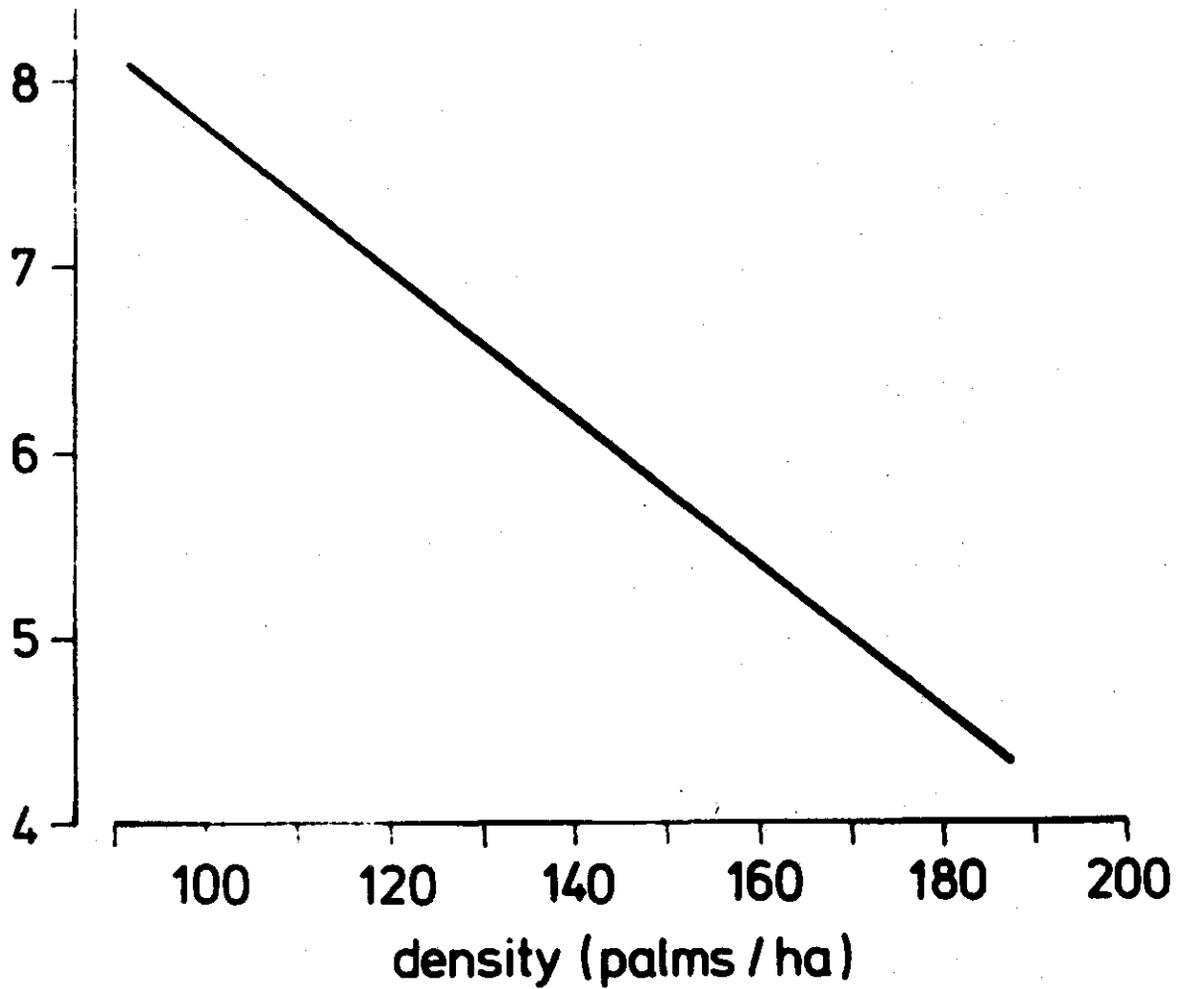**weeks / leaf**

mean annual number
of bunches per palm
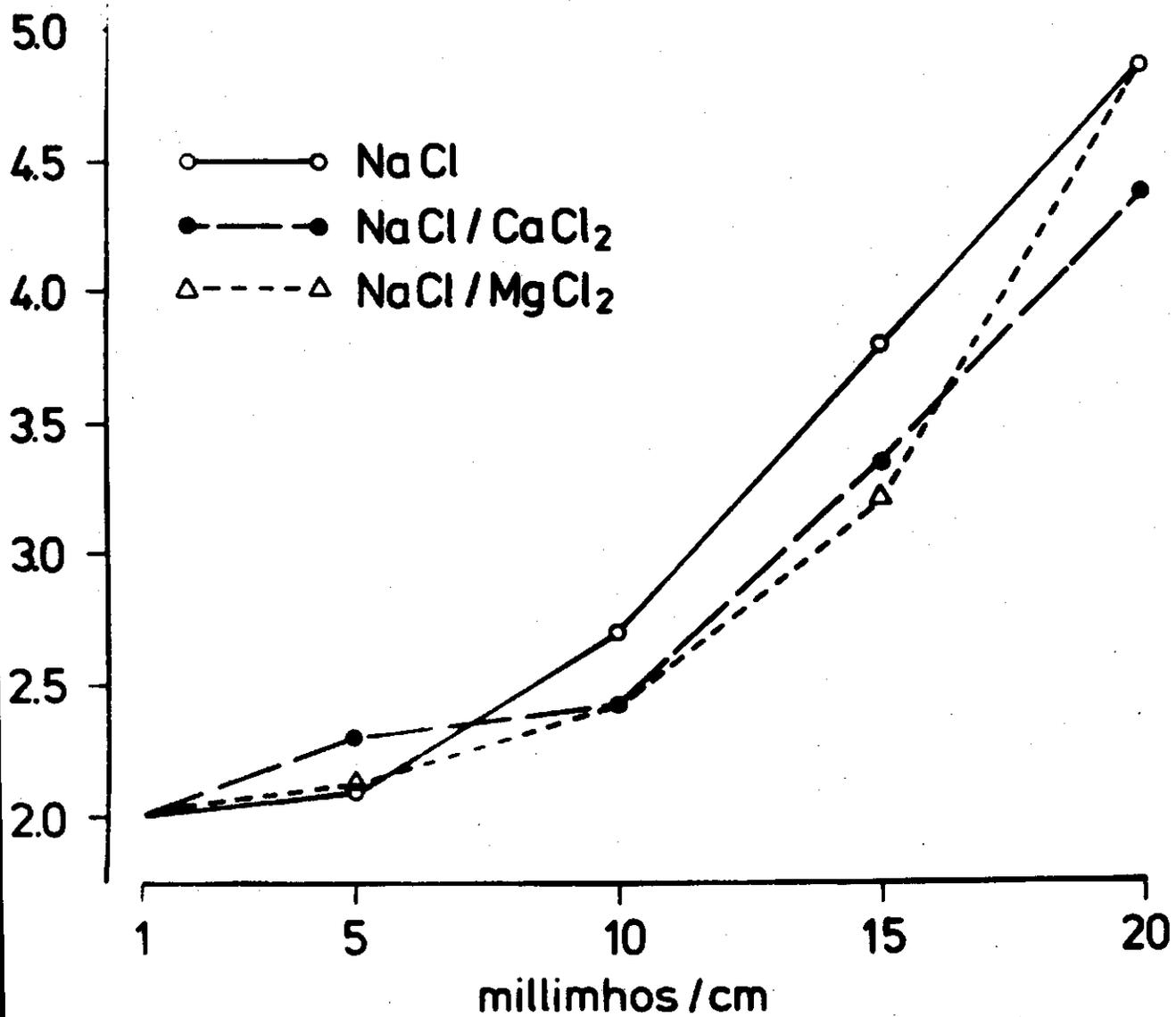
Figure 5. Mean annual bunch weight and density (after RAMACHANDRAN et al, 1973)
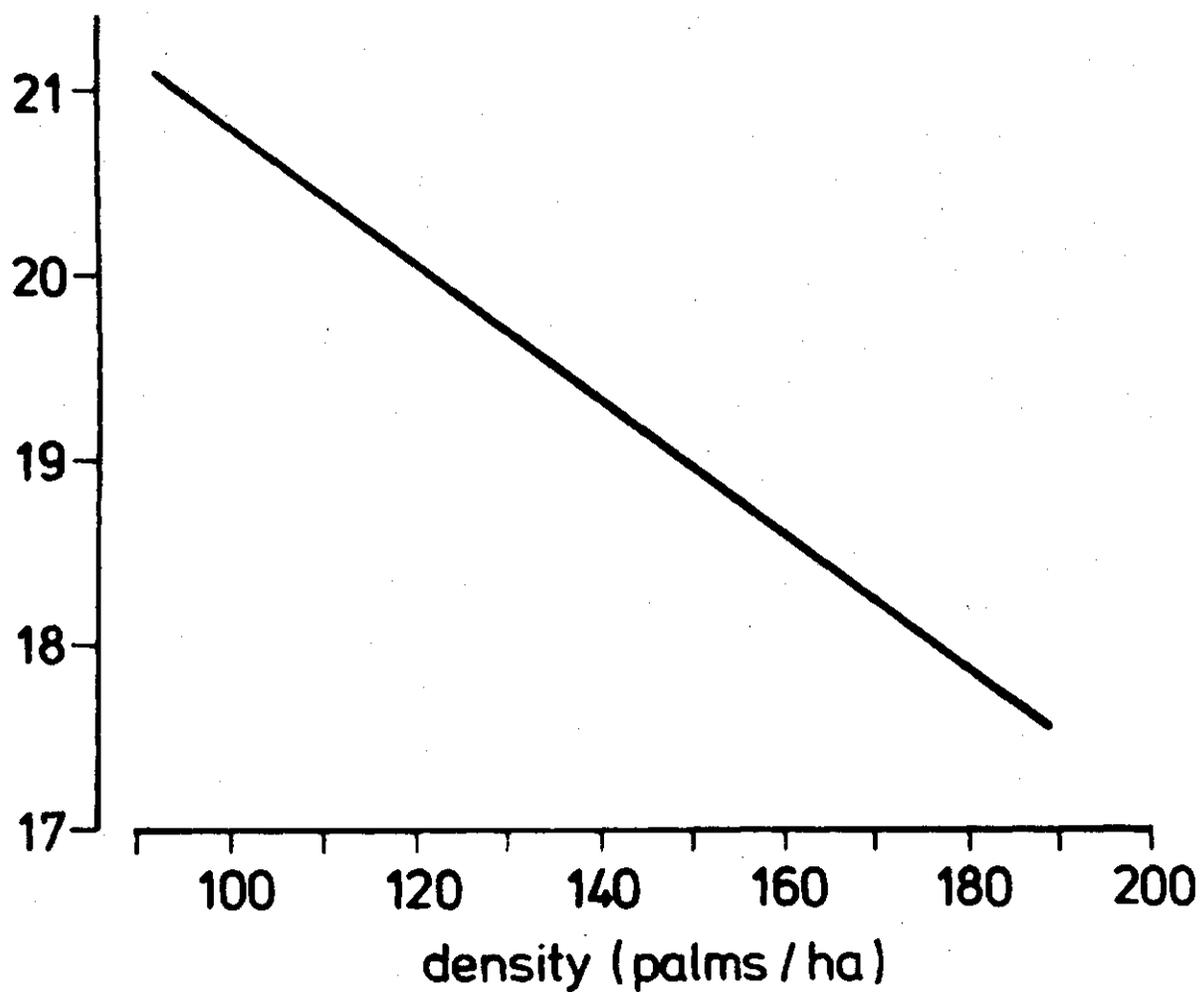
mean annual
bunch weight (kg)

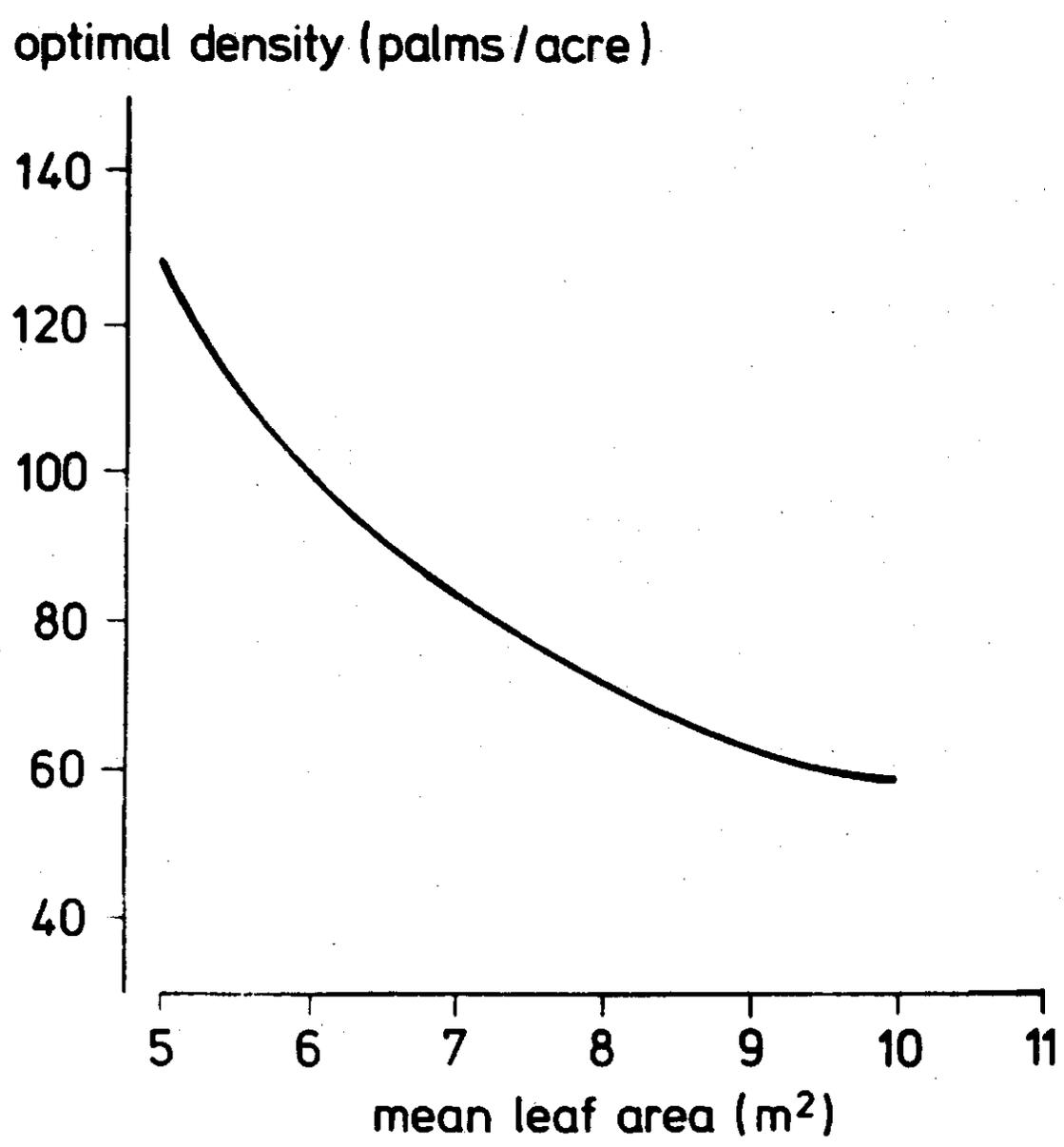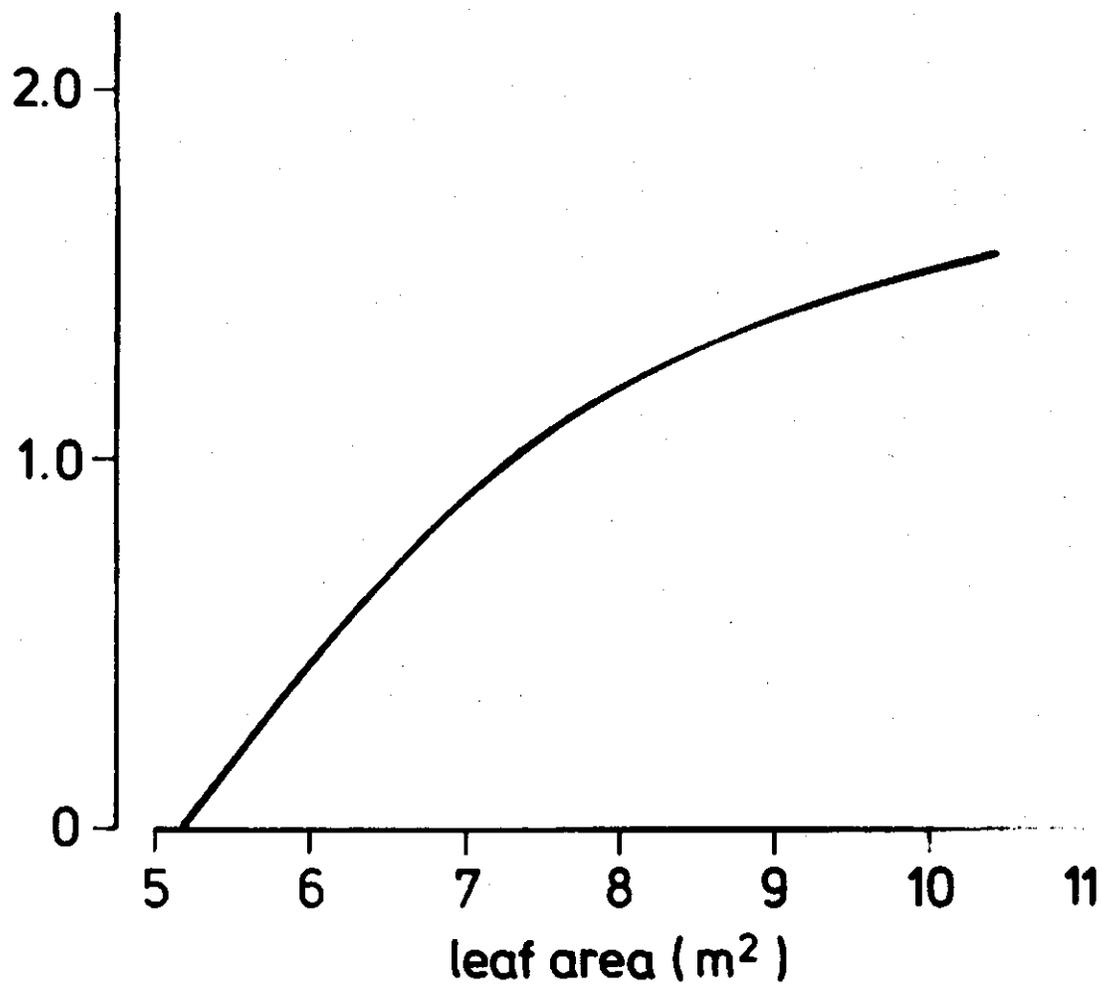**Figure 6.** Optimal density and leaf area (after CORLEY et al., 1973).

Figure 2. Competition factor and leaf area (after CORLEY et al., 1973)

competition factor

CAPITA   SELECTA   NUTTIGE   PALMEN,

februari - maart 1977

D E   D A D E L P A L M

(J.A. Samson)

Dit overzicht is gebaseerd op EL-BARADI(3) en MUNIER(7); zie
overigens de literatuurlijst.

INLEIDING

Vele gewassen, b.v. rubber, oliepalm en koffie, worden nu ver van
hun centrum van diversiteit verbouwd. Dit geldt echter niet voor
de dadelpalm, die al 50 eeuwen in Mesopotamië en omringende landen
in cultuur is; de cultuur is nog steeds vrijwel tot die landen
beperkt. Dit wijst op hoge eisen aan het milieu, maar hangt ook
samen met het cultuurpatroon van de inwoners van die streken. Door
zijn goede houdbaarheid is de dadel een belangrijk voedsel voor
woestijnbewoners. Irak is verreweg de grootste producent en
exporteur.

BOTANIE

Het genus Phoenix telt 12 spp en is te herkennen aan de op doorsnee
V-vormige blaadjes. Er zijn enkele sierplanten onder, b.v.
P.canariensis. Bij P.sylvestris wordt sap van de stam geoogst; het
bevat 12-15 % suikers en is rijk aan vitaminen. Per palm en per
seizoen kan men 40 kg "jaggery" (bruine suiker) verkrijgen (2).
P.dactylifera L. is de enige economisch belangrijke soort. Het is
een 2-huizige palm met uitlopers aan de stam, waardoor vegetatieve
vermeerdering mogelijk en gebruikelijk is. Meestal gebruikt men de
basis-uitlopers; vertakking hogerop wordt als een ongunstige eigen-
schap beschouwd.
De vrouwelijke bloeiwijze heeft 10-30 takken en gaat bij afrijping
hangen. Parthenocarpie komt voor, maar de vruchten ontwikkelen
zich niet, of zijn waardeloos. Voor de bestuiving laat men één
mannelijke op elke 50 vrouwelijke bomen staan. Daar windbestuiving
onzeker is, moet kunstmatig bestoven worden.

Per jaar komen er 12-20 bladeren bij. Een volwassen palm heeft +
100 actieve bladeren, die 4-7 jaar functioneel zijn; daarna vallen
ze echter niet af, men moet ze afsnijden. Een boom kan tot 200 jaar
oud worden.

CULTIVARS

Bij zaaien ontstaat een heterogene aanplant. Wil men het type van
de moederplant behouden, dan moet men van scheuten uitgaan. Er
zijn honderden cvs en naar de consistentie van de rijpe vrucht
worden ze ingedeeld in 3 groepen: droog, half-droog en zacht. Elk
gebied heeft zijn eigen favoriete cvs. Bekende cvs zijn:
'Deglet-Noor' en 'Zahidi' (half-droog), 'Sayir' en 'Rhars' (zacht).

Knopmutaties komen regelmatig voor, men kan er soms nieuwe cvs van
maken. Bij selectie en veredeling streeft men naar resistentie
tegen ziekten (vooral "bayoud"), grotere vrucht met kleinere pit,
vroege rijpheid en gelijkmatige afrijping. Veredelingswerk is
moeilijk door de lange duur van een generatie.

KLIMAAT

Dadel hoort thuis in aride en semi-aride streken. Voor de teelt
zijn vereist: hoge temperatuur en veel zon, lage luchtvochtigheid
en regenval, maar voldoende water voor irrigatie. De palm groeit
tussen gem. temperaturen van 10 en 40° met een optimum van 30°;
de boom tolereert echter temperaturen van -15° tot $+50^{\circ}$. Overigens
is gebleken dat de interne temperatuur van het vegetatiepunt
minder schommelt dan de buitentemperatuur, nl. maar 4 à 5 graden,
en daaraan omgekeerd verloopt. Het maximum wordt vroeg in de
ochtend bereikt, het minimum in de middag. Dit is te danken aan
beschermende weefsels en aan de verdamping.

Bloei treedt op na koude, als de gem. dagelijkse temperatuur een
bepaalde drempel overschrijdt. Afhankelijk van klimaat en cv. ligt
die drempel op waarden tussen 12 en 24°, maar in de regel neemt men
18°. De bloei duurt 30-50 dagen, de rijping nog eens 120-200 dagen.
Voor de afrijping is een bepaalde warmtesom vereist: de som van
alle gemiddelde dagelijkse temperaturen na aftrek van de drempel-
waarde (18°). Die som moet minimaal 800° zijn (Elche, Spanje),
maar ligt gewoonlijk rond de 1800°.
Regen en hoge luchtvochtigheid tijdens de bloei en/of vrucht-
rijping hebben tot gevolg dat de bloemen beschimmelen, het stuif-
meel niet goed kiemt en de verdamping van de vrucht stagneert. Ook
zeer lage vochtigheid is schadelijk: de vrucht verdroogt. Optimaal
is een relatieve vochtigheid van rond 60%.
In het Middellandse Zee-klimaat regent het 's winters. Tijdens de
bloei is het meestal en bij de vruchtrijping vrijwel altijd droog.
Ten zuiden van de Sahara daarentegen, valt de (korte) regentijd in
de zomer. Een koude periode ontbreekt hier. Nog verder naar het
zuiden treden twee regenperioden en dus ook twee bloeiperioden per
jaar op. Het kan dus zijn dat bloei en(of) vruchtrijping regen-
schade ondervinden. Sommige cvs zijn daar zeer gevoelig voor,
andere hebben er betrekkelijk weinig last van.

BODEM

Dadel kan op zeer zandige, maar ook op lemige, of zelfs kleiige
gronden groeien; diepe zandige leemgronden zijn het best. Hoofd-
zaak is dat de grond goed doorlatend en geaëreerd is, tot een
diepte van 1½ m. Hoewel de plant nogal zout-resistent is, zal
schade optreden bij hoge concentraties, nl. boven 1% zout in de
bodemoplossing. Daarom moet voor goed irrigatiewater en voor goede
drainage gezorgd worden.

VERMEERDERING

Bij vermeerdering uit zaad krijgt men 50% mannetjes. Het duurt
jaren voor deze als zodanig herkend zijn. Ook de vrouwtjes zijn
niet alle geschikt en nog meer jaren zijn nodig om de non-valeurs te
verwijderen. Daarom wordt zaaien nu vnl. toegepast bij veredelings-
werk. De optimale kiemptemperatuur is 25-35^{o}(15).
Men vermeerdert liefst met basis-scheuten. Ze moeten 3-10 jaar
oud zijn en 7-50 kg wegen. In het zuiden van Algerije heeft men
vooral succes met scheuten van ± 20 kg. De scheut moet ten minste
een jaar in contact met vochtige grond of zaagsel (1) zijn geweest.
Het scheiden van scheut en stam is een moeilijk werk dat zorgvul-
dig dient te geschieden. Daarna moet de scheut direct uitgeplant
worden, of gedurende een jaar in een kwekerij gehouden worden.
Men moet dan wel met kluit overplanten.
Proeven met hormoonbehandeling (K-zout van IBA) en opkweek in een
nevelbak hadden succes. Om beschimmeling tegen te gaan moest
wekelijks met een fungicide behandeld worden (12).
Voor het planten wordt de scheut gesnoeid, waarbij veel, weinig,
of vrijwel geen blad achterblijft. Het uitplanten geschiedt
verticaal (maar Moslims planten soms schuin, naar Mekka gericht).
Totdat de scheut goed beworteld is moet vaak, b.v. 2 keer per week
begoten worden. Hoewel stamscheuten minder gewenst zijn, worden
ze af en toe toch gebruikt.

TEELTMAATREGELEN

Plantverband. Bij planten met een cirkelvormige kroon zou het
logisch zijn een gelijkzijdig driehoeksverband te kiezen. De
dadelpalm wordt echter meestal in vierkantsverband geplant,
misschien omdat het dan gemakkelijker is er andere gewassen tussen
te zetten. De dichtheid varieert tussen 100 en 200 bomen per ha.

Windbescherming kan verkregen worden van levende hagen (Tamarix,
Casuarina, Prosopis), eventueel met secundaire riethagen.

Tussencultuur is in het algemeen niet aan te bevelen. Zo bleek
een tussengewas van lucerne de dadeloogst aanzienlijk te drukken
(14). In Irak wordt vaak citrus onder dadel verbouwd, maar men
krijgt de indruk dat daardoor citrus het hoofdgewas is geworden,
dat beschermd moet worden tegen extreme temperaturen.

Irrigatie is noodzakelijk, zelfs al kunnen de wortels het grond-
water bereiken. Jonge planten worden wekelijks, later maandelijks
bevloeid. Het minimum is 4-6 keer per jaar. In totaal is 1500-
2500 mm water per jaar nodig. Daar men aan het blad niet ziet
dat het verwelkt, moet het vochtgehalte van de grond regelmatig
gecontroleerd worden. Druppelirrigatie gaf reeds in het tweede
jaar significant hogere opbrengsten en grotere vruchten (13).

Bemesting in hoofdzaak met N, in totaal 2-3 kg per boom/jaar.
Organische mest verdient de voorkeur, vooral van slachtvee, omdat
die tot 2% N bevat (8). Gebrek aan P en K is in aride gebieden niet
waarschijnlijk, maar een beetje gemakkelijk opneembare P kan van nut
zijn(4).

Bestuiving. Bij dadel treden metaxeniën op, dus de aard van het
stuifmeel is van invloed op b.v. de grootte van vrucht en pit, of
de tijd van afrijping. Er moet daarom naar goede vaderplanten
gezocht worden. De kans op bevruchting is ruim 90% als het stuif-
meel binnen 4 dagen na het opengaan van de bloem wordt toegediend.
Dit moet bij rustig, droog en warm weer geschieden. Een ♂ boom
levert 20 bloeiwijzen met elk 250-750 g stuifmeel. Met 1 gram kan
men 12 bloeiwijzen bestuiven. Handbestuiving kost 20 werkdagen per
ha, terwijl het met een stuifapparaat in 5 dagen gaat. Het stuif-
meel is bij droge en koele bewaring minstens een jaar houdbaar.

Snoei dient om niet-functionele bladeren te verwijderen en om de
boom beter toegankelijk te maken door het wegnemen van doorns aan
de bladbasis. Soms snijdt men groene bladeren weg, om de vrucht-
rijping in een minder vochtig milieu te laten verlopen.

Vruchtdunning heeft tot doel grotere vruchten te krijgen, die
tegelijk rijp worden. Men haalt hiertoe liefst de binnenste tak
van de bloeiwijze weg. Dat veroorzaakt verlies van opbrengst en
wordt daarom vooral toegepast bij de teelt voor export. Ook zet
men de vruchttrossen soms vast om schuren te verhinderen en bedekt
men ze tegen vogelschade met papieren of plastic zakken. Rode
zakken voldeden het best (5).

Oogst. Bij de rijping onderscheidt men 5 stadia die in Irak heten:
habakouk (I), kimri (II), khalal (III), rutab (IV) en tamar (V).
Afhankelijk van cv., klimaat en gebruik (vers of gedroogd) plukt
men in een van de laatste drie stadia. Soms wordt geschud, waar-
door de rijpe vruchten vallen, maar meestal wordt de tros in zijn
geheel geoogst. In stadium I weegt de vrucht minder dan een gram,
hij bereikt zijn maximale gewicht van 5-12 g in II, verliest dan
vocht en wordt lichter in III en IV, terwijl de volledige rijpheid
in V tot stand komt. Stadium II duurt het langst: 100 dagen. De
kleur verandert intussen van geelwit, via groen en geel naar bruin.
De opbrengst ligt tussen 20 en 100 g kg per boom.

ZIEKTEN EN PLAGEN

We noemen slechts enkele. De gevaarlijkste vijand van de dadelpalm
is de schildluis Parlatoria blanchardi. Een geintegreerde bestrij-
ding is mogelijk, met behulp van parasieten (6). Veel schade doet
verder "bayoud"; de schimmel (Fusarium) wordt door irrigatie
verspreid en twee jaar na het uitbreken is ruim 80% van de palmen
dood (16).

NUT EN GEBRUIK

Dadels bevatten ongeveer 70% suikers, bij 'Deglet-Nour' vnl.
saccharose, bij de andere meest monosacchariden. In sommige landen
bedraagt het verbruik 48 kg per hoofd.jaar, in Nederland slechts
40 gram. Het is een energierijk voedsel, dat o.a. in de 2e wereld-

oorlog als noodrantsoen voor woestijnlegers diende (1). Alle delen
van de plant, bladeren, stammen, pitten enz. worden voor een of
ander doel gebruikt.

LITERATUUR

1   BOLHUIS, G.G.   Collegedictaat, 1952 (?).

2   DAVIS,   HA 43, 6372

3   EL-BARADI, T.A.   Date growing. Trop.Abstr. 23(1968), 473-9.

4   GEUS, J.G. de   Fertilizer guide for tropical and subtropical
          farming. Centre d'étude de l'azote, Zurich, 1967.

5   KAPLAN,   HA 43, 2417

6   KEHAT,   HA 46, 5075

7   MUNIER, P.   Le palmier dattier. Paris, 1973.

8   NIXON, R.W.   Growing dates in the United States.
          Washington, D.C., Agr. Inform. Bull. 207, USDA, 1966.

9   PEREAU-LEROY, P. Le palmier dattier au Maroc. IFAC, 1958.

10 PERKINS,   HA 45, 3505

11 PURSEGLOVE, J.W. Tropical crops, Monocotyledons, 1972.

12 REUVENI,   HA 43, 8106

13 idem   HA 43, 809

14 RODERBOURG,   HA 44, 5098

15 SENTO,   HA 43, 2415

16 TOUTAIN,   HA 44, 6101

HA = Horticultural Abstracts, 43 = 1973.

COLLEGEDICTAAT "NUTTIGE PALMEN"
ONDERDEEL "DE SAGOPALM".

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A B S T R A C T

A comparison of sagopalm production in equatorial swamps shows in wild condition 7-11 ton in semi wild condition on peat soils 11 tons and under cultivation on clayish soils 25 tons of waterfree starch. Useful dry matter production under cultivation is approximately of the same level as the yield potential of rice. The main impediment for development of commercial sagopalm cultivation is the eight years between planting and first harvest. Based on careful consideration of evidence and analogy with other monocotyledonous crops the growth pattern of the sago palm is decribed.

It follows that a solution to the impediment could, after research, be found in (i) the possibility of earlier harvesting of first trunks from first plantings and (ii) introduction of a planting system of permanent and filler palms. Also (iii) it may be possible to increase growth rate as measured by rate of leaf formation, by determining optimum waterregime, salinity conditions and fertilizer needs.

Introduction

Sago is the starch the sago palm accumulates in its trunk as a reserve.
The pith of a sago trunk has the composition as given in table 1; it closely
resembles cassava roots and therefore can be used for the same purposes, i.e.
for human food, for preparation of industrial starches and probably also as an
animal feed.

Table 1. Composition of cassava roots and sago pith (4)

	tapioca root		sago pith	
	fresh	dry matter	fresh	dry matter
Moisture	62.4%	-	80.0%	-
Soluble carbohydrates	33.5%	94.4%	18.5%	92.5%
Protein	0.4%	1.1%	0.3%	1.5%
Fat	0.2%	0.5%	0.1%	0.5%
Fibre	0.8%	2.1%	0.3%	1.5%
Ash	0.7%	1.9%	0.8%	4.0%
Convertible to chips (at 14% moisture)	43%		22.8%	

Rasped and dried sago pith already for a long time has been used as a feed for
pigs, poultry and horses (9), while refuse from starch factories is used as a
feed for pigs and also for cattle. It is likely that rasped, dried and pelletized
sago pith will be completely acceptable for the animal feed industry. However,
this needs to be proven in experiments.

Botany

The palm genus Metroxylon consists of some six species. The name is derived from
Greek, i.e. metra meaning pith and xylon meaning xylem. The genus is indigenous
in the lowlands of southeast Asia and Melanesia; there it occurs between 10° N
and S up to an altitude of 700 m. Most species are found on and around New
Guinea which is supposed to be the gene centre. Probably the economically most
important species are M. sagu ROTTBOL and M. rumphii (WILD.) MARTIUS. In New
Guinea, however, a spined palm with reddisch flour is harvested as well (13);
this propably is M. sylvestre MART.

The name M. rumphii was given in honour of RUMPHIUS (1755) who, in his 'Amboinsch Kruyd-boek' gave the first description of the palm accompanied by a drawing. The main difference between the two most important species is that M. sagu has no spines, whereas in M. rumphii leaf sheath and petiole are covered with sometimes up to 8 cm long sharp spines. Also their leaflets often are slightly spiny. BARRAU (2) favours the idea that they should not be considered to be separate as they appear to cross readily. This was proven in our department: the offspring of two palms without spines in Singapore Botanical Garden also gave a few spiny palms.

Under natural conditions the palm occurs in fresh water swamps in the tropical rain forest zone. Single palms occur outside this natural habitat and appear to do well, provided they are tended properly. Probably in its natural habitat the palm possesses a competitive advantage. The best natural stands occur in clayish fresh water swamps, high in organic matter and bordering mangrove or nipah; the palm also grows on shallow peats but deep peat soils clearly are less well suited. Although sago occurs in swamps, permanent innundation appears to present a disadvantage.

In technical terms the palm is a once-flowering and tillering perennial. The trunk acts as a sink in which the palm collects its superfluous carbohydrates as starch, part of which is used for flowering and fruiting after which the trunkdies. Mostly already in the first year the palm forms a number of buds in the axils of lower leaves which develop into shoots or suckers. Such suckers may develop into new trunks (photo 1).

The crown of the palm consists of some 6-18 feathered leaves each composed of leaf sheath, petiole and approx. 50 pairs of leaflets of 60-180 cm (6). The rachis is on the upper side concave whereas it is convex on the underside. On the trunk the leaf sheath may reach a width of 30 cm. The oldest leaves break at their leaf sheath; later the leaf sheath also may drop; then a leaf scar remains on the stem.

Appearance of the inflorescence is preceeded by a number of leaves rapidly decreasing in size; this announces the end of the life cycle of the trunk. The terminal inflorescence, resembling an enormous antler, consists of a primary axis dividing into secondary and tertiary axis. The tertiary axis bear the small flowers in pairs, a male and an apparently complete flower together (photo 4).

Male flowers open and shed their pollen before the complete flowers open; in the latter the stamens probably are not functional. The palm therefore probably is an obligatory cross pollinator. This would explain the large variability in natural stands and also the lack of seeds of single palms reaching the fruiting stage. In male and in complete flowers the six stamens have grown together into a tube. In the complete flowers the half inferior ovary contains three ovules out of which only one develops. This results in a beautiful scaled fruit with only one seed (photo 3). From New Guinea (13; 2) was reported a regularly occurring palm with an exceptional high starch yield. This palm is supposed to be sterile.

The palm possesses a large number of mostly superficial primary roots from which often pneumathodes grow above ground level. Also the trunk may be covered with roots. Each sucker develops its own root system, provided it does not grow to far above the soil. After the first trunk has disappeared, the connexion between its suckers may be severed. Suckers may produce their trunks at considerable distances, sometimes even a few meters from the original trunk (photo 1). The stem part connecting such suckers is said not to contain starch.

The height of a flowering trunk without its inflorescence may vary from 10-15 m. Usually at its base the stem has a girth of 35-50 cm, slowly increasing till 50-60 cm and tapering off again till approximately the girth at its base. At harvesting the average trunk weighs over 1000 kg.

The palm may be propagated from seeds (photo 3). In harvested wild stands, however, the palm as a rule is not permitted to produce ripe seeds, because then the product to be harvested is used. Only low producing palms will receive the opportunity of giving ripe seeds. This probably results into negative mass selection. In cultivation, however, the palm usually is propagated by means of suckers, mostly from selected mother trees, which results into positive mass selection.

Yields of wild stands

In wild condition as on New Guinea and in the Moluccas palms are harvested as their first young fruits are formed. This apparently is the moment with the highest starch production per trunk. It is however, very difficult to obtain data on production per unit of surface and time under such conditions. Wild stands show large variations in numbers of clumps per hectare of which also

the number of trunks may vary. Moreover the age of harvested trunks is only vaguely known. Best estimates on possible yields of very nearly pure wild stands are 40-60 stems per ha and year (13). At 1000 kg pith per trunk and a starch content of 18.5% this would result in 7-11 tons of waterfree starch or $28-44 \times 10^6$ kcal per ha and year.

It is amazing that such potentials, high even if compared to modern methods of cultivation of other crops, have not been realized, especially if one considers that Indonesia possesses several hundreds of thousands hectares of nearly pure stands. According to all reports the transport of the harvested stems to a factory was the main difficulty. In a high producing wild stand transport of 40-60 tons of raw material per ha and year to a central point is required for processing. This raw material, containing 80% moisture, has to be transported in a swampy area, without roads and mostly also without navigable waterways. The indigenous population has a very simple solution to this problem. The trunks are harvested and processed in the swamp. Only the wet starch is taken out of the swamp.

Only in 1957 systematic research in this field was started by a Dutch company in New Guinea. Trunks were cut and rasped in the wild stands. Rasped pith with its contents of starch was mixed with clear water and pumped through a pipe line towards a floating factory and refined there. In 1962 results appeared promising, but the experiments were ended because of the political situation.

Yields under semi wild conditions

The situation in the semi wild cultivation in Sarawak differs in a few aspects from the situation in Indonesia. In Sarawak most sago areas are established on peat soils instead of on mineral soils. On peat soils the palms have less leaves; the leaves may show all kinds of deficiency symptoms and growth is slower. A trunk grown on mineral soil may reach maturity after 8-10 years, whereas a palm on peat soil is said to reach maturity after 15-17 years (3). Yields from good sago land are reported at a level of some trunks per ha and year. The quality of the soil is believed to influence the size of the trunks also. Best trunks are said to be produced in the coastal fringes in swamps on mineral soils with a slight salt content (3).

There is another difference between the sago area in New Guinea and the area in

Sarawak. In Sarawak the sago area shows a fairly dense network of small rivers and creeks. Although transport even of one-meter logs from the site of felling to the river is difficult, transport in the water is fairly easy. This resulted into the establishment of a number of sago starch factories. These factories often produce second quality starch mostly because in the processing they have to use water coloured by peat. Refuse of starch production is not utilized but washed into the river.

Yields under cultivation

RIDLEY (7) already mentions the existence of sago plantings around Batu Pahat, Johor, West Malaysia. NICHOLSON (5) gives an accurate description which, as I could see for myself in 1971, stilll holds true. Such cultivation existed also on the island Benkalis and in the Lingga archipelago, east of Sumatra in Indonesia (9; 8). Whether cultivation is still practised there remains uncertain. But cultivation is still extended around Batu Pahat. Official 1970 estimates amount to 2000 ha while in the last few years at least 100 ha were planted.

In the Batu Pahat area the palm usually is planted in clayish soils in coastal areas, under tidal influence but above the salt water line. This results in twice daily flooding and draining of the plantings with fresh water. In the best plantings the palm is propagated by means of carefully selected well sized suckers planted at 6 x 6 m (277 suckers per ha). Suckers of approx. 2 kg each are cut from the mother trees by means of a sharp implement. Care is taken that the cut surface is straight. Preferably there should be some roots on the sucker. All leaves of the sucker except for the spear and the youngest two leaves are cut off. The cut surface is dried in the sun for a few hours. Then the suckers are planted in a well sized planting hole, usually one cubic foot. If ground water level is sufficiently high the soil is crumbled in the water standing in the hole. The sucker is placed in the hole, with its heart above ground water level. Then slowly the hole is filled. In order to prevent the sucker to move often the sucker is tied to a stick. If all precautions are taken, after a month or so the sucker resumes growth by forming new leaves and later on by suckering.

Around the palms the soil is kept clean weeded; the plants are regularly and carefully pruned in order to ensure an even spread of suckers in time and over the surface. In general one trunk per clump is allowed to grow every second year. By means of a careful selection of suckers to be left an even spread of the

trunks over the area is ascertained.

After eight years of growth the first trunks may be harvested (photo 2). Each clump of palms, derived from one planted sucker, produces one trunk per two years. So 138 trunks per ha and year on good sago land - clayish soil, high in organic matter - are produced. This leads to a production of 25 tons of waterfree starch or 100×10^6 kcal.

By means of opening up of growing points of harvested trunks it was observed that trunks were harvested before flower initiation. This probably is the moment with the highest production per unit of surface and time.

Trunks are cut as low above ground level as possible, divided into one-meter logs and transported to the processing plant as rafts. For this purpose the whole area is provided with a dense network of interconnected small canals connected with the river. This network also enables the area to flood and drain easily.

The tidal flooding and draining of the sago area probably also provides the nutrients for the sago palm, as no fertilizer is used. From data of WOODMAN et al (12) it was calculated that the pith of the palms be used for analysis contained the nutrients given in table 2. It is assumed that these figures also apply to Batu Pahat, because of lack of better figures. All nutrients in other plant parts are assumed to be returned to the soil, approximately in situ.

It stands to reason that in an area flooded and drained twice daily the nutrient contents of the soil are in equilibrium with the nutrient contents of the fresh water that floods the soil. Data on the river running through the area is not available, contrary to a survey on the nearby Halacca river (10). A comparison of these data with the nutrient contents of sago pith is given in table 2. It is assumed that the area is flooded twice daily with a layer of 10 cm water above ground level.

Table 2. A comparison of nutrient contents of harvested sago pith and nutrient contents of flooding river water

Nutrient	Nutrient contents of pith of 138 trunks per ha and year	Total of nutrient flowing over the soil in aqueous solution in kg per ha and year	Percentage to be withdrawn from the aqueous solution in order to maintain the yields
N	85 kg	763- 903	10.5- 8.9
P_2O_5	30 kg	161- 301	18.6-10.8
K_2O	170 kg	1,883-2,772	8.5- 5.8
CaO	100 kg	1,834-2,030	5.5- 4.9
MgO	40 kg	1,295-2,296	3.1- 1.7

The conclusion can be drawn that the sago cultivation as described could be considered to be a kind of water culture. This probably is the explanation for the continuous high yield level without the addition of fertilizer. As application of fertilizer in such a situation is very difficult, it might also be a limiting factor to an increasing yield level.

Comparison of yields

Yields of the sagopalm were estimated (i) in wild stands in New Guinea, Indonesia, (ii) under semi-wild conditions in Sarawak, East Malaysia and (iii) under cultivation in Batu Pahat, West Malaysia. The results of these estimates are summarized in table 1.

Table 3. Sagopalm yields per hectare and year

GROWTH CONDITIONS	NUMBER OF STEMS	WATERFREE STARCH	WATERFREE STARCH
WILD	40 - 60	7 - 11 TON	28 - 44.10^6 KCAL
SEMI-WILD	60	11 TONS	44.10^6 KCAL
CULTIVATED	138	25 TONS	100.10^6 KCAL

It is amazing to note that this interesting and high yielding culture hardly received any attention in research. This level of production was reached by the farmers themselves without any outside influence. It is therefore of interest to calculate whether yields still could be higher and research is worth-while.

Growth pattern

Introduction. The sagopalm has an extremely extensive duration of growth. It is therefore necessary, even more so than with other crops, to identify carefully the main research objectives. In this part an attempt is made to do so by scrutinizing available data and by reasoning of analogy with other crops. In this way a still somewhat speculative hypothesis on the growth pattern is formulated which can be used to direct research into the main possibilities and impediments for sagopalm cultivation.

Leaf production. Other monocotyledonous crops with a terminal inflorescence often show a more or less determined number of leaves e.g. sisal and banana. If this holds also for the sagopalm one would possess in the speed of leaf formation a parameter indicating whether the palm is growing under optimum conditions.

Trunks in full sunshine and on clayish soils may show up to 18 leaves, each approx. 7 m long with up to 50 pairs of leaflets varying in length from 50-150 cm, each leaflet having a width of 5 cm. The younger and lower the trunk the less the number and size of its leaves.

Seedlings (photo 3) usually start of with juvenile leafs with only two leaflets. During growth the number of leaflets per leaf increases. This process was carefully followed in hothouses in our department with four seedlings. Results are presented in fig. 1. It appears that there is an approximately linear connexion between leaf number and number of leaflets. By extrapolation it appears that leaves would attain their full size between leaf number 80 and 90.

From the same experiment it appears that under good light conditions (summer at $52^{O}N$) the seedlings formed two new leaves per month. Under such circumstances a palm producing 80-90 leaves would have reached an age of 40-45 months or 3 years and 4-9 months. Probably at this time, full maturity of the leaves, also trunk formation starts.

In Sarawak a few counts were made of leaf scars on standing flowering stems
and also on harvested stems. The number of leaf scars was in the order of
magnitude of 126 ± 10. On harvested trunks in Sarawak one finds leaf scars of
all leaves until flowering.

In Batu Pahat, however, only leaf scars are available until flower initiation
as on that moment trunks are harvested. Unfortunately leaf scras were not
counted in Batu Pahat. So no estimate is available of the number of leaves
appearing between flower initiation and flowering. As a rough estimate may
serve that some two years elapse between flower initiation and the time of fruit
formation. These two years would equal roughly 50 leaves.

Suckering. As many other monocotyledons the sagopalm suckers freely. Axillary
buds develop into new shoots. In their first growth period such new suckers
derive carbohydrates from the main trunk until their photosynthetic apparatus
is developed sufficiently and catches sufficient sunlight. The same holds for
supply of plant nutrients; these the sucker also derives from the main trunk
until the sucker forms its own roots. And even then the roots of the new sucker
are that close to the main stem that competition for nutrients seems logical.

Thus (i) the number of suckers should be kept to a minimum and (ii) a very even
spread over the surface should be ascertained, in other words pruning is very
important. Influence of pruning could be shown in our hothouses. The four
seedlings forming two new leaves per month under good light conditions showed
after taking away all suckers an increase in leaf formation. One of these seedlings
gave the usual two, two gave three and the last even four leaves in the month
after pruning. In the system of cultivation as developed in Batu Pahat this
knowledge is already applied.

Determination of girth. Just as in other monocotyledons the girth of the sagopalm
trunk is determined in the growing point.
Carbohydrates produced in the leaves are, after transport, sedimented in the
'sink', i.e. stem tissue. We may assume that, for reasons of economy of trans-
port, the starch will be sedimented as close as possible to the crown.

Thus, unless proven otherwise, we have to assume that palms growing in full
sunlight will fill their trunks from the bottom upwards, immediately after
formation of such trunk parts. Trunks growing in shade, however, one expects
first to reach for full sunlight. Such suckers are expected first to grow in
height, thus form a trunk and, after reaching full sunlight start filling their
trunks.

This assumption is illustrated in fig. 2. In support of the assumption is the following observation. Trunks throughout their life growing in full sunlight, especially those from first plantings, have approximately the same girth from bottom to top. Following trunks, however, mostly show a clear increase in girth at the top of the trunk. This increment in girth then would have to be explained as the result of an increase in photosynthesis when the fronds reach full sunshine after the harvest of the preceeding trunk.

If this assumption holds the consequences are (i) first stems of new plantings can be harvested earlier than following stems and (ii) an even spread of trunks over the surface in cultivation is of the utmost importance, especially so in new plantings.

Starch accumulation. As seen earlier trunk formation is supposed to start when the photosynthetic apparatus, the fronds, attains its full size. At the start of the formation of the trunk also starch accumulation is assumed to begin. In trunks with their fronds in full sunshine starch accumulation, seen over longer periods, should progress linearly. If flower initiation takes place in the eight year followed by formation of the inflorescence and fruiting, part of the starch produced will be used for fruiting. At flowering the photosynthetic apparatus diminishes due to decreasing leaf size and at fruiting it even disappears. This would lead to an approximate starch accumulation curve as presented in fig. 3. Of course both years and leaf numbers on the horizontal axis are arbitrary.

On the basis of fig. 3 the differences in harvesting time can be fully explained. In plantings with a fixed number of clumps per hectare, as in Batu Pahat, the farmer wants to harvest at the moment of highest production per hectare and year. This would be the moment when the starch accumulation curve flattens off again. In natural stands, as in New Guinea, and under semi-wild conditions as in Sarawak, in a situation with superfluous ripe trees, the farmer harvests when production per trunk is highest. This is at the start of fruit formation.

Photosynthesis. In an experiment in our department photosynthesis was measured of attached single leaflets of a young sagopalm. Leaflets of various ages were measured, i.e. 31, 45 and 59 days after unfolding of the leaves. Results of this experiment are presented in fig. 4. As only a small part of each leaflet could be fitted into the leaf chamber of the installation for measurement of photosynthesis, the measurements are not very accurate. Despite this it appears that photosynthesis is at a normal level for plants following the Calvincycle of photosynthesis.

Distribution of dry matter
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Distribution of dry matter over the various plant parts was estimated for the
Batu Pahat situation.

Leaves. As stated before, vigorously growing young sagopalms form two new
leaves per month. As no fully grown leaves of sagopalm were available, fully
grown leaves of oil palms were used for determination of dry weights. Results
are summarized in table 4.

Table 4. Size and weight of fully grown oil palm leaves

LEAF	1	2	3	4
LENGTH CM	712	620	416	542
FRESH WEIGHT g	5975	3530	1500	2290
DRY WEIGHT g	1606	1049	503	654
% DRY MATTER	27%	30%	34%	29%

Size of these leaves is more or less comparable to the leaves of the sagopalm.
Average dry weight can be calculated at 1000 g.

In the last two years before felling the stem is assumed to produce 24 leaves
of 1 kg d.m. each or 24 kg of d.m. per year. It appears reasonable to assume
that each pair of previous years the same stem produced approx. half the
amount of d.m. On basis of this assumption each stem would have produced until
felling in its eight year 90 kg of d.m. in leaves. Rough estimate of the Leaf
Area Index for the Batu Pahat situation leads to 6.5 m^2 of leaf per m^2 of land.
Bark. Bark of a stem is estimated using the figures given by AHMED & SIM (1).
Each stem is supposed to contain approx. 100 kg of dry matter in its bark.
Pith. Pith is estimated as in table 1 at 1000 kg per stem, containing 20% d.m.,
or 18,5% starch and 1,5% other substances.
Roots. Roots for the moment are not taken into consideration. Insufficient data
are available and the estimate of the potential photosynthesis is that rough that
this will allow for a root mass.

Potential Production
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If all other conditions are optimal the dry matter production of a crop is deter-
mined by photosynthesis and thus by sunlight. In the tropics theoretically one
can grow a crop the year round. In the region between 10° N and S gross photo-
synthesis amounts to on the avergae 400 kg of carbohydrates per ha and day on
a day without clouds. On a clouded day, however, photosynthesis reaches only

220 kg carbohydrates (11). Roughly 30% of the carbohydrates produced the plant uses for respiration. Assuming that in the humid tropics the sky will be half clouded on the average, production of carbohydrates could be roughly estimated at 200 kg per ha and day. Of course, depending on the cloudiness production could be higher or lower. As an average, however, the figure given serves well. So the potential production of the sagopalm can be estimated at roughly 200 kg carbohydrate per hectare and day (200 kg CH_2O $ha^{-1}.day^{-1}$) or 73 tons CH_2O $ha^{-1}.year^{-1}$.

Based on the assumptions under production of dry matter and potential production fig. 5 was developed by multiplying all figures by the yearly trunk yield of 138 trunks per ha. It appears from this figure that a surprisingly large part of the potential production is realized in Batu Pahat, i.e. 75%.

A comparison of the potential production of rice and sagopalm and the actual production of sagopalm in Batu Pahat is given in table 5.

Table 5. A comparison of the potential production of rice, the actual production in Batu Pahat and the potential production of sagopalms.

	rice potential	sagopalm Batu Pahat	sagopalm potential
estimated duration of growth	120 days	30 years	30 years
closed canopy after	50 days	4 years	4 years
dry matter production a before	$\frac{50 \times 200}{2}$ kg	$\frac{4 \times 365 \times 150}{2}$ kg	$\frac{4 \times 365 \times 200}{2}$ kg
b after closed canopy	70x200 kg	26x365x150 kg	26x365x200 kg
per day of vegetation	158 kg	140 kg	186 kg
useful d.m.	40%	47%	60%
average useful d.m. production in kcal/day	252×10^3	275×10^3	446×10^3

It appears from the table that the actual production of the sagopalm is already higher than potential production of rice. This mainly is caused by the more favourable dry matter distribution of the sagopalm.

Main advantages and disadvantages

As a starch crop the sagopalm possesses a number of clear advantages over other starch crops:

(i)   It is a perennial tree crop fitting into the climax vegetation.

(ii)   The crop is well suited to equatorial swamps, especially those under tidal influence, which cannot be used without expensive measures for watercontrol.

(iii)   The crop is a relatively simple one as regards care and maintenance.

(iv)   Harvesting of the crop is not confined to a season; neither is harvesting limited to a strict physiological growth phase.

(v)   Harvested trunk parts can be saved in water during some weeks without serious deterioration.

In other words the sagopalm is a relatively simple crop, suitable for small scale farming and well adapted to continuous production of either animal feed or starch, in regions where other uses of the soil are limited, the equatorial swamp.

On the other hand there are a few disadvantages for cultivation.

(i)   Raw produce is bulky and heavy. In swamp areas quite a number of canals is needed for transport to processing plants, which may be expensive to construct. Other means of transport probably will be more expensive.

(ii)   The sagopalm needs even in a system of cultivation as in Batu Pahat at least eight years between planting and first harvest. This long juvenile period is the main research objective to be studied.

Research objectives

Based on the evidence presented in this paper ways and means should be sought to overcome the economic disadvantage of the long juvenile period. This problem could be approached in various ways.

(i)   Research into the possibility of earlier harvesting of first trunks from first plantings, in accordance with the assumption illustrated in fig. 2.

(ii)   Adaptation of the planting system. In the first four years in new plantings ineffective use is made of sunlight. It might therefore be

possible to plant sagopalm in a system of permanent and filler trunks. A possibility is demonstrated in fig. 6.

(iii)   Research into the possibility of increasing the growth rate by means of optimalization of growth conditions. A good parameter for growth rate may haven been found in the rate of leaf formation. In this respect research is needed into the optimum waterregime as it is not yet certain whether the sagopalm needs to be grown under wet conditions. Also research is needed into the salinity tolerance as in Sarawak the best trunks are said to be produced in coastal areas with a slight salt content. Thirdly research is recommended with respect to respons to fertilizer application, preferably in existing dry land plantings.

(iv)   On the long run results could be expected from selection and possibly breeding for earlier maturity. With most other tree crops this has been an important means in decreasing the juvenile phase.

If selection work on shortening the juvenile phase were started an other objective might be included as well. This is breeding for improvement of dry matter distribution. Best chances for improvement of dry matter distribution are found in simply an increase of starch content in the stem.
For selection a search should be made for the most suitable types in and around the gene centre, New Guinea.

LITERATURE

1   AHMED, M.I. and E.S. SIM, 1975.
        Utilization of peat soil for sagopalm cultivation in Sarawak.
        Paper for Third Asean Soil Conference. Kuala Lumpur, Dec. 1975.

2   BARRAU, J. (1959). The sago palm and other food plants of marsh dwellers
        on the South Pacific islands. Econ.Bot. 13, 151 - 162.

3   JOHNSON, R.M. & W.D. RAYMOND (1956). Sources of starch in colonial terri-
        tories I: the sago palm. Co. Plant and Animal Prod. 6, 20 - 32.

4   LIM, H.K. (1967). Animal feeding stuffs. Mal. Agric. J. 46, 63 - 79.

5   NICHOLSON, G.P. (1921). Le sagoutier en terrains marécageux (Malacca).
        Bull. Econ. Indoch. 24, 159 -200.

6   OIJEN, L.A.T.J.F. (1909). Sagoe en sagoepalmen. Bull. Kol. Mus. Haarlem
        no. 44, 12 - 69.

7   RIDLEY, H.N. (1895). Sago. Agric.Bull. Malay Penins. 4, 62.

8   REEP, C. (1907). Sagocultuur op Benkalis. Tijdschr. Binnenl. Best. 32,
        393 - 394.

9   SCHEFFER, R.H.C.C. & K.F. HOLLE (1873). Een sagoboom op Java. Tijdschr.
        Ind. Mij Nijverh. & Landb. 18 : 397.

10   TAN, Y.T. & G.A. PROWSE (1972). A chemical survey of the Malacca river.
        Mal. Agric. J. 48, 185 - 221.

11   WIT, C.T. DE (1965). Photosynthesis of leaf canopies. Agric. Res. Rep. 663;
        Centre Agric. Publ. & Doc.; Wageningen.

12   WOODMAN, H.E., A.W. MENZIES, A.W.M. KITCHIN & R.E. EVANS (1931). The value
        of tapioca flour and sago pith meal in the nutrition of swine.
        J. Agric. Sci 21, 526 - 546.

13   ZWOLLO, M. (195). Rapport sago onderzoek Inanwatan. Report available in
        the Archives of the former Directorate Netherlands New Guinea; the
        Hague.

fig. 6. Proposed system of planting of sago palm. Permanent sago palm clumps indicated as o; filler trunks indicated as x. At an age of six years the largest trunks of the permanent clumps are harvested. At seven years all filler trunks are harvested.

fig. 1. Relation between leaf number and number of pairs of leaflets of four young sago palms, grown in a hothouse in Wageningen.

fig. 2. Assumed relationship between trunk growth and starch accumulation in trunks throughout their life in full sunligt as compared to trunks grown in shade.

fig. 3. Assumed rate of starch accumulation in a sago palm trunk on clayish soil. Starch accumulation is presented as a function of time and of leaf number.

fig. 4. Rate of photosynthesis of a young sago palm grown in a hothouse in Wageningen.

fig. 5. Dry matter distribution in sago palms under the system of cultivation developed in Batu Pahat as compared to the potential yield level.

number of
youngest leaf

84
80
76
72
68
64
60
56
52
48
44
40
36
32
28
24
20
16
12
8
4

86

76.7

75.10

74.10

73.10

71.10

4 8 12 16 20 24 28 32 36 40 44 48 52
pairs of leaflets on youngest leaf

Fig.1

trunk in full sunlight
trunk in shade

first trunk cut   second trunk cut

growth

starch accumulation

year 0   year 2   year 4   year 6   year 8   year 10
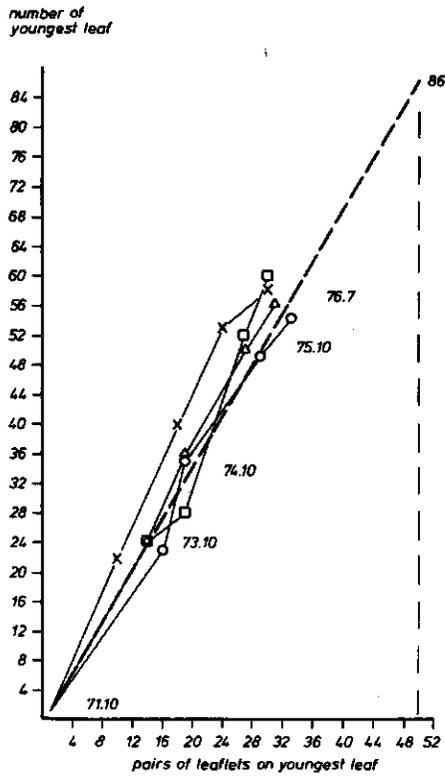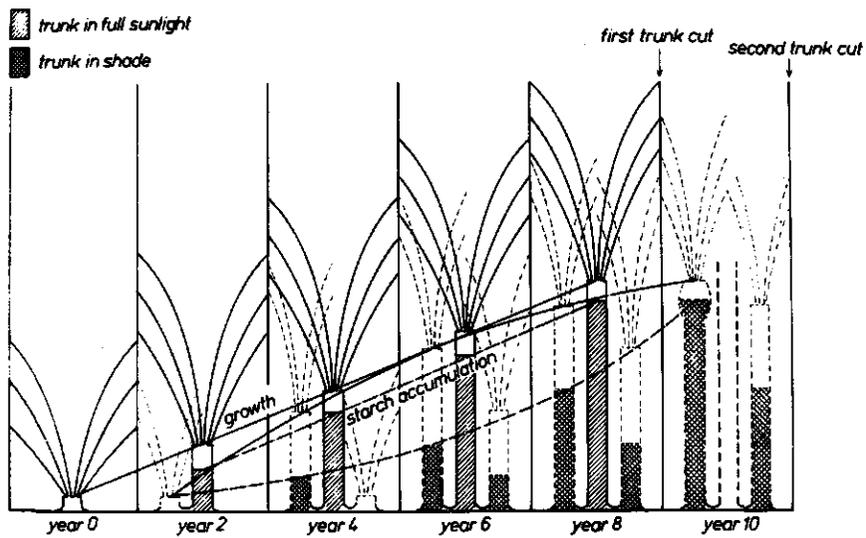
Fig.2
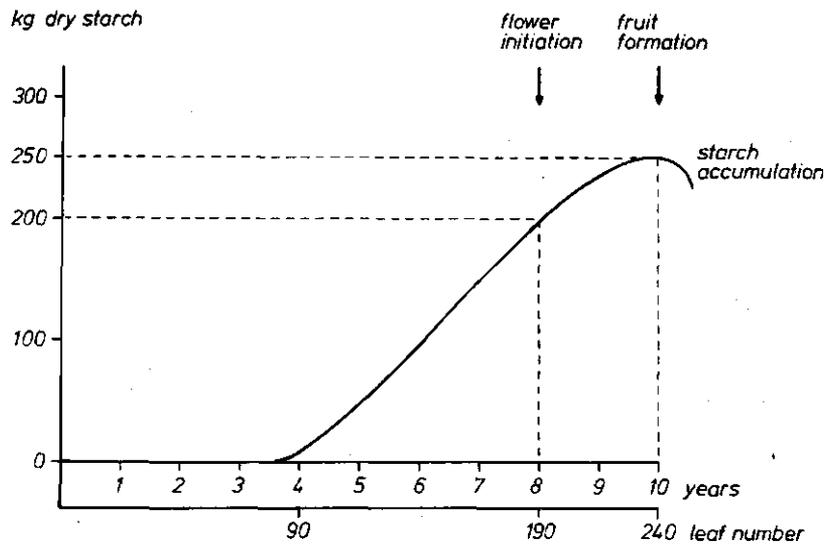
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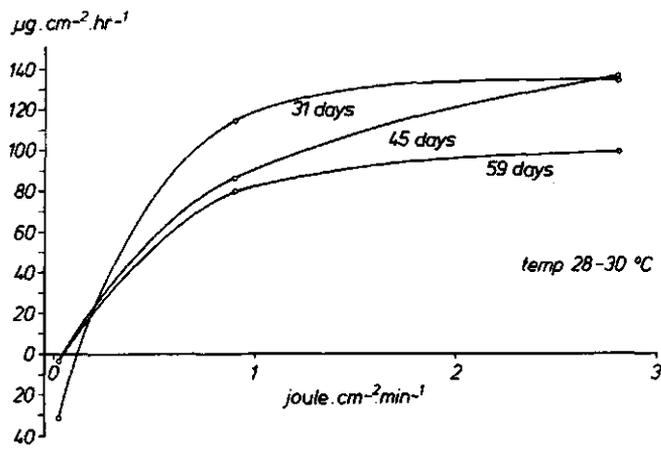
Fig.4
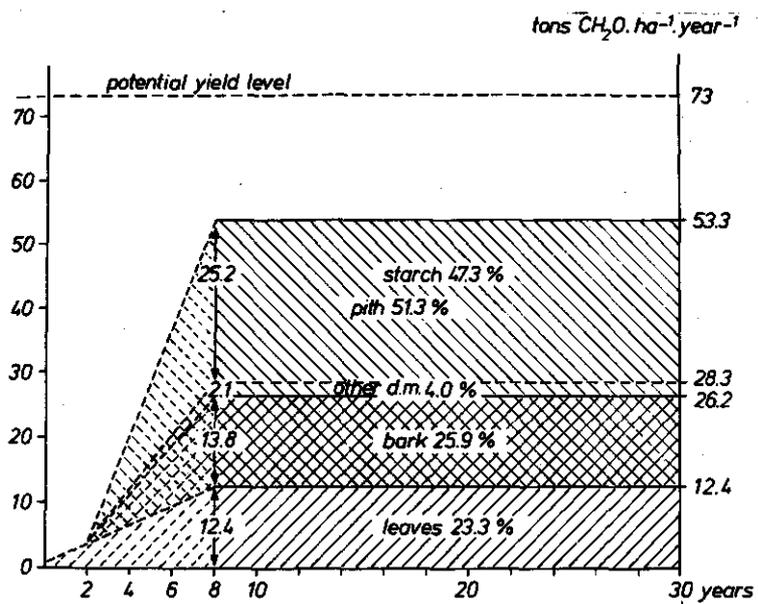
Fig.5
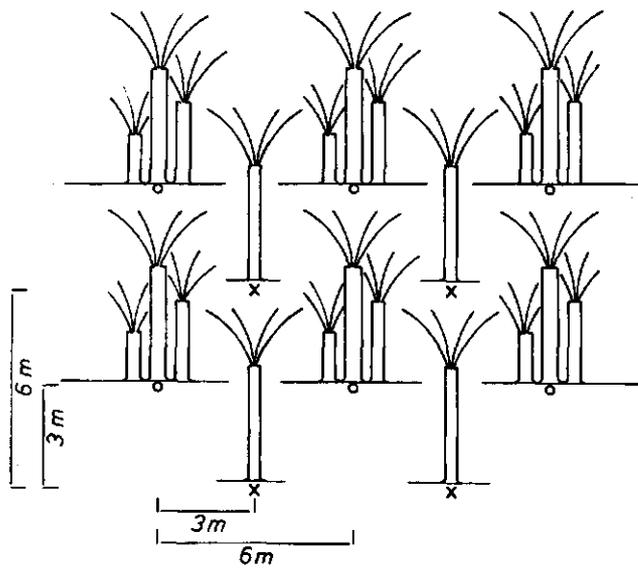
Fig.6
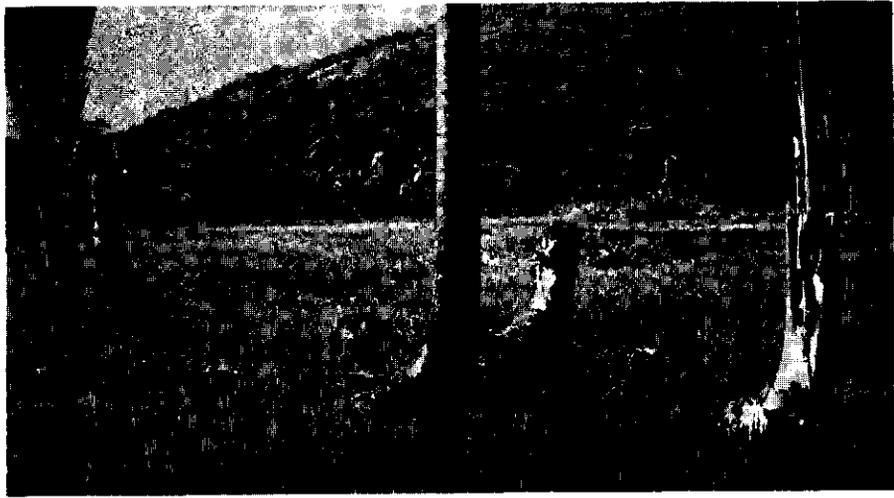
PHOTO 1   FREE GROWING SAGO PALM STOOL IN WET RICE
FIELD (SARAWAK)

PHOTO 2   WELL MAINTAINED SAGO PLANTING CLOSE TO
BATU PAHAT (W.MAL.)

PHOTO 4

FLOWERS OF THE SAGOPALM; ABOVE COMPLETE
FLOWER; UNDER MALE FLOWER

PHOTO 3

FRUIT, SEED AND SEEDLINGS OF THE SAGO PALM

PRELIMINARY RESULTS OF INVESTIGATIONS

INTO TOLERANCE TO SALINITY AND

FLOODING OF YOUNG SAGO PALM

SEEDLINGS

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SUMMARY

In an experiment in hothouses in Wageningen approx. one-year-old
potted sago palm seedlings were subjected to an experiment in which
salinity and water control was varied. The waterregimes simulated
(i) dry land cultivation (ii) dry land cultivation in an area
subject to saline spring tide and (iii) cultivation in the tidal
area subject to saline spring tide. Results indicate that the
sago palm is highly tolerant to salinity (EC $\subset$ 10 mmho /cm).
Its tolerance to wet conditions, however, appears to be far less
than might be expected from its natural habitat, the equatorial
swamp. It might be worth-while testing the palm in the Nypah-palm
zone.

Introduction

In a previous paper (FLACH; 1977) attention was drawn to the possibility
that the sago palm (Metroxylon sagu and rumphii)
(i) only appears to do well under extremely wet conditions, because the
palm possesses a competitive advantage over other plants under such
conditions and
(ii) might be tolerant to a fairly high salinity.

With a view to obtaining insight into tolerance to flooding and salinity
an experiment was designed. In the Batu Pahat region (Johor, Malaysia
Barat) the sago palm is found planted in the coastal belt, partly under
tidal flooding with approx. fresh water and in addition brackish spring-
tide, partly under the influence of only a brackish springtide and partly
under approximately dry land conditions. It was attempted to imitate all
three conditions in the experiment. It was hoped that such an experiment
might lead to conclusions with respect to the possibilities of sago palm
cultivation under such marginal conditions.

Materials

Young sago palm seedlings were obtained from the province of Benkulu,
southwest Sumatra, Indonesia. In January 1975 some 200 seedlings were
collected, approx. 3 month old. Largest and smallest seedlings were
discarded; the remaining 100 were transported to Wageningen, Netherlands
and raised in pots in a hothouse. Both spiny and smooth seedlings were
included in the material.

In the beginning of April 1975 the seedlings were transplanted into
larger pots and supplied generously with fertilizer. Halfway May the
seedlings were transplanted again, this time in 12 liter plastic con-
tainers. From that time onward data about leaf formation were collected.

In October 13 a number of 63 plants was selected for the experiment. This
group of plants was as homogenous as the material allowed. These seedlings
were grown in a mixture of two parts of decomposed leaves and one part
of a sandy loam.

Each container was fitted with a vertical drain-pipe with holes and filled with gravel. This drain-pipe enabled the container to drain quickly.

Methods

The experiment consisted of a combination of three waterregimes and seven solutions of increasing salinity. Each treatment involved three plants. The complete experiment thus was done with 3 x 7 x 3 or 63 plants. The treatments are presented in table 1. All saline solutions received also 1 g/l nutrifol N/P/K : 18/18/18 .

TABLE 1. The treatments used in the experiment.

Explanation : D = drip-irrigation with water of the indicated salinity

    S = springtide with saline water

    n = tapwater with 1g/1 nutrifol N/P/K 18/18/18

    h = sourcewater with Hoagland solution

(1)	(2)	(3)	(4)	(5)
Drip irrigation only	Drip irrigation and in addition a fortnight-ly saline Springtide	Daily Tide and in addition a fortnight-ly saline Springtide	EC in mmho /cm of water applied	
			from Nov. 10 till Feb. 15 (10 weeks)	from Feb. 15 till April 1 (9 weeks)
Dh	Dh S	Th S	h ∽ 2.4	h ∽ 2.4
Dn	Dn S	Tn S	n ∽ 1.6	n ∽ 1.6
D1	D1 S	T1 S	1 ∽ 4.7	1 ∽ 2.1
D2	D2 S	T2 S	2 ∽ 6.5	2 ∽ 3.0
D3	D3 S	T3 S	3 ∽ 9.6	3 ∽ 4.5
D4	D4 S	T4 S	4 ∽ 13.2	4 ∽ 5.6
D5	D5 S	T5 S	5 ∽ 18.4	5 ∽ 8.8
			S ∽ 27	S ∽ 8.5

Under drip-irrigation it was tried to simulate cultivation under dry-land conditions with increasing salinity (col.1)

Under drip-irrigation and springtide (col.2) dry land cultivation in the zone under influence of saline springtide was simulated, also with increasing salinity.

Under daily tide and springtide (col.3) cultivation under tidal conditions was simulated.

Various difficulties were experienced, the main being that, probably due to faulty calculation, the EC of the solutions used in the second part of the experiment (col.5) was approximately half the initial value (col.4). Results of the experiment thus became of a lower value; with respect to salinity tolerance only an indication was obtained. Exact borders for salinity tolerance will have to be determined in a new experiment.
As the experiment was conducted during winter at 52°N light was feared to be in the minimum. Thus artificial light was added with 72 Philips high pressure mercury lamps of 400 watt each (HLRG 400 W.). By means of careful measurement the light intensity was spread very evenly. The light received amounted to on the average approx. 200 cal.cm^{-2}.day^{-1}, which compares well with an averagely half clouded sky between 0° and 10° N and S. As with artificial light the light intensity decreases with the square of the distance to the lamp and the sagopalms were of a somewhat unequal size, differences in growth due to light energy might be expected. Careful consideration of the light effect, however, did not show any measurable difference.

Day temperature reached normally its highest point at 35°C with a few times an exceptional 41°C for a short period. Night temperature normally came down to 25°C, with exceptionally for short periods 21°C. Relative air humidity control was suboptimal. It varied from 55% in the hottest periods till 95% and higher at nighttime.

Results

Data on various possible parameters were collected, i.e. formation and death of leaves; speed of formation of new leaves; size of newly formed leaves;

length of new leaves and suckerformation. The most promising parameter
proved to be the speed of formation of new leaves. This observation
coincides with the theoretical approach given by FLACH (1977). This para-
meter was selected for this presentation. Results are presented in fig. 1
in which the notation of table 1 is followed.

After finishing the experiment a number of pots was washed out daily with
2 1 sourcewater (EC = 0.4 mmho /cm). The EC of the drained water was
measured at certain intervals of time. Results are presented in fig. 2
only for the most saline treatments of each waterregime.

Conclusions

If one keeps in mind that the experiment was executed with young and potted
seedlings the following conclusions can be drawn.

1. There has been a considerable accumulation of salt in the drip-irrigation
-only part of the experiment. This can be concluded from fig. 2. The accu-
mulation probably was caused by evaporation of water from the soil. Actual
salinity in this part of the experiment can be estimated at at least double the
salinity of the water used for irrigation as indicated in table 1. In the first
half of the experiment, with water of double EC of the second half, the
salinity showed effect at levels higher than D3, thus higher than EC 9.6
mmho /cm. Actual salinity probably was far higher. In the second half the
effect starts earlier, around D2 (EC 3.0 mmho /cm). This earlier start
might be caused by salt accumulation during the experiment. Thus the ten-
tative conclusion can be drawn that (i) the seedlings probably can
withstand a salinity of EC∽10 mmho /cm. The exact level, however, needs
to be determined in a following experiment.

2. There hardly is any difference between the salinity levels h, n, 1, 2
and 3 in the treatments with or without saline springtide. This holds for
the first half of the experiment with a springtide of high salinity
(EC 27 mmho /cm).So (ii) the plants hardly are harmed by one rather saline
flooding per fortnight. This conclusion apparently is confirmed by the
second part of the experiment.

3. There is a considerable difference between the wettest waterregime
(daily tide and fortnightly springtide) and the other waterregimes at all
salinity levels. In the first part of the experiment, the more saline part,
this influence is less pronounced than in the second half, the less saline
part. It appears that the influence of waterregime increases with time.
So (iii) <u>the seedlings apparently are harmed under conditions of daily
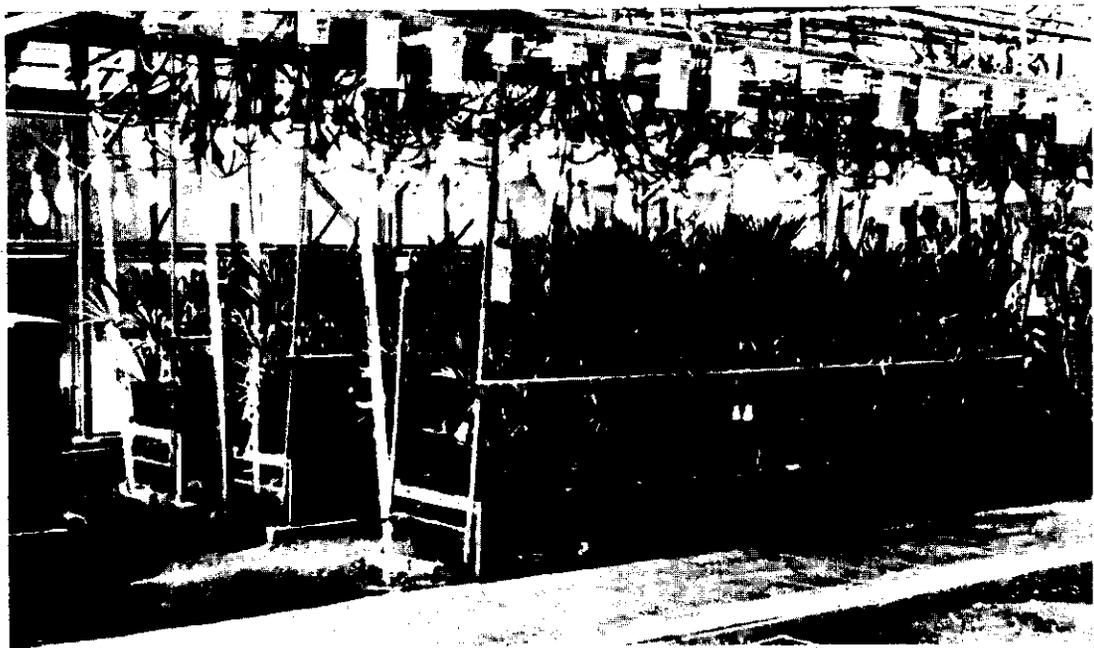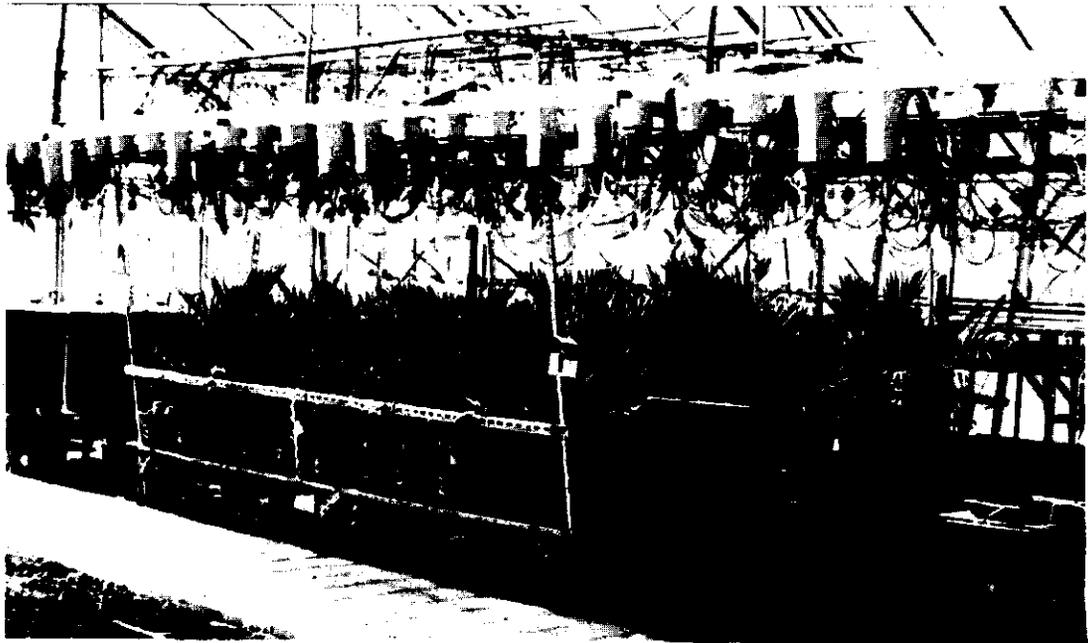flooding.</u>

Discussion

Despite the limitations of the experiment, that
- the plants were only young seedlings,
- the plants were raised in pots, it can be concluded that sago palm appears
  to be highly tolerant to salinity. The exact borders, however, cannot be
  determined in this experiment, due to errors in preparing the solutions.

It appears also that the sago palm does not find its optimum growth condi-
tions in its natural habitat, the equatorial swamp. It might be, however,
that the slower growth under wet conditions in pots is caused by the limited
space for the palm roots. It might well be that the palm does far better
if, as under natural circumstances, its root system is not confined to a
limited space.

The results of this experiment indicate that it might be worth-while testing
under somewhat saline and wet conditions. For such a test the Nypah-palm
zone might be chosen.

Literature

FLACH M. 1977. Yield potential of the sagopalm and its realization.
        Proceedings of the first international sago symposium Kuching,
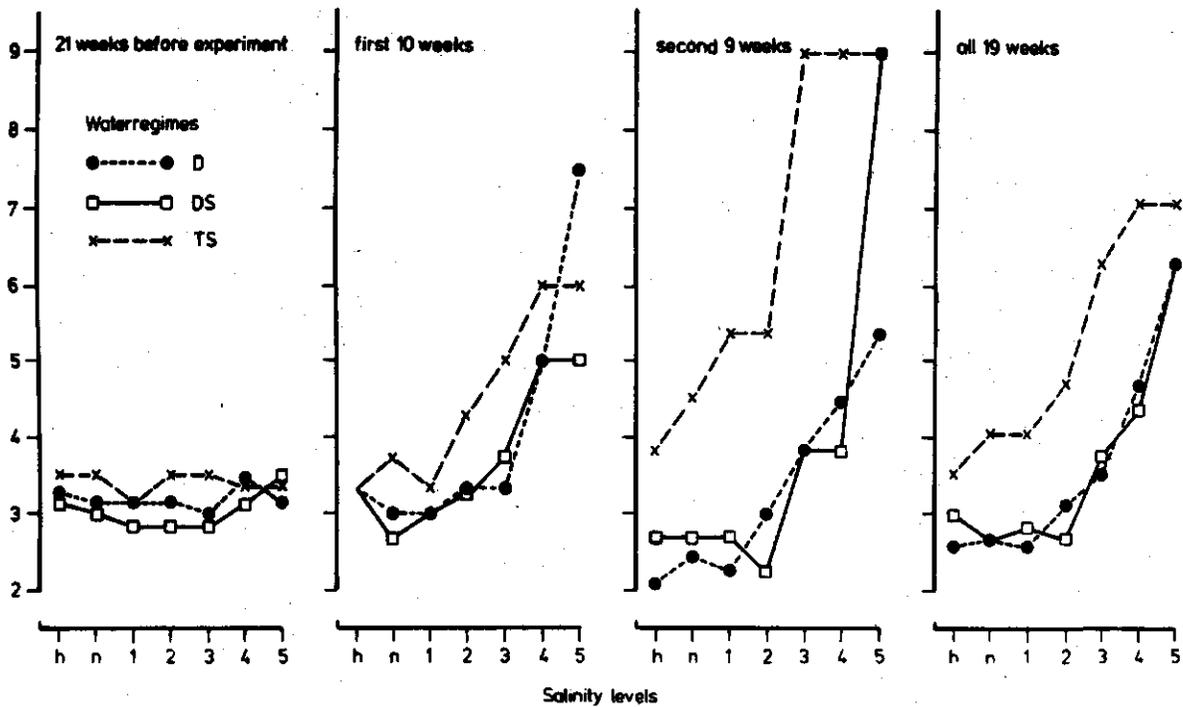   Sarawak July 5 - 7 1976.

Photo's The experimental set-up

Fig. 1. Average time needed for leaf formation in weeks
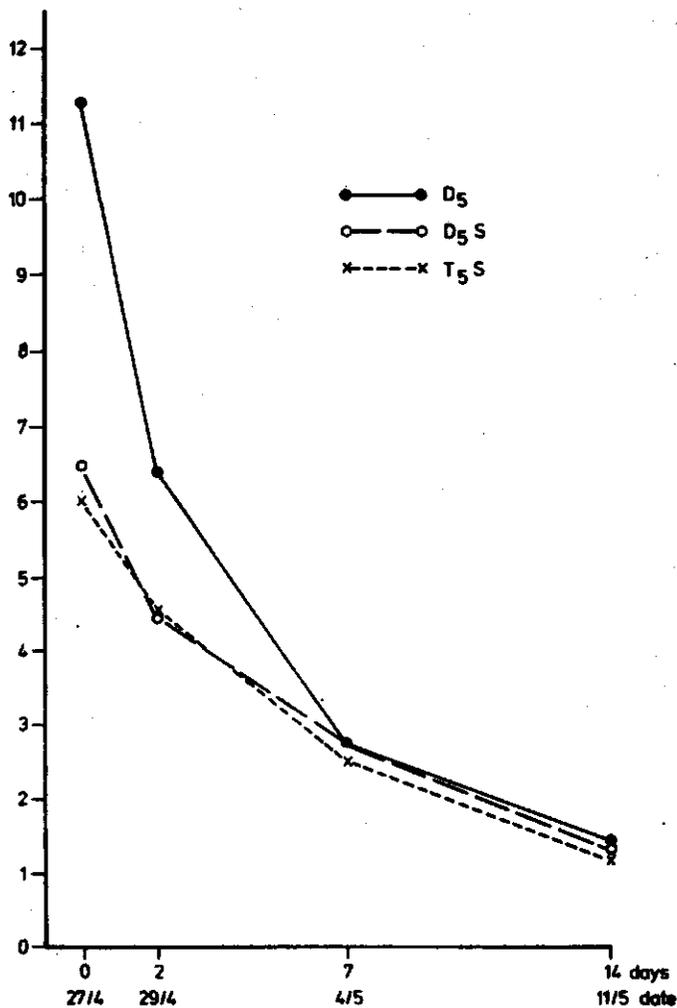per newly formed leaf.

Fig. 2. EC values of percolated water after flooding
the pots with 2 1 sourcewater per day, after
finishing the experiment.