

EARLY RESULTS FROM AN OIL PALM PROGENY X ENVIRONMENT TRIAL AT TWELVE SITES IN PAPUA NEW GUINEA

N. J. MENDHAM*

ABSTRACT

Twelve sites were chosen to represent a range of climatic and soil conditions in eight lowland districts of Papua New Guinea with potential for oil palm cultivation. Two sources of Malaysian tenera seed, with four progenies from each source, were planted at each site. This report deals with growth in the pre-bearing phase, 1968-70, and yield in the first year of bearing, 1970-71.

There were differences in growth rate between sources and sites in both the nursery and early field stages. The growth of one source, Deli dura x (Deli x African pisifera), was consistently poorer than the other source, Deli dura x Sumatra (originally Congo) pisifera. Differences in overall growth between progenies within sources were small, but there were some differences in leaf characteristics and production rate.

Sites with volcanic soil and high rainfall in the New Britain, Bougainville and Northern Districts gave the best growth, although growth at another site in the Gulf District on recent alluvial soils was similar. Initial growth was slow at Buin in Bougainville, possibly due to low sunshine levels, but improved at a later stage. Rainfall was usually greater than the estimated evaporation rate at most sites, and the only moisture stress seen was on poor sandy soil in the Northern District, where nutrient stress also occurred. Some very low sunshine levels were recorded, down to one hour per day, but no effects on growth or sex ratio were found.

Growth in New Ireland was poorer, with acute potassium deficiency at one site. In the Markham Valley, poorer growth was probably due to high pH, base-saturated soils with poor drainage. Growth at a Central District site at an altitude of 550 m was slow, with delayed planting and poor soil added to the effect of lower temperatures.

Early yields on the better sites appeared directly related to efficiency of assisted pollination, as sex ratios were high and natural pollination poor. Yields without pollination were very low at most sites, but with pollination were high and ranged from 750 to 1400 kg f.f.b/ha/fortnight over short periods, depending on efficiency of pollination.

Low leaf magnesium levels were recorded on the Islands sites and low potassium levels on the Mainland sites. Deficiencies may be occurring, and will need to be corrected if the high yields are to be maintained.

INTRODUCTION

The oil palm has only recently been introduced as a commercial crop in Papua New Guinea. It was considered necessary therefore to study the growth and yield of modern types of oil palm under a range of environmental conditions in areas of the country likely to be suitable for the crop.

Twelve sites were chosen to represent the range of soil types and climatic conditions found in lowland areas with enough land

available or potentially available to make establishment of an industry worthwhile. Sites are shown on the map (Figure 1). At each site, Malaysian *tenera* seed from two sources was used, with four progenies from each source. The sites selected and the establishment of the trials were discussed in DASF Annual Reports (DASF 1968, 1969),

Agronomist, Dami Oil Palm Research Station, West New Britain.

Present address: School of Agriculture, University of Nottingham, U.K.

but will be summarized here. The growth of the palms in the pre-bearing period, and yields in the first year of bearing are discussed and interpreted with results from leaf analysis, meteorological records and observations on other factors such as pests and diseases. Results are thus preliminary in nature. The New Britain sites have been dealt with in detail by Mendham (1971a), and some of the data in this paper have been adapted from that report.

SITES

The main features of the sites are summarized in *Table 1*. The climatic details given for Keravat, Bubia and Bisianumu are from DASF (1969). The Buin rainfall figure, from McAlpine (1967), is only for five years and may normally be higher. The rest of the data is from Brookfield and Hart (1966). Five years' sunshine records at Talasea gave means ranging from 3.5 hours per day in January to 6.5 hours per day in June (records, Commonwealth Bureau of Meteorology). From maps given by Brookfield and Hart, Mosa and Siki receive more rainfall than

Talasea in the dry season (May to August), and probably slightly less in the wet season (January to April). On New Ireland, Charles and Douglas (1965) showed strong responses to potassium by coconuts on soils similar to that at Katu, but no response on soils similar to Tigak. The coconuts on the Katu site were typical of poor areas on New Ireland, with many palms missing and the rest apparently dying slowly from potassium deficiency. Saiho probably has a higher and less seasonal rainfall than Sangara, being closer to a mountain range. The higher altitude of Bisianumu gives lower temperatures. One area with potential for oil palms omitted from these trials is the Cape Rodney area of the Central District. A small observation plot of 86 palms was established at Banguina in 1967, and two more observation plots of 1.2 hectares each were established in 1970 on the main soil types in the area, a brown alluvial clay loam and a red lateritic loam. The nearest rainfall station, Baramata, has 2,200 mm rainfall, with peaks in June and September, and a low of 90 mm in October (Brookfield and Hart).

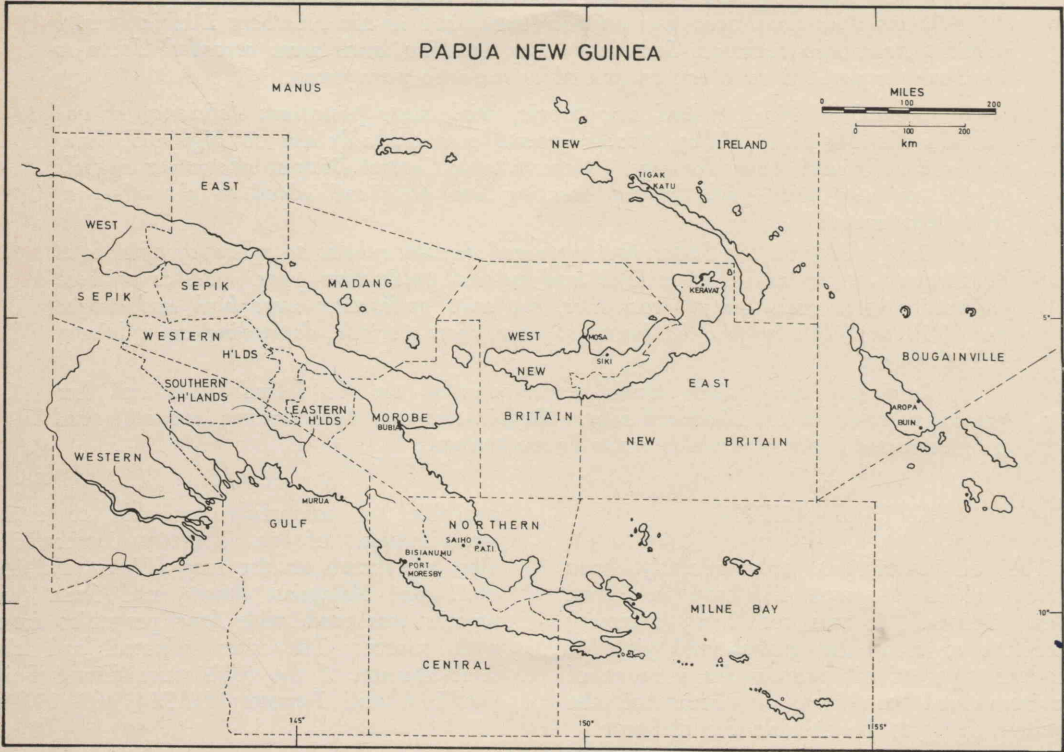


Figure 1.—Map showing trial sites.

Table 1. — Main features of oil palm sites. Climatic details from nearest available station (see text for sources)

Site	District	Annual Rainfall (mm)	Other Climatic Features	Soil Type and Reference	Previous Site Vegetation	Planting Date
Keravat	East New Britain	2800	Little seasonal rainfall variation, mean sunshine 5.6 hours/day.	Volcanic sand, developed on ash and pumice (Graham and Baseden 1956).	Oil palms planted 1934 removed 1964	August, 1967
Mosa	West New Britain	3900 (Talasea)	Strongly seasonal: up to 700 mm per month Jan. - Apr., 100 mm per month June-Sept. (see text).	Multiple horizon pumice soil, sandy loam to clay loam surface layers (Soil Survey report, unpublished).	Forest	January, 1968
Siki	West New Britain	As above	As above.	Multiple horizon pumice soil; lighter texture than Mosa, sand mainly (Soil Survey report).	Forest	December, 1967
Aropa	Bougainville	3000 (Kieta)	Little seasonal variation.	Ash soil: brown loam with an ash pan (Scott 1967).	Forest	July, 1967
Buin	Bougainville	3300 (approx.)	Heaviest rain June-Aug., suspected low sunshine most of year.	As for Aropa; suspected nutrient deficiencies.	Forest	July, 1967
Tigak	New Ireland	3200 (Kavieng)	Little seasonal variation; apparently occasional droughts affect coconuts.	Red-brown clay loam over raised coral (van Wijk 1959), with coral outcrops.	Secondary forest	November, 1967
Katu	New Ireland	3500 (pre-1940 rec.)	As above.	Brown clay (van Wijk 1959), shallow with coral outcrops.	Very poor coconuts (see text,	November, 1967
Bubia	Morobe	3000	Heaviest rain July-Aug., with low sunshine (3.7 hours/day).	Alluvial and colluvial, base-saturated, pH up to 8.5 (DASF 1961), poor drainage on site and with gravelly patches.	Secondary regrowth	June, 1967
Saiho	Northern	3400 (Sangara)	Some seasonal variation: minimum 120-130 mm in July, Aug.; altitude about 300 m (see text).	Weathered brown ash soil, commonly stony; sandy clay loam upper layers (Haantjens 1964).	Secondary forest, old gardens	May, 1967
P.A.T.I.	Northern	2400 (Popondetta)	May-Aug. dry; 75 mm in July.	Unweathered volcanic sand with black topsoil of loamy sand (Haantjens 1964).	Grass - Imperata and Saccharum	January, 1968
Murua	Gulf	3600 (Kerema)	Maximum rainfall May-Sept. with probable low sunshine.	Undifferentiated recent alluvial soil, some areas strongly gleyed (Ruxton et al 1969).	Forest	July, 1967
Bisianumu	Central	2300	June-Aug. dry; 80 mm in July; altitude 550 m.	Chocolate clay loams overlying yellowish clay formed from volcanic agglomerate (DASF 1961); very hilly site.	Grass and regrowth	March 1968

PLANTING MATERIAL

Tenera seed is used now in almost all new commercial plantings throughout the world. Hardon and Thomas (1968) described the development of this in Malaysia. The Deli *dura* was the main planting material used until about 1956 but since then Deli *dura* x *pisifera* has mostly been used. This gives 100 per cent *tenera* progeny, and is now the standard commercial type. Hardon (1970) showed how breeding within the Deli *dura* has been done on very limited foundation material, with consequently considerable inbreeding. Selection for higher-yielding progenies has probably largely been selection of the less inbred ones. The original *tenera* selection, which formed the basis for most commercial *tenera* produced now, was in the Congo, also on a very limited genetic base (Hardon 1970) with consequent inbreeding.

The two sources of seed used in the present trials, designated "C" and "H", are from two different companies. However, both used very similar Deli *dura* female parents, and the main difference is in the *pisiferas* used as male parents.

The crosses can be summarized as follows:

Source C: Deli *dura* x (Deli x African *pisifera*)

Source H: Deli *dura* x Sumatra *pisifera*

The *pisiferas* for source C are descended from *pisifera* pollen imported from either Nigeria, the Congo or Malaya (originally from Africa). This was used on Deli *duras* closely related to those used for the female parents of the final cross and then bred for at least one generation. Thus the trial progenies have quite a high proportion of Deli "blood" and hence inbreeding. The varied origins of the *pisiferas* mean that the final four progenies should be fairly variable.

The *pisiferas* for source H are descended from three excellent quality *tenera* palms in Sumatra, one being SP540. This palm came from Eala in the Congo, from an excellent palm selected there ("Djongo"), which gave rise to much of the good quality *tenera* now found in Africa, Asia and South America (Hartley 1967). There has been considerable inbreeding in this line also, but no crossing with Deli *duras*. The parents for the final crosses are thus unrelated. However, for the four progenies from this source, the four Deli *dura* parents come from two closely related families, and only two *pisifera* parents were used, both from the same family. Thus the progenies should be very uniform in their performance.

ESTABLISHMENT

Nursery

Nursery germination, establishment and growth were dealt with in detail in an Annual Report (DASF 1969). Tables 2 and 3 summarize the data.

The C progenies performed poorly in all aspects. The "establishment" figure is the number of usable seedlings as a percentage of the number of seeds received. Full ger-

Table 3. — Mean seedling height (cm) of the two sources at each nursery site in April, 1967.

Nursery Site	C	H	Site C x 100	
	Mean	Mean	Mean	H
Keravat	61.7	79.5	70.6	78
Hoskins	57.6	76.3	66.9	76
Aropa	51.8	62.7	57.2	83
Buin	42.7	51.0	46.9	84
Tigak	48.5	59.8	54.1	81
Bubia	64.0	72.9	68.4	88
Popondetta	39.6	52.8	46.2	75
Murua	56.4	67.8	62.1	83
Sogeri	31.2	32.5	31.8	96

Table 2. — Establishment and nursery growth of the eight progenies, means over all sites

	C1	C2	C3	C4	C Mean	H5	H6	H7	H8	H Mean
Estab. per cent										
Nov., 1966	40.5	61.3	48.7	39.2	47.4	81.6	81.7	78.5	83.2	81.3
Height (cm)										
April, 1967	49.8	54.9	46.7	49.8	50.3	58.4	62.7	61.3	64.0	61.6
No. of leaves										
April, 1967	8.6	9.5	9.1	8.9	9.0	9.3	9.4	9.5	9.3	9.4

mination of the C progenies was mostly delayed compared to the H, and hence some of the growth differences are due to the earlier establishment of most of the latter. Differences between sites were large. The poorer growth at Aropa was due to the seedlings not being spaced out properly, and shade not removed after a few months. The palms in the Sogeri nursery (used for the Bisianumu block) were also not spaced out properly, but growth was very slow as well. At Popondetta, the nursery used poor sandy soil, and even though normal watering and fertilizing were carried out, it was apparently not enough for rapid growth. The difference between the sources was most marked there. Poor growth at Buin was probably related to sunshine levels, as watering, fertilizing and nursery care were good. It was observed that conditions were very overcast up to April. Between April and planting out in July, weather was sunny and growth improved greatly. The poor germination and establishment of C4 meant that a closely related substitute progeny had to be used at Keravat, Mosa and Siki. This progeny was used for both C1 and C4 at Katu also.

Field Establishment

Planting-out dates are listed in Table 1. Unfortunately the Mosa and Siki plantings were delayed about four months, as Mosa Plantation was in the establishment stages and the site could not be prepared in time. The Siki planting was thus held back to give a better comparison with Mosa. Growth became very slow after about 14 months in the polybag nursery and field establishment took longer, so these sites were effectively set back four months compared to the others. Planting of the New Ireland sites was held back about two months to avoid dry weather, and the P.A.T.I. site about four months. The original site near Sogeri could not be used, and the Bisianumu planting was set back about six months. Slow growth in the nursery, combined with lack of attention, meant that the field palms there were well behind those of the other sites. Horses and cattle severely damaged the seedlings at Katu shortly after field planting. These palms were thus set back considerably compared to Tigak.

Pueraria cover-crops were established on all blocks, and most were good by July, 1968. On the P.A.T.I. and Bisianumu blocks, originally mainly grass, it proved difficult to establish full covers. At Keravat, about one third of the block (replicates 5 and 6) was covered with Para grass (*Brachiaria mutica*), and apparently poorly drained. Drains were dug and legume planted, but the effects on the palms were quite marked, in reduced growth and yellowing of the leaves. The symptoms disappeared after 1968, but the palms remained slightly smaller than those in the rest of the block. Drains were dug initially through most of the Bubia block, but several small areas later showed up as poorly drained, necessitating further treatment. Growth of palms in these areas was retarded.

Site layouts

Due to the reduced numbers of C palms available a modified design had to be used instead of normal randomized blocks. A type of split plot design was used, with two main plots per replicate, for the two sources H and C. Each main plot was divided into four subplots for the four progenies of each source — six palms per H subplot and four palms per C subplot. This design gives some complications in analysis, mainly relating to the spatial separation of the progenies of the different sources. Six replications were used at each site except Murua. Damage to nursery seedlings there by the taro beetle, *Papuana woodlarkiana*, caused quite heavy losses and only five replicates could be planted.

RECORDINGS

Crop Growth

It was intended to record leaf production on all sites, by marking the newest fully expanded leaf at regular intervals, and then counting the leaves produced between markings. This was only done regularly for the New Britain blocks and Saiho. Annual visits to the other sites meant that even if the marking was done properly by staff on the site, the older records were lost. Leaf production on all sites thus was only available for January to June, 1968 and the same period in 1969. In the former period palms at the later-planted sites were still establishing, so comparative records are only of value for the latter period.

The area of leaves increases steadily with age of the palm, and a regular estimate of area of the newest leaf is a good measure of the rate of growth of the palms. Estimates of this by the method described by Mendham (1971b) were taken every six months on all sites from early or mid 1968 to July, 1969. January, 1970 measurements were made only on the New Britain blocks, Saiho and Bisanumu, and July, 1970 measurements on all except Katu and P.A.T.I.

The two methods of measuring leaf area were:

(1) $L(l \times b)$, i.e., length of rachis (L) multiplied by the (length $\times$ breadth) of a leaflet in the region of largest leaflets; and

(2) Leaf ($l \times b$), i.e., number of leaflets multiplied by ($l \times b$) as above.

The first estimate was used for most of the measurements in this paper, but the second gives a simpler linear relation with area, and is more precise, so it should be used for future work, even though more tedious to carry out. Calibration curves were derived for each progeny for each method, and used to convert field data.

Flowering and Yield

The palms on all blocks except Siki and Murua were castrated, i.e., had the developing inflorescences removed, at approximately monthly intervals from late 1968 to about October, 1969. Records were kept of the number of palms of each progeny flowering, and the sex ratio of the inflorescences produced, i.e., the ratio of female to total inflorescences.

Harvesting then began in about April, 1970. However, it soon became obvious that natural fruit set was very poor on most blocks. Assisted pollination was started at Saiho in February, Mosa in June and most other blocks in about September, 1970. Records are being kept on a per plot basis, of the total weight of good fruit, number of good bunches, number of rotten bunches (usually unpollinated) and number of male inflorescences.

Data from four sites only, Keravat, Mosa, Saiho and Buin, are used in this report. Results from the first year of harvesting only are available so far.

Nutrition

Since an important aspect of these trials is the wide range of soil types being used, regular foliar samples were taken for chemical analysis of 3rd and later of 17th leaves. Leaf samples were taken monthly at Keravat to help interpretation of seasonal and longer term trends. At most other blocks they were taken annually.

In about April, 1968 a standard dressing of 230 g per palm of fertilizer 12:12:17:2 (N: P_2O_5 : K_2O : MgO) was used on most sites, except for Aropa, Buin, Murua and Bisanumu where it was delayed until late 1968 by non-availability of fertilizer. At Saiho and P.A.T.I. a mixture of 15:15:15 NPK and ammonium sulphate was used, 450 g per palm at Saiho and 230 g at P.A.T.I. Thereafter only small applications were made on some of the poorer blocks, until 1971 when a general application was again to be made.

Environmental

Rainfall records from mid 1967 are available for all sites, with Campbell Stokes sunshine records from Keravat, Mosa and Bubia only. Jordan sunshine records are available for 1969 and 1970 at most sites and temperature recordings for the same period for Keravat and Bisanumu only.

CROP GROWTH RESULTS

Leaf Area

Sites. — The six-monthly estimates of leaf area are summarized in *Figure 2*, as site means. The figures represent the mean area derived from the $L(l \times b)$ estimate, of the newest fully expanded frond on the first day of the month indicated. *Tables 4, 5 and 6* give the source and site means for July, 1968, 1969 and 1970 respectively.

The fastest growing sites were clearly Keravat, Aropa, Saiho and Murua over the whole period of recording. Bubia caught up with these in January and July, 1969, but fell behind at the last reading. These sites were significantly different from the next group both in 1969 and 1970. This second group comprises Mosa, Siki and Buin, although Siki was

Table 4. — Area of newest leaf in m²
Source and site means, 1st July 1968.

Site	C Mean	H Mean	C x 100 H	Site Mean
Keravat	1.08	1.25	86	1.17
Aropa	1.08	1.21	89	1.15
Saiho	1.02	1.29	79	1.15
Murua	0.92	1.02	90	0.97
Bubia	0.80	0.86	93	0.83
Siki	0.70	0.86	81	0.80
Buin	0.79	0.81	98	0.80
Mosa	0.70	0.79	89	0.75
Tigak	0.65	0.65	100	0.65
P.A.T.I.	0.53	0.61	87	0.57
Mean	0.83	0.93	89	0.88
Katu	0.46	0.41	112	0.44
Bisianumu	0.50	0.63	79	0.56

behind in July, 1969. Allowing for the four months' planting delay at the first two of these, they would be little different from the best sites, and appear to have grown at the same rate, but about four months behind. Nursery growth and initial field growth was slow at Buin, but after July, 1968 it was almost identical to Mosa. The growth rate at Tigak was slower than at the other sites until July, 1969. Growth at P.A.T.I. was poor, in complete contrast to Saiho, although the palms were from the same nursery. Even allowing for the four-month planting delay, it was well behind the other sites. Bisianumu was even poorer, with a continuing slow growth rate. At Katu, even though all palms

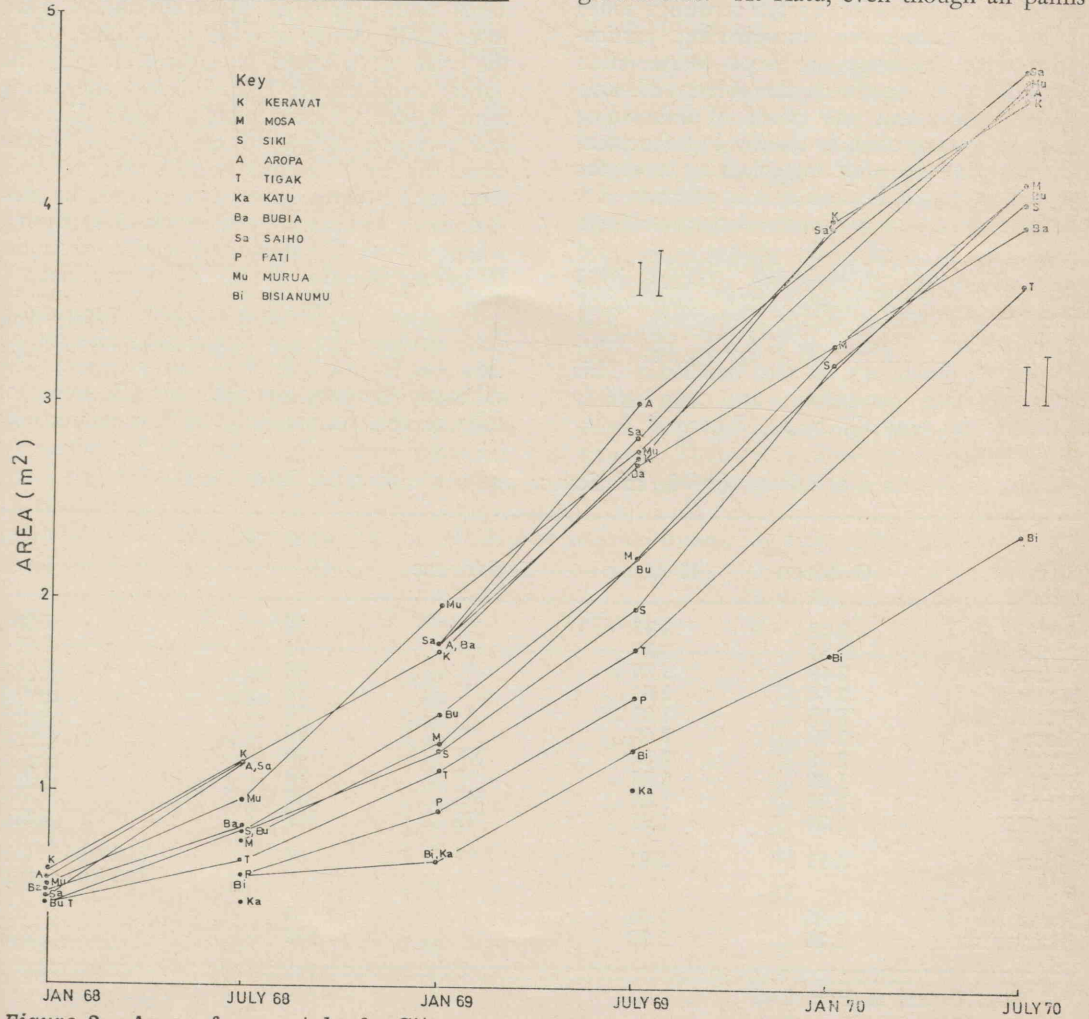


Figure 2.—Area of newest leaf. Site means at six-monthly intervals. Least significant differences (P=0.05 and P=0.01) shown for July, 1969 and July, 1970.

recovered from the damage by livestock, growth continued to be very slow.

Sources. — The C and H means for each site for July, 1968, 1969 and 1970 are contained in *Tables 4, 5 and 6*. The significance of the difference between them is indicated in the last two, and the C means are also given as a percentage of the H means. These can be compared with the corresponding mean heights in the nursery (*Table 3*).

For 1968 (*Table 4*), the differences between the sources at most sites were much reduced compared to the nursery. This is normal, as transplanting effects are large, and tend to cancel out differences. Larger seedlings suffer more root damage on transplanting, particularly when seedlings are kept longer than about 10 to 12 months in the nursery. Hardon (1970) notes that the effect of inbreeding depression on growth is usually lost (presumably temporarily) after transplanting from the nursery to the field, and this is probably due to the greater growth check to larger seedlings.

By July, 1969 (*Table 5*), differences between sources had become quite large again, and mostly significant or highly significant. The poorest sites, Tigak and P.A.T.I., had non-significant differences, as also had Buin. This last is rather anomalous, and was 'mainly cause by the high C1 mean (*Figure 3*).

The July, 1970 differences (*Table 6*) were fairly similar to those of 1969, although there was some variation. The differences over all sites were still highly significant. Only four replicates were measured at Murua, Aropa, Tigak and Bubia, thus contributing to the reduced significance compared to *Table 5*. Also, the large differences between the C progenies in their leaf area calibration curves at high values (Mendham 1971b) contribute to the reduced significance for the better sites.

The difference between sources was visibly apparent on most of the blocks. The C palms were generally smaller, with smaller fronds and shorter, less sturdy developing trunks. On aerial photographs of Mosa Plantation taken from 3,000 metres altitude in October, 1970, the trial block could be clearly seen by the darker strips of the H main plots alternating with lighter C main plots. Larger diameter and increased height of the H palm crowns were the main factors contributing to this. Examined under a stereoscope it could be seen that there was some variation in this pattern, where not all C palms were smaller than the H palms, but the overall effect was clear.

Progenies. — The best available comparative data between the individual progenies for all sites was for the July, 1969 measurement. The calibration curves, especially for C3, were not fully reliable for the July, 1970 measurements

Table 5. — Area of newest leaf in m². Source and site means, 1st July, 1969.

Site	C Mean	H Mean	Difference	C x 100 H	Site Mean
Aropa	2.63	3.36	**	78	3.00 a
Saiho	2.38	3.27	**	73	2.83 b
Murua	2.46	3.07	*	80	2.76 b
Keravat	2.50	2.93	*	85	2.71 b
Bubia	2.35	3.01	*	78	2.68 b
Mosa	2.03	2.42	**	84	2.22 c
Buin	2.08	2.33	NS	89	2.21 c
Siki	1.69	2.22	**	76	1.95 d
Tigak	1.59	1.87	NS	85	1.73 e
P.A.T.I.	1.39	1.61	NS	86	1.50 f
Mean	2.11	2.61	**	81	lsd 0.05 = 0.17 lsd 0.01 = 0.23
Katu	1.03	1.04		99	1.03
Bisianumu	1.24	1.22		102	1.23

* Significant at P = 0.05

** Significant at P = 0.01

Site means followed by the same letter are not significantly different at P = 0.05

(Mendham 1971b). The 1969 data are contained in Figure 3.

The difference between the sources was large, although only at Aropa, Saiho and Siki were all H progenies significantly different from all C progenies. The only consistent differences between progenies over most sites were that H8 tended to be the lowest of the H progenies and C3 and C4 tended to be the lowest C progenies, especially at the better sites. This trend can be clearly seen in the combined, or overall mean data. These differences largely arose from the calibration curves (Mendham 1971b). In the general area of the curves from which these figures were taken, H8 gave slightly lower area readings than the other H's for the same $L(1 \times b)$. C3 and C4 gave lower readings than the other C's. These differences may be real ones, as the fitted calibration curves differed significantly from each other.

Leaf Production

Figure 4 shows the monthly rates of leaf production at two representative sites, Mosa and Saiho. These have been adjusted to account for months of unequal length.

The effect of late planting at Mosa is obvious in the rapid increase in production up to the end of 1968, as the palms recovered from the setback of being held in the nur-

sery and then transplanted at a large size. In 1969 and 1970 leaf production at Mosa was mainly higher than Saiho, considerably so at the last readings. Decreasing production at Saiho, although slight, is probably the normal result of onset of fruit bearing, and the same trend was likely at Mosa after recording ceased. Variation between months was greater at Mosa, although this is probably just the effect of using a shorter measuring period. Differences between the source means at each site were very small at all times, with no consistent difference emerging, in contrast to the leaf areas. There were, however, differences between individual progenies. C3 normally produced the most leaves and C1 the least of all progenies.

The best set of comparative data for all sites was for January to June, 1969, and this is given in Table 7. The later-planted blocks had mainly attained normal growth by then (Figure 4). The figures given for Siki in Table 7 are based on estimates for January to March. These may have been too low as production was rising rapidly then. Some of the differences between sites may be due to variation in marking dates, which were not recorded at some sites. Hence the figures for Murua are probably too high.

The means over the better sites show that there was no difference between the two sources. There was little difference between the H progenies, but C1 was low and C3

Table 6. — Area of newest leaf in m². Source and site means, 1st July, 1970.

Site	C Mean	H Mean	Difference	$\frac{C \times 100}{H}$	Site Mean
Saiho	4.26	5.25	*	81	4.75 a
Murua	4.34	5.05	NS	86	4.70 a
Aropa	4.28	5.06	*	85	4.67 a
Keravat	4.24	4.98	NS	85	4.61 a
Mosa	3.78	4.54	*	83	4.16 b
Buin	3.74	4.56	*	82	4.15 bc
Siki	3.58	4.56	**	79	4.07 bc
Bubia	3.54	4.38	*	81	3.96 c
Tigak	3.32	3.96	*	84	3.64 d
Mean	3.90	4.70	**	83	lsd 0.05 = 0.20 lsd 0.01 = 0.26
Bisianumu	2.26	2.46		92	2.36

* Significant at P = 0.05

** Significant at P = 0.01

Site means followed by the same letter are not significantly different at P = 0.05

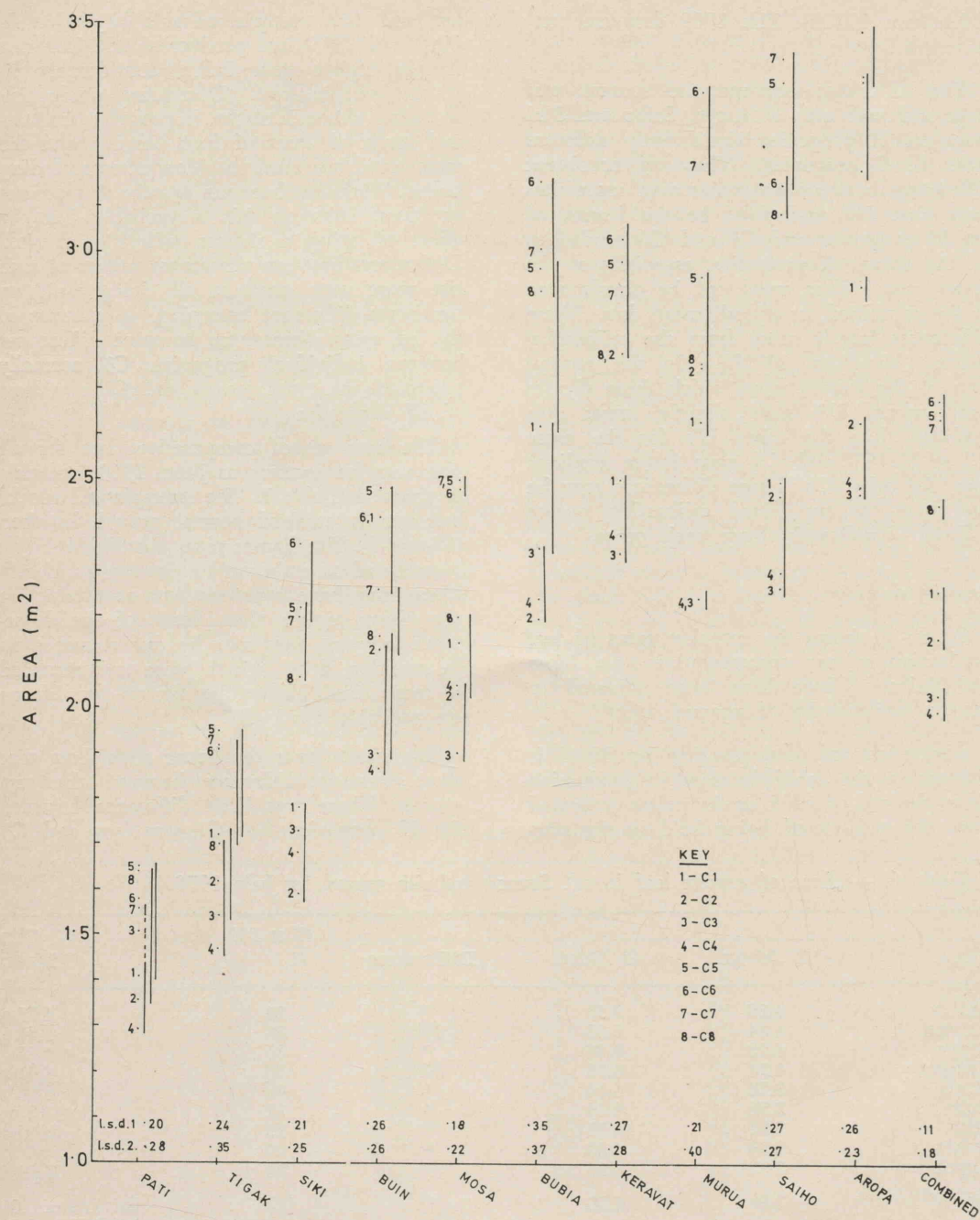


Figure 3.—Area of the newest leaf on 1st July, 1969. Progeny means for 10 sites. Means connected by the same line are not significantly different at P=0.05. Least significant differences 1 and 2 are for comparisons within the same source and from different sources respectively.

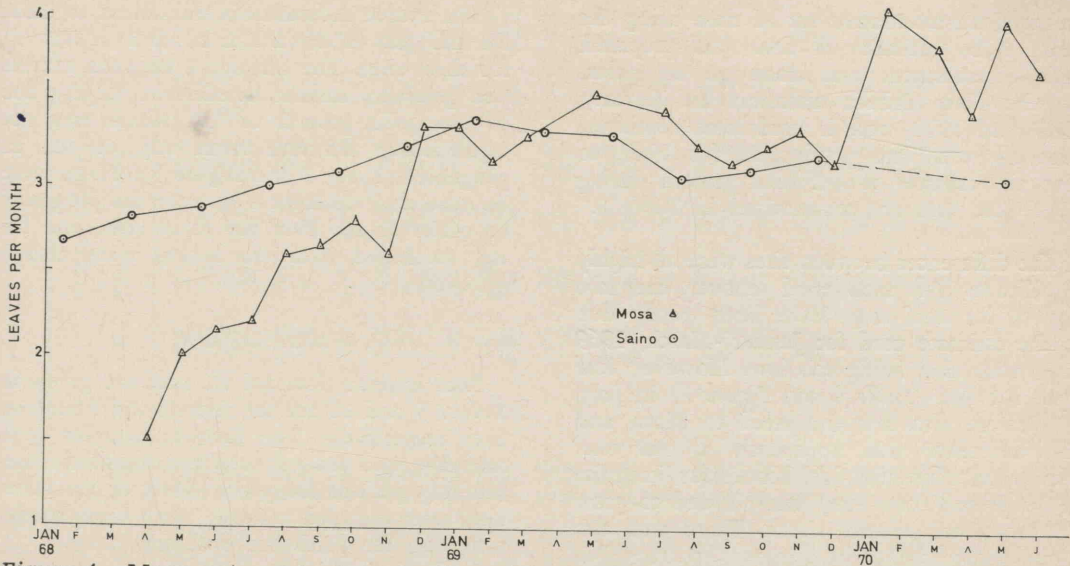


Figure 4.—Mean rate of leaf production at two sites. Mosa data monthly, Saiho two-monthly.

high. The substitute progeny for C4 on the New Britain blocks had a low rate of leaf production similar to C1. These trends were followed for most sites, and throughout the recording period. Generally there was little difference between the better sites, but production was greatly reduced on the poorer ones.

When these results are considered together with progeny leaf areas as in Figure 3, the rate of leaf area growth of the different progenies would have been of the same rank-

ing as the area of individual fronds, except for C1, which would have been reduced, and C3 which would have been increased. Thus, progeny C3 tended to produce a larger number of small fronds.

Leaf Area Combined with Production using leaf(l x b)

To confirm the difference in leaf area between sites, sources and progenies found by the above method, using the L(l x b)

Table 7. — Number of leaves produced January to June, 1969

Site	C1	C2	C3	C4	H5	H6	H7	H8	C Mean	H Mean
Keravat	20.3	21.0	23.0	19.9*	21.6	21.1	21.9	22.0	21.0	21.6
Mosa	19.0	21.0	22.1	19.2*	21.2	19.8	20.7	20.8	20.3	20.6
Aropa	20.9	21.0	21.9	22.4	20.6	20.9	21.5	19.6	21.6	20.7
Buin	19.4	20.8	21.6	20.7	20.4	19.8	19.1	19.7	20.6	19.7
Tigak	18.0	19.5	19.3	20.1	20.0	19.2	18.8	19.8	19.2	19.5
Bubia	17.6	19.3	21.2	19.1	19.6	19.1	19.5	20.1	19.3	19.6
Saiho	16.9	21.0	20.9	20.1	20.2	19.3	20.0	20.2	19.7	19.9
Murua	20.0	21.5	24.3	22.6	22.7	21.2	23.0	22.0	22.1	22.2
Mean of 8 sites	19.0	20.6	21.8	20.5	20.8	20.1	20.6	20.5	20.5	20.5
Siki**	17.9	18.1	18.8	16.0*	17.0	17.8	19.7	17.9	17.9	18.1
Katu	16.0	17.9	19.0	17.2	17.7	17.7	18.7	17.3	17.5	17.8
P.A.T.I.	14.5	14.6	15.5	15.4	16.5	15.0	17.1	15.9	15.0	16.1
Bisianumu	16.1	13.6	14.7	13.3	14.4	13.0	12.8	13.6	14.4	13.5

* Substitute progeny

** Estimate for January to April used

estimate, an alternative set of data using the leaf(l x b) estimate of area was prepared. This measurement was done on all palms on the New Britain sites on 1st January, 1969 and 1970, and is used here combined with the total leaf production for 1969, to give an estimate of leaf area growth during 1969. The data are summarized in Table 8.

The differences between sites were all highly significant. As mentioned above, the low figures for Siki may have been partly due to the estimate used for January-March, 1969 leaf production being too low. However, leaf areas for Siki (Table 6 and Figure 2) in July, 1969 were also low compared to Mosa, and the difference was apparently a real one. Maintenance on the Siki block was irregular in 1968, and cover-crop was allowed to grow up the palms several times. There was also considerable damage by *Scapanes* sp., the New Guinea rhinoceros beetle, and the difference in leaf area production between Mosa and Siki is probably explained by these factors.

Table 8. — Leaf area production for the New Britain sites, 1969, in m² per palm, using the leaf(lxb) estimate

Progenies	Keravat	Mosa	Siki	Combined
C1	119.8	90.0	79.8	96.5
C2	132.2	89.5	74.6	98.8
C3	123.7	84.3	85.0	97.7
C4	119.7	86.1	71.8	92.5
C Mean	123.8	87.5	77.8	96.4
H5	134.3	108.3	90.5	111.0
H6	131.8	102.9	96.0	110.2
H7	135.2	113.5	91.7	113.5
H8	140.2	106.3	101.6	116.0
H Mean	135.4	107.8	94.9	122.7
Difference in the means	NS	**	**	**
Site mean	129.6	97.6	86.4	
lsd 1	12.4	9.1	8.9	8.4
lsd 2	13.9	9.1	10.1	9.4

** Significant at P = 0.01
lsd (sites) 0.01 = 7.3
lsd 1 Least significant difference at P = 0.05 for comparison of progenies of the same source
lsd 2 Least significant difference at P = 0.05 for comparison of progenies of the same source

The source differences were similar to those for the July, 1969 L(l x b) data (Table 5) for these sites. The difference between sources was generally smaller at Keravat, largely due to the good growth of C2, which was not significantly different from any of the H progenies (Table 8 and Figure 3). There were no consistent differences between the progenies of either source over the three sites, and for the combined data the means were closely grouped.

NUTRITION

Leaf analysis data for all sites are given in Tables 9 and 10 for the Islands and Mainland sites respectively. The Keravat samples were monthly, and means over approximately six-monthly periods are given. Most of the other sites were sampled annually, with some special sampling for particular problems.

The "tentative critical levels" given in Table 9 are based on those given by Ollagnier, Ochs and Martin (1970) with some modifications based on levels used in Malaysia, and what appear to be appropriate for Papua New Guinea. A higher third leaf critical level for magnesium, 0.30 per cent, is usually used in Malaysia. Manganese levels in Malaysia are usually above 200 p.p.m., but on local soils levels as low as 8 p.p.m. have been found. This may be related to the generally higher soil pH here, as manganese is less readily available under neutral than under acid conditions. The above authors quote levels of about 50 p.p.m., as found in Colombia, as being low. A critical level for SO₄-S has not been established for oil palms, and the suggested levels given here are based on experience with coconuts, and the oil palm samples so far analysed. Levels of the other minor elements are just "normal" levels from Malaysia, as responses have not been shown to any of them except boron, where certain leaf symptoms such as "hook leaf" are often associated with low boron levels (around 3 p.p.m.) and can sometimes be cured with boron fertilizer applications (Turner and Bull 1967).

Keravat. — With the large number of samples taken, the mean figures presented here should be quite reliable. Generally the levels appear adequate. Some low nitrogen levels were recorded in the last half of 1968, but the mean of 2.77 was near the critical level. Manganese appeared to be decreasing

Table 9. — Selected leaf analysis data from oil palm trial blocks, New Guinea Islands 1968-70. 3rd and 17th leaf samples

Site	Leaf	Date & Notes	% on dry basis					p.p.m. on dry basis					
			N	P	K	Ca	Mg	S	Mn	Fe	Zn	Cu	B
Keravat*	3rd	9/67-12/67 (6)	3.12	0.210	1.67	0.81	0.27	188	94	70	20.4	10.2	18.0
		1/68-6/68 (5)	3.13	0.196	1.54	0.87	0.34	189	64	65	20.9	6.8	14.4
		7/68-12/68 (6)	2.77	0.213	1.68	0.70	0.32	240	39	59	23.6	11.6	17.0
		1/69-7/69 (7)	2.93	0.211	1.81	0.75	0.40	431	39	61	23.0	3.5	14.1
	17th	9/69-12/69 (4)	2.59	0.175	1.20	0.94	0.25	123	52	72	30.5	10.5	12.2
Mosa	3rd	1/70-7/70 (6)	2.59	0.215	1.34	0.90	0.31	112	67	65	16.2	9.5	13.8
		5/68-7/68 (2)	3.14	0.216	1.53	0.96	0.44	282	101	57	23.6	6.3	13.3
		1/70	2.60	0.162	1.03	1.16	0.26	140	23	28	15.5	10.3	11.5
		1/70 orange frond	2.62	0.163	1.20	1.16	0.18	140	17	42	16.0	8.8	11.8
	17th	10/70 H	2.53	0.160	1.15	0.98	0.20	115	33	57	16.3	6.0	14.3
Siki	3rd	10/70 C	2.56	0.150	0.95	1.05	0.15	130	29	60	15.4	5.0	15.0
		7/68	3.15	0.215	1.44	1.27	0.79	180	106	63	22.5	10.5	14.1
		1/70	3.17	0.209	1.90	0.69	0.31	280	21	69		8.8	12.3
		11/70 H	2.51	0.130	0.90	1.07	0.22	105	35	51	14.0	5.8	11.0
	17th	11/70 C	2.61	0.150	1.00	1.18	0.18	95	35	47	14.8	5.4	11.5
Aropa	3rd	7/68		0.249	1.84	0.68	0.36	205	35	61	23.3	7.2	13.3
		8/69	2.89	0.190	1.40	0.60	0.19	370	43	92	34.3	5.2	14.0
	17th	8/70	2.88	0.180	1.00	1.05	0.20	145	71	63		7.1	15.7
Buin	3rd	7/68		0.236	1.47	0.75	0.44	187	69	66	25.5	8.5	12.5
		8/69	3.06	0.173	1.12	0.60	0.20	277	61	60	26.0	5.5	9.1
	17th	8/70	2.75	0.160	0.95	1.05	0.30	175	91	100	18.7	8.2	15.0
Tigak	3rd	7/68	3.08	0.194	1.57	0.88	0.44	197	112	52	22.5	6.3	14.2
		8/69	2.98	0.195	1.26	0.74	0.25	214	122	58	27.2	5.4	14.0
	17th	8/70	3.12	0.190	1.25	1.23	0.23	205	200	79	24.3	10.2	18.0
Katu	3rd	7/68	3.20	0.201	1.09	1.34	0.76	140	116	56	19.0	9.3	19.0
		8/69	2.62	0.175	0.64	0.76	0.25	235	166	51	28.8	4.5	9.0
		8/70	3.11	0.230	0.55	0.68	0.35	190	162	66	27.1	10.1	14.5
Tentative critical levels (see text)		3rd leaf	2.8	0.19	1.30	0.30	0.24	200	50	60	15.0	5.0	10.0
		17th leaf	2.5	0.15	1.00	0.60	0.24	150	50	60	15.0	5.0	10.0

* For Kerevat and Mosa, number of samples indicated in brackets

on the third leaf samples, but seemed to stabilize at over 50 p.p.m. on the 17th leaf samples. The later sulphur levels were quite low, and may indicate an incipient deficiency, as sulphur deficiency is common on the Gazelle Peninsula in other crops.

Mosa and Siki. — Results from these two were quite similar, as expected since they are on similar soils. Owing to the large growth difference that had developed between the two sources H and C, separate samples were taken. It had been observed that the C source palms, as well as being slower growing, seemed to be more susceptible to symptoms resembling magnesium deficiency, "orange frond" (Turner and Bull 1967). This had been noticed on many other sites also. The "orange frond" sample from Mosa, taken from the 20 worst affected palms, did show lower magnesium levels than the general sample taken at the same time. Also, the C magnesium level was lower than H for Mosa and Siki on the October, 1970 samples. All levels were low for these samples, and it appears that magnesium declined from an initially high level to quite a low level, indicating the possibility of a response to fertilizer. Potassium levels were fairly low for the later samples and were grouped around the critical level of 1.0 per cent, and a deficiency of this nutrient may also have been developing. Both sulphur and manganese appeared low also.

Aropa and Buin. — The Aropa figures showed low magnesium in 1969 and 1970, and marginal potassium in 1970. At Buin, potassium was low in 1969 and 1970, and magnesium only in 1969. At both sites in 1970 nitrogen was higher than on the New Britain sites.

Tigak and Katu. — With the expected potassium deficiency in New Ireland, 230 g per palm of 16:0:28 (N:P₂O₅:K₂O) was applied in October, 1968 and the same amount of 12:12:17:2 in May, 1969. Leaf levels at Tigak were surprisingly good and mostly normal. At Katu, however, extremely low potassium levels occurred in spite of the applied fertilizer. The palms were slow-growing and visible symptoms were apparent on some palms, similar to "confluent orange spotting" described by Turner and Bull.

Bubia. — This site had been poorly drained, and this was reflected in the 1968 nitrogen

level. Samples taken in January, 1968 from drained and waterlogged areas gave 2.65 per cent and 2.05 per cent N respectively. 1969 and 1970 potassium levels were low. A deficiency would be quite likely on this base-saturated, high pH soil, and would be increased by high soil calcium and magnesium. Leaf calcium levels were high, but magnesium seemed normal. Sulphur levels were very high initially, but may have been declining in the 1970 samples. The difference in magnesium level between the C and H sources was apparent, as at Mosa.

Saiho. — A considerable amount of "white stripe" (Turner and Bull) occurred on these palms, and on most other sites also. For most palms it seems a transient stage, but some are affected more seriously. C2 particularly appeared to be susceptible at Saiho and also at some other sites. A separate leaf sample was taken from the 20 worst affected palms in 1969. The only difference from the general sample was that sulphur levels were lower. However, later samples did not show this difference (K. A. Handreck, personal communication). In 1970 samples were taken from H and C palms separately. The difference in magnesium levels between the sources was clear, and it seems that the C palms generally tend towards lower magnesium uptake and more magnesium deficiency symptoms. Potassium levels were low on the 1970 samples.

P.A.T.I. — Levels of some nutrients tended to be low on this poor sandy soil, as expected. The palms were very yellow in September, 1968, so a dressing of 450 g ammonium sulphate per palm was given, after which the yellowing rapidly disappeared. The 1968 leaf levels showed very low nitrogen and quite low potassium, whereas the 1969 levels (after fertilizing) were normal. In 1970, nitrogen was marginal and some deficiency symptoms appeared to be returning. Potassium was very low and sulphur also rather low.

Murua. — Most levels appeared normal, although potassium levels were low in 1969 and especially in 1970. Sulphur levels may also be low. Nitrogen levels were very high.

Bisianumu. — On this uneven site, palm growth was observed to be satisfactory on the lower parts of the slope and on a flat area at the end of the block, but poorer on the

Table 10. — Selected leaf analysis data from oil palm blocks, Mainland New Guinea and Papua, 1968-70. 3rd and 17th leaf samples

Site	Leaf	Date & Notes	% on dry basis					p.p.m. on dry basis					
			N	P	K	Ca	Mg	S	Mn	Fe	Zn	Cu	B
Bubia	3rd	10/68	2.67	0.178	1.40	0.64	0.31	610	39	71	17.3	6.3	16.0
		10/69	2.89	0.180	0.93	1.23	0.28	830	82	104	12.0	4.5	18.5
	17th	9/70 H	2.69	0.220	0.83	1.14	0.34	210	116	40	16.5	6.6	18.5
		9/70 C	2.70	0.215	0.90	1.10	0.25	170	124	53	13.5	6.5	16.3
Saiho	3rd	9/68	2.93	0.225	1.52	0.78	0.36	275	72	51	17.0	16.7	17.5
		10/69	2.88	0.180	1.48	0.74	0.28	285	58	80	19.5	4.2	12.0
		10/69 white stripe	3.02	0.181	1.43	0.68	0.24	117	55	72	17.0	4.5	14.5
	17th	9/70 H	2.91	0.225	0.78	1.14	0.34	228	80	49	14.8	6.9	16.5
		9/70 C	3.00	0.225	0.79	1.08	0.27	188	78	56	16.5	9.3	16.5
		10/70 H white stripe	2.92	0.190	1.20	1.06	0.32	173	98	57	16.0	7.7	18.0
P.A.T.I.	3rd	9/68	2.34	0.180	1.13	0.85	0.58	185	96	65	17.5	18.7	15.8
		10/69	2.83	0.170	1.30	0.55	0.34	205	48	80	21.5	4.2	8.9
	17th	9/70	2.54	0.205	0.75	1.02	0.42	133	75	63	15.0	6.2	14.5
Murua	3rd	10/68		0.150	1.65	0.33	0.26	185	55	57	13.0	4.5	12.0
	17th	10/69	3.10	0.182	0.93	0.96	0.27	520	157	66	15.5	5.1	10.5
		9/70	3.17	0.220	0.75	0.86	0.33	135	170	56	20.0	5.2	
Bisianumu	3rd	9/68	2.77	0.173	1.77	0.48	0.44	425	335	80	14.3	13.8	15.0
		10/69	2.36	0.147	1.50	0.40	0.28	420	96	70	18.5	4.1	12.0
		9/70 bottom	3.13	0.240	1.08	0.64	0.38	250	145	56	24.0	8.2	14.3
		9/70 hillside	2.83	0.235	0.99	0.60	0.39	185	77	51	22.0	8.3	16.8
Cape Rodney	3rd	10/68 Bamguina	3.18	0.230	1.45	0.65	0.41	125	42	52	21.0	7.4	14.3
	17th	10/69 Bamguina	2.24	0.148	0.75	1.00	0.31	173	50	71	18.0	4.8	11.0
		9/70 Bamguina	2.63	0.225	0.68	1.02	0.40	145		56	14.5	6.9	12.0
	3rd	9/70 alluvial	3.27	0.325	1.10	0.66	0.39	233	149	68	18.0	10.5	12.3
		9/70 laterite	3.50	0.275	1.10	0.66	0.38	238	280	79	20.5	10.3	14.0

upper parts of the slope. Fertilizer applications were as follows: 300 g 15:15:15 per palm in December, 1968 and 450 g 12:7:7:2 in April and also September, 1970. The 1969 levels of nitrogen and phosphorus were very low, in spite of the fertilizer applied 10 months previously, but the fertilizing in 1970 increased all nutrients except potassium to adequate levels. Lower levels of most nutrients can be seen on the "hillside" samples compared to the "bottom" one.

Cape Rodney. — The observation plot at Banguina was partly sited on an old rubber nursery, and palm growth was very uneven, many being quite poor. 900 g per palm of an NPK fertilizer had been applied in July, 1968, and leaf levels were all adequate by October, except possibly for sulphur. In 1969, however, levels of nitrogen, phosphorus and potassium were all low and would indicate quite marked deficiencies. 1350 g per palm of an NPK fertilizer was applied in May, 1970, and by September nitrogen and phosphorus were adequate, but potassium even lower than

previously. This seems odd in view of the heavy fertilizer application. However, from experience with coconuts in this area (K. A. Handreck, personal communication), high rates of potassium chloride (2 kg per palm) did not raise leaf levels, but increased K levels in the nut water and probably gave a growth response. The high exchangeable Mg to K ratio in the base-saturated soil is probably the reason for this.

The new plots on the two different soils were well established with a good *Pueraria* cover-crop by September, 1970, and leaf levels were high except for potassium.

FLOWERING PATTERNS

The flowering pattern of some of the sites is summarized in *Figures 5 and 6*, for the period when castration was carried out. *Figure 5* shows that the Saiho palms commenced flowering earlier than the other sites. Over 90 per cent of palms were flowering by January, 1969, which was about 19 months

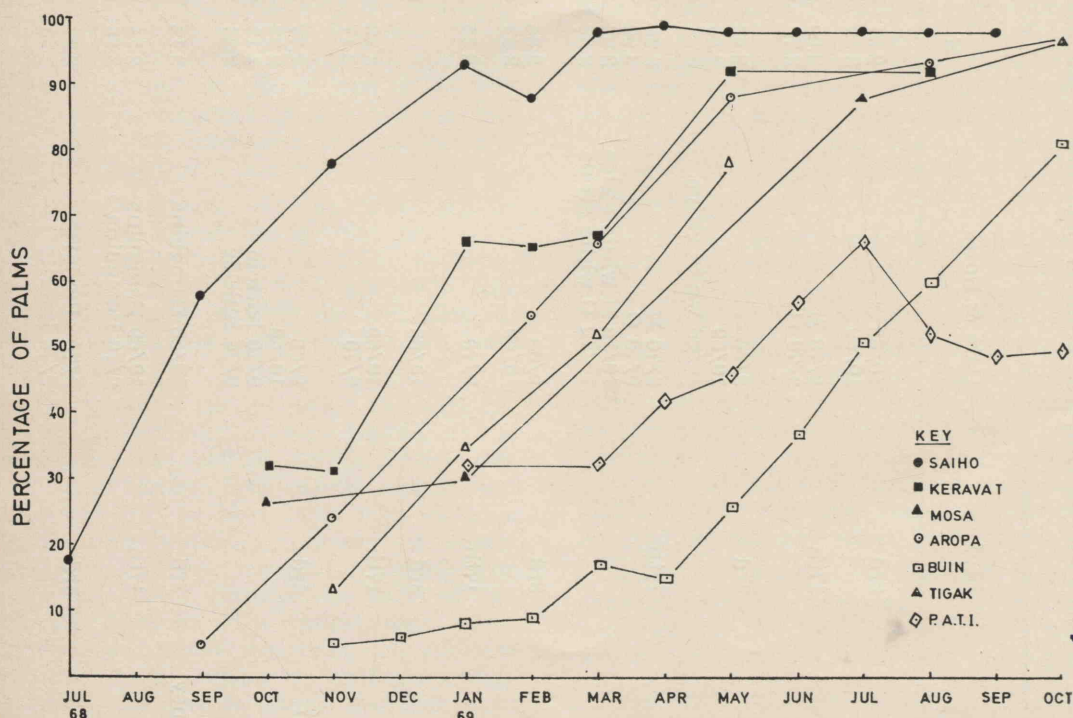


Figure 5. — Percentage of palms from which inflorescences were removed at the times indicated, for seven sites.

after field planting. The main increase in the proportion of palms flowering at all sites except P.A.T.I. occurred at a similar rate, comparing the slopes of the lines in *Figure 5*, but there were large differences between sites when this stage occurred. Thus, Keravat was about $3\frac{1}{2}$ months behind Saiho, Aropa $4\frac{1}{2}$ months, Tigak and Mosa about 6 months and Buin about 10 months. The increase at P.A.T.I. was slower than for the other sites, and broke down after July, 1969. The rate of leaf production was only about two per month there, and this, possibly combined with abortion of some inflorescences, meant that some palms, although they had produced inflorescences previously, over a month did not produce any. In this way, the data given in *Figure 5* are not identical to the percentage of palms "flowering" which would have been carrying inflorescences if castration had not been done.

The changes in sex ratio with time can be seen from *Figure 6*. Initially at all sites most inflorescences produced were males, but after January, 1969 there was a rapid rise in sex

ratio at Saiho, reaching over 90 per cent by September. Aropa followed this pattern closely, but about two months behind Saiho. Bubia (not shown) was similar. The Keravat pattern was initially similar to Saiho, but tapered off at about 60 per cent. This has continued since, with the ratio rising slowly, and many more male inflorescences have been produced there than on the other well-grown blocks. At Tigak (not shown) there was an increase similar to Aropa until May, 1969 when castration ceased, but observations showed that the sex ratio then followed a similar pattern to Keravat. At P.A.T.I. the trend was similar to this, but several months behind again. At Buin, the ratio appeared to be increasing until February, but then dropped right back until May, after which the increase was normal, tapering off at around 90 per cent. However, in the early months there were only a few palms flowering, so the trend is not of much significance. At Mosa there was a long delay until the sex ratio started to rise, but the increase was then rapid, to about 95 per cent in December, 1969. Differences between sources and progenies were small and not consistent between sites.

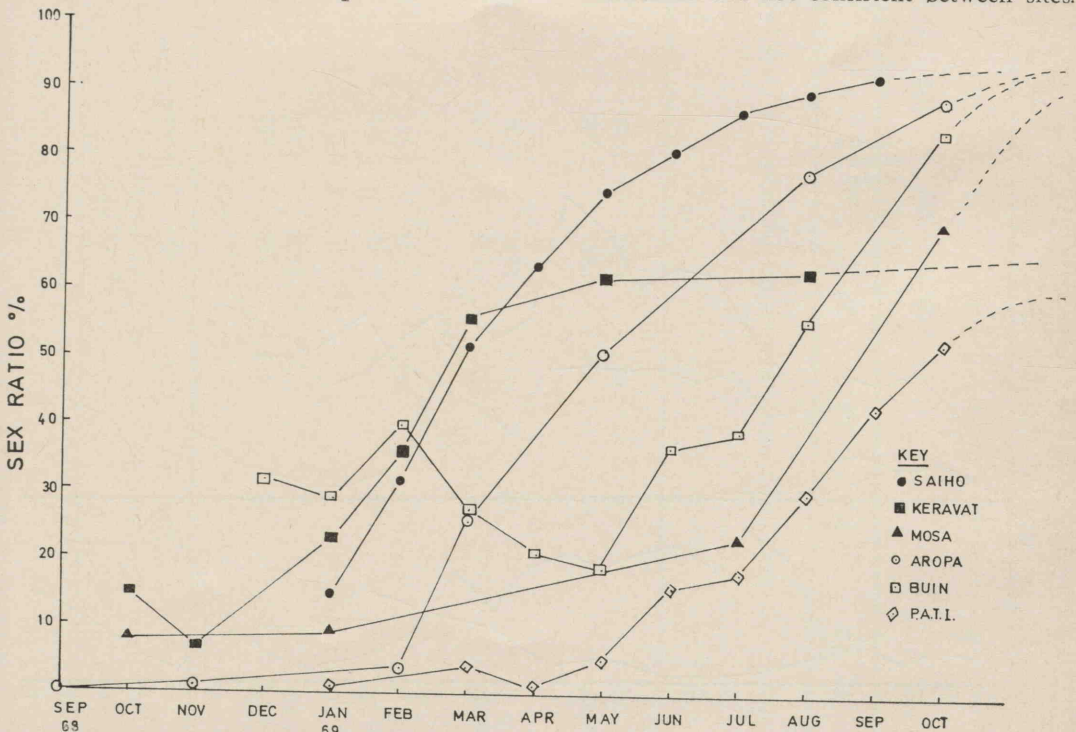


Figure 6.—Sex ratio of inflorescences removed during castration for six sites. Approximate trends after October, 1969 indicated.

YIELD

Figure 7 shows the results of the first year's harvests at three sites, as yield of f.f.b. and proportion of good bunches. Table 11 summarizes results for the two sources at each of the above sites plus Buin with the proportion of good bunches for Mosa and Saiho only. Table 12 gives the approximate male inflorescence production at three of the sites during 1970.

Keravat. — Yields without pollination were moderately good, and came from a large number of small bunches with some pollination and some parthenocarpic development. The fruit set was better than at the other sites, and was due to the lower sex ratio, with more male inflorescences (Table 12). Assisted pollination increased yields greatly to 1500 kg/ha/fortnight, and bunch weights increased to 6.5 kg. This was lower than for pollinated bunches at the other sites, and there was still a considerable number of bunches with inadequate fruit set. The C source palms consistently produced a larger number of bunches than the H source. This result is suspect, and on subsequent

checking of the recording technique it appears that there was some confusion between palms of the four-palm C plots and the six-palm H plots. Later harvests since Table 11 was compiled have shown the expected trend, with the H palms yielding more than the C palms.

Mosa. — The yield and proportion of good bunches at Mosa were very low until October, 1970, indicating very poor natural pollination. With assisted pollination, yields increased to 756 kg/ha/fortnight, considerably lower than for the other sites. The low number of good bunches (38 per cent) explains the poor result, and the standard of assisted pollination was generally not high. There was a period of ineffective pollination in February to March, 1971 due to staff changes. Consistently higher yields were produced from the H source palms, corresponding with their more rapid growth.

Saiho. — Yields without assisted pollination were low and similar to Mosa. High yields with 65 per cent good bunches were recorded for a period of 10 harvests when pollination was effective. After June, 1970, fresh pollen

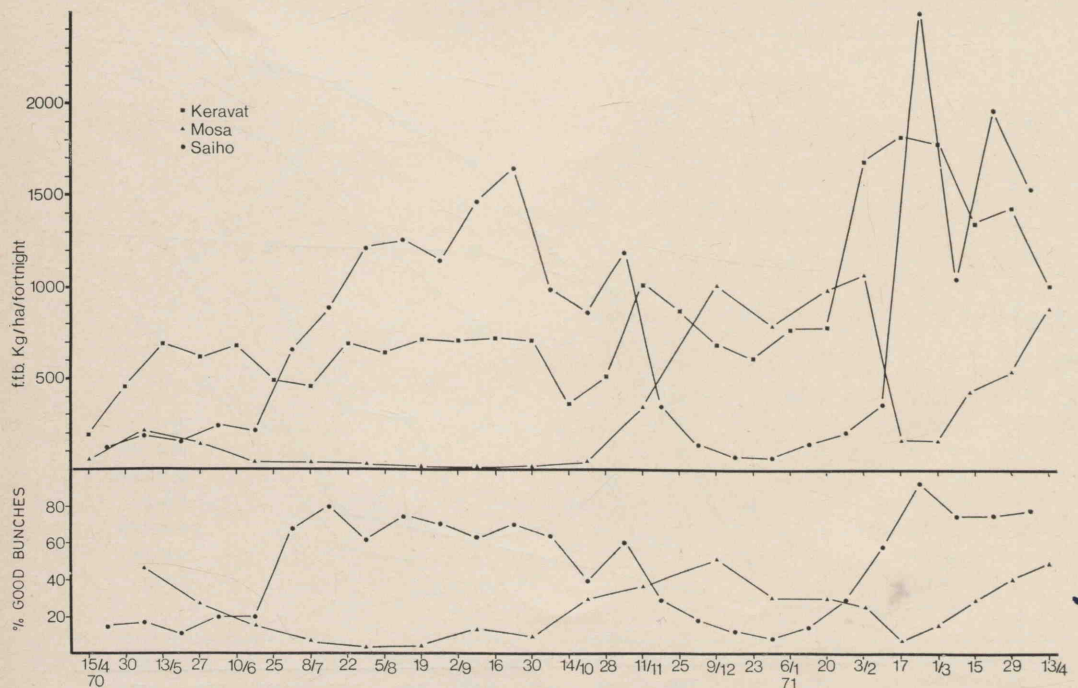


Figure 7.—Fortnightly bunch yields, Kerevat, Mosa and Saiho, and percentage of good bunches.

Table 11. — Summary of yields for the two sources at four sites. Periods of effective assisted pollination separated from unpollinated and ineffective periods.

Site	No. of Harvests	Yields of f.f.b. (kg/ha/fortnight)			Mean Bunch Weight (kg)			% Good Bunches		
		C	H	Mean	C	H	Mean	C	H	Mean
<i>Keravat</i>										
unpollinated	21	703	569	636	3.69	3.73	3.71			
pollinated	6	1728	1310	1519	6.48	6.50	6.49			
<i>Mosa</i>										
unpollinated	12	60	99	79	4.07	3.77	3.92	12.5	20.4	16.4
pollinated	8	655	857	756	7.90	9.45	8.67	34.9	41.0	37.9
<i>Saiho</i>										
unpollinated	11	130	289	210	5.82	6.43	6.12	16.8	25.5	21.1
pollinated	15	1014	1428	1221	8.76	9.64	9.20	61.1	71.8	66.4
<i>Buin</i>										
unpollinated	16	134	257	195	3.1	2.9	3.0			
pollinated	5	977	1185	1081	7.8	7.7	7.7			

Table 12. — Male inflorescence production. Approximate total per hectare per month in 1970, Keravat, Mosa and Saiho

	J	F	M	A	M	J	J	A	S	O	N	D	Mean
Keravat				75	128	107	82	55	52	52	34	25	68
Mosa	23	19	37	39	26	20	18	24	24	32	26	40	27
Saiho	27	22	36	24	12	16	17	11	17	11	15	13	18

was mixed in error with old stored pollen, which meant that viability was lost and subsequent yields severely reduced. Effective pollination was resumed in September, with a dramatic effect on yields in February. The H source palms gave substantially higher yields than the C source over the whole recording period, being 40 per cent greater for the period of effective pollination.

Buin. — Yields during the unpollinated period were similar to those at Saiho and Mosa. Pollinated yields were better than at Mosa due to more effective fruit set, but were not quite as high as at the other sites, probably due to the poorer vegetative growth.

Thus, these preliminary results indicate that yields in the early part of the bearing life of palms will be dominated by effectiveness of pollination, either natural or assisted. Natural pollination was very poor at most sites, probably due to:—

(1) A very high sex ratio, giving few male inflorescences;

(2) Rapid vegetative growth of palms and cover-crop, giving a dense screen which could hinder pollen dispersal in young palms; and

(3) High rainfall and humidity at some sites, also hindering pollen dispersal.

Yields with assisted pollination were very high. 1000 kg/ha/fortnight would give 26 tons/ha/yr, a very high rate of yield for palms in their first bearing year, and "overbearing" (Turner and Bull 1967) may occur if nutrition and management are neglected. If this happens the frequency of pollination rounds can be reduced.

Gray (1969) gives comparable figures for the first year of bearing of *tenera* palms in Malaysia. In his Table 11, the average yield for the first six months without pollination was 360 kg/ha/fortnight (his figures were monthly), less than Keravat but more than at the other sites. For the next four months with assisted pollination (presumably with at least 60 per cent good bunches), yields were 900 kg/ha/fortnight, less than at Saiho, Keravat and Buin, and only slightly more than at Mosa where assisted pollination was not carried out properly.

PESTS AND DISEASES

Generally the effects of pests and diseases were negligible on growth and yield of the palms. However, certain conditions were serious or fatal for individual palms, and may increase in importance in the future.

Pests. — The only pest of note was the New Guinea rhinoceros beetle, *Scapanes* sp. This only caused important damage at Siki, which is a small clearing in the forest. Some palms attacked at other sites (e.g. Mosa and Buin) contracted secondary bud rots and died.

Diseases. — The only appreciable number of palms lost was at Keravat, where five palms died with a condition apparently identical to "stem wet rot" (Turner and Bull 1967). Six other palms contracted "bud rot", similar to the condition of that name described by Turner and Bull, and only three recovered. Only about two of these cases appeared to be initiated by beetle damage. Odd palms with bud and stem rots were found at other sites, and it is possible that the larger number at Keravat may have been due to a build-up of pathogenic organisms in the previous oil palm stand.

CLIMATIC DATA

Available climatic data are given in the Appendix.

Rainfall and Evaporation

Evaporation rates, as measured with U.S. Class A pans at Mosa and Keravat, ranged from 110 to 160 mm per month, with a mean of about 130 mm. Evapotranspiration would probably be slightly lower than this normally. The monthly rainfall at most sites normally exceeded 130 mm, with usually one or two months per year below it. For the Islands sites, two consecutive months below 130 mm were recorded only at Siki in 1970, and this had little effect on soil moisture levels due to the high water storage capacity of the pumice soil (Mendham 1971c). Dry periods were more frequent at the Mainland sites, except for Saiho. Drought symptoms were only observed on the P.A.T.I. palms in September, 1969, after four relatively dry months, and on the sandy soil there. The dry season was similar in severity at Bisianumu in 1969, but the palms did not show such marked effects. This was presumably due to the greater moisture-holding capacity of the soil, and possibly also due to the lower temperatures and hence evapotranspiration rates.

Mosa and Siki have the most distinct wet seasons, with the highest rainfall usually in January or February. Buin can also have heavy rain in the wet season (around August), although this occurred in only two years out of the four recorded. The mean annual rainfall for three full years recorded was 4300 mm, compared to 3300 mm in *Table 1*, and the latter figure is probably too low.

Sunshine

Hartley (1967) states that the areas of the world with highest oil palm yields have at least five hours sunshine per day in all months of the year, and considers that high sunshine levels are an important factor in yield determination. The limited data given in the Appendix show that some sites have months with very low sunshine levels, particularly Mosa, Hoskins, Buin and Murua. Nearly all sites have numerous months with less than four hours per day. Levels in 1970 were generally higher than in 1969 (by about one hour per day on the annual means), and it may be that 1969 was a period of particularly low levels.

Temperature

Data for Keravat and Bisianumu show little seasonal variation. Generally maximum temperatures are about 2 degC lower at Bisianumu than at Keravat, and minimum temperatures only 1 to 2 degC lower. The lowest temperatures were generally recorded during the dry seasons (July to August at both sites), and at Bisianumu the absolute lowest temperature was 16 degC.

DISCUSSION

There appears to have been little or no restriction to the growth or early yield of palms at the better sites, namely Keravat, Aropa, Saiho and Murua. Mosa and Siki are similar to these if the planting delay is allowed for. Moisture shortage did not appear to have occurred at any of these sites. Quite low sunshine levels at some sites did not appear to impede growth, flowering or yield. African workers considered that low sunshine levels gave low sex ratios (Broekmans 1957), but sex ratios increased to high levels on most sites. Lower soil fertility was possibly responsible for lower sex ratios at Keravat and Tigak.

Growth at Bubia was poor initially, then improved, and at the last leaf area recording again appeared to lag behind. Poor drainage appeared to be the main trouble initially. High pH, base saturation and possible potassium deficiency are likely to have caused the poorer growth in the later stages.

The slower growth at Buin in the nursery and in the first year after field planting remains a puzzle, as the palms grew well subsequently. This initially poor growth was reflected in the late flowering and sex ratio changes. Unfortunately no sunshine data are available before late 1968, but observations by local residents indicated that periods of very overcast weather had occurred, and a period of sunny weather in April to June, 1967 appeared to greatly improve growth, as mentioned previously. However, low sunshine levels were also experienced at Hoskins in early 1967 without marked effects on the oil palms. A nutritional deficiency or imbalance is the other possible cause of the trouble, but fertilizers were applied in the nursery and early field stages, and leaf analysis results were generally normal. Initial yields with assisted pollination were good, but it remains to be seen whether these will continue, as coconut yields are very poor in this area.

Growth at Tigak was slower than at the above-mentioned sites, in spite of fertilizer application, and generally adequate leaf nutrient levels. Restricted nutrient uptake is still a possible cause of the poorer growth although the soil also has rather unfavourable physical characteristics. It is a stiff red clay which tends to dry out and crack, and is rather shallow (over coral). These factors probably restrict rooting and hence uptake of nutrients and water. Very poor growth at Katu, initially due to livestock damage, was later almost certainly due to acute potassium deficiency, probably aggravated by the same physical characteristics as at Tigak.

The poor growth and flowering at P.A.T.I. was expected, and was due to both nutrient and moisture shortage. The sandy soil is poor in nutrients, particularly nitrogen, and has a low moisture-holding capacity, and this combined with the likelihood of a marked dry season makes the environment unfavourable for palm growth and yield. The situation is aggravated by the growth of coarse grasses

which are difficult to eradicate on the low fertility soil.

At Bisianumu it has not been possible so far to identify the limiting factors. However, a combination of nutrient deficiencies, lower temperatures and occasional dry spells makes the environment unfavourable. Part of the poor growth was also due to delayed planting and poor nursery treatment.

Thus, on the better soils very good growth and early yields were achieved, and the technical prospects seem favourable for commercial development of the crop in New Britain, Bougainville and the better areas of Papua such as parts of the Northern and Gulf Districts. With the high yields which can apparently be achieved, nutrition by fertilizing will be a very important aspect of research and field practice if development is undertaken. Magnesium deficiency is likely in the Islands region and potassium in the Mainland. Nitrogen may be important also in some areas, as in 1970 leaf levels were mostly not far above 2.5 per cent, whereas in Malaysia a critical level of 2.7 per cent is often used for adult palms.

The H source, *Deli dura* x Sumatra (originally Congo), *pisifera*, should prove very suitable for commercial development. Reduced growth and yield of the C source palms is apparently due to inbreeding, and was rather severe at the better sites such as Aropa and Saiho. Out-crossed types such as the H source are likely to be able to take advantage of the excellent conditions for growth in the better areas, and inbreeding should thus be completely avoided when selecting material for commercial development. The greater susceptibility of the C source palms to magnesium deficiency symptoms and low leaf Mg levels may be due to the greater proportion of Deli in their parentage, as the Deli type apparently has a higher magnesium requirement than the African types (Ollagnier, Ochs and Martin 1970).

Yield recording and collection of other data are continuing on these trials and are required before more definite conclusions can be drawn.

ACKNOWLEDGEMENTS

The author would like to thank Mr A. E. Charles, Chief Agronomist, DASF Konedobu and Dr D. R. Laing, Lecturer in Agronomy,

University of Sydney for advice at many stages of this work. Mr G. A. McIntyre of the CSIRO Division of Mathematical Statistics assisted with analysis of the data.

Dr B. S. Gray and Dr J. J. Hardon selected the trial progenies in Malaysia, and thanks are due to Harrisons and Crosfield (Malaysia) Sdn. Bhd. and Kumpulan Guthrie Sdn. Bhd. for supplying the seed.

Many officers of the Department assisted the author in the establishment and running of these trials. The efforts of Mr J. R. Horne at Saiho were particularly appreciated. Mr H. Gallasch at Keravat, Mr W. Fullerton, Mr R. Frost and Mr J. M. Adams at Buin, Mr M. N. Hunter at Bubia, and Mr A. van Haaren at Bisianumu also assisted greatly by carrying out the programme at those sites.

The leaf samples were analysed by the Chemistry Section, DASF Konedobu, and thanks are due to Mr P. J. Southern, formerly Senior Chemist, and Mr K. A. Handreck, formerly Senior Plant Nutrition Officer, for assisting in interpretation.

Mr J. Aufo of Dami Oil Palm Research Station assisted the author with most of the growth recording.

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(Accepted for publication July, 1971.)

APPENDIX

Climatic Data

(a) Monthly rainfall, in mm

Site	Jan.	Feb.	Mar.	Apr.	May	June	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Total
Keravat													
1967							280	221	285	239	337	252	
1968	296	288	201	425	266	65	147	178	146	163	169	274	2618
1969	309	256	280	281	238	68	258	246	307	216	338	279	3076
1970	271	568	219	251	118	319	215	55	277	284	269	235	3081
Mosa													
1967							149	206	304	252	375	261	
1968	614	662	244	244	155	222	190	183	158	170	103	134	3079
1969	633	752	366	531	197	72	162	146	264	88	344	531	4086
1970	352	1012	398	400	130	72	131	189	259	220	180	758	4101
Siki													
1967							136	121	128	67	191	482	
1968	859	730	286	410	172	228	150	191	194	146	92	383	3841
1969	653	767	417	757	173	80	197	177	288	180	287	492	4468
1970	476	999	493	488	524	52	93	180	237	215	220	604	4581
Aropa													
1967							345	278	104	131	348	198	
1968	268	449	138	187	348	101	392	277	141	171	182	151	2805
1969	106	211	226	299	169	403	347	386	381	251	142	273	3194
1970	167	316	389	310	202	309	156	335	265	267	211	435	3362
Buin													
1967							367	316	171	223	490	182	
1968	205	152	203	330	100	541	710	518	216	440	407	233	4055
1969	338	307	453	274	274	271	453	1165	870	520	158	289	5372
1970	269	384	380	209	286	375	297	208	228	471	94	256	3457
Tigak													
1967							205	319	228	195	234	418	
1968	355	266	192	461	439	54	190	277	141	443	253	338	3409
1969	297	131	436	298	97	236	224	348	331	359	405	496	3658
1970	275	409	666	206	188	246	168	138	136	278	164	362	3236

Site	Jan.	Feb.	Mar.	Apr.	May	June	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean
Bubia													
1967							506	301	257	191	143	232	
1968	264	147	76	103	270	271	274	314	357	246	110	325	2757
1969	165	122	322	231	184	287	291	480	346	471	263	176	3338
1970	105	182	278	203	382	283	418	345	302	481	363	188	3530
Saiho													
1967							214	193	309	498	468	574	
1968	528	424	329	310	199	111	221	171	487	230	701	426	4137
1969	307	589	595	340	339	203	215	224	66	235	377	365	3855
1970	159	377	619	405	487	238	234	253	303	471	425	380	4351
P.A.T.I.													
1967							133	145	84	350	148	657	
1968	205	261	137	265	163	47	153	150	58	96	333	264	2132
1969	389	349	323	344	266	112	12	122	55	93	233	306	2604
1970	433	323	320	316	328	135	129	224	250	284	213	180	3135
Murua													
1967							428	447	127	242	34	132	
1968	267	150	59	51	230	198	245	274	518	259	61	170	2492
1969	704	203	80	56	163	353	441	587	127	242	39	132	3127
1970	188	151	200	302	526	258	448	475	284	466	155	272	3725
Bisianumu													
1967							81	151	164	129	94	167	
1968	218	278	280	159	218	33	102	205	156	201	49	321	2220
1969	389	443	215	429	103	79	12	30	97	176	206	266	2445
1970	200	475	344	237	154	89	154	152	246	442	231	358	3082
Cape Rodney													
1967							545	275	261	322	95	43	
1968	240	76	84	170	215	75	158	326	255	201	25	111	1936
1969	361	149	118	704	227	388	152	150	109	197	39	133	2727
1970	348	286	353	70	194	176	325	423	178	488	316	98	3255

(b) Jordan sunshine recordings, in hours per day

Site	Jan.	Feb.	Mar.	Apr.	May	June	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean
Keravat													
1968							5.7	4.6	7.0	5.9	5.5	5.2	
1969	3.2	3.5	4.5	4.2	6.0	7.2	5.9	5.1	3.9	5.3	5.5	3.6	4.8
1970	5.3	4.3	4.7	5.3	5.3	4.6	5.6	6.0	5.8	5.9	6.5	4.2	5.3
Mosa													
1968							4.0	6.2	6.1	5.2	5.4	5.1	
1969	2.9	1.0	3.2	1.2	4.0	4.7	2.8	2.6	3.8	5.7	5.8	4.0	3.5
1970	3.7	3.4	3.7	4.8	4.9	5.3	5.2	6.2	5.4	4.8	6.6	3.3	4.8
Hoskins													
1968									6.3		5.8		
1969	3.3	1.9	6.0	3.0	5.4	4.0	3.3	3.6	4.0	7.1	6.5	5.3	4.5
1970	5.7	3.6	5.1	6.1	5.1	5.9	6.4	7.5	6.2	5.9	5.7	2.9	5.5
Aropa													
1969	4.2	4.4	6.3	5.4	6.6	6.4	6.5	4.6	6.3	6.0	6.4	5.0	5.7
1970	7.1	4.5	6.2	6.3	6.1	5.1	6.4	5.7	6.4	6.5	7.1		6.1
Buin													
1968										4.3	2.8	3.7	
1969	2.8	3.5	4.0	4.6	4.6	4.2	3.7	2.1	2.6	4.5	5.7	3.9	3.8
1970	6.0	4.8	4.2	5.0	5.4	4.3	5.6	5.7	6.1	6.5	6.2	5.5	5.4
Tigak													
1968									6.3	5.6	4.8	4.7	
1969	4.4	5.3	4.3	4.2	6.5	5.2	3.4	4.3	3.0	4.7	4.6	3.1	4.4
1970	4.7	4.3	3.7	5.3	6.1	5.1	6.5		6.6	5.9	7.0		5.5
Bubia													
1970	7.2	6.0	5.1	6.5	5.1	3.7	3.9	5.6	5.8	4.3	7.4	5.0	5.5
Saiho													
1968											4.5	3.9	
1969	4.6	4.9	5.8	5.1	5.9	5.4	5.8	5.1	3.4	4.9	4.3	5.4	5.1
1970	7.2	5.3	5.2	6.1	5.8	6.3	4.8	6.3	5.7	5.3	6.6	5.4	5.8
P.A.T.I.													
1968										4.4	4.4	4.2	
1969	4.3	3.7	4.3	4.1	5.9	4.8	5.7	5.4	4.1	5.1	4.9	4.6	4.7
1970	6.7	4.8	5.2	6.3	5.7	5.9	4.7	6.9	6.9	5.2	5.6	4.5	5.7
Murua													
1968										3.9	5.6		
1969	5.1	3.2	5.9	5.2	3.3	2.9	2.7	3.2	1.8	4.5	4.4	5.2	3.9
1970	7.7	4.9	5.7	6.2	4.8	2.6	2.6	2.3	4.7	5.6	6.4	5.9	5.0
Bisianumu													
1969	3.3	3.9	4.3	3.7	5.8	3.2	4.6	2.9	3.7	3.1	5.6	5.2	4.1
1970	6.6	4.2	5.3	5.6	4.2	5.7	5.3	4.3	4.8	4.8	5.7	5.0	5.1

(c) Campbell Stokes sunshine recordings for three sites, in hours per day

Site	Jan.	Feb.	Mar.	Apr.	May	June	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean
Keravat													
1967	4.2	5.2	3.8	5.5	6.2	6.7	5.8	5.5	7.3	6.1	4.9	5.7	5.6
1968	4.3	3.3	7.3	4.8	6.4	6.8	5.6	5.9	7.2	6.7	5.2	5.0	5.7
1969	3.8	4.0	5.2	4.6	7.0	6.9	5.4	5.1	3.3	5.2	5.6	3.1	4.9
1970	5.1	3.9	4.1	5.1	5.6	4.9	6.0	6.4	5.8	6.4	6.8	3.8	5.3
Mosa													
1968	2.2	2.7	6.5	5.1	6.4	5.7	4.1	5.4	6.0	4.0	4.5	3.4	4.7
1969	3.1	1.2	3.0	1.2	4.4	4.6	3.5	3.8	3.8	5.8	5.7	3.5	3.6
1970	4.4	3.4	3.2	5.5	5.1	4.8	5.9	7.5	5.4	4.9	6.3	3.3	5.0
Bubia													
1967	4.6	6.4	5.5	7.1	5.1	6.4	4.2	4.3	5.6	4.6	7.9	7.4	5.8
1968	5.1	4.6	6.5	6.9	6.2	4.9	3.1	4.9	6.0	5.9	6.0	6.9	5.6
1969	6.3	5.1	5.9	6.7	7.1	4.8	4.1	4.5	4.4	5.4	7.0	5.7	5.6
1970	7.2	5.7	5.1	6.2	5.2	3.5	3.6	5.7	6.3	5.5	7.0	5.2	5.5

(d) Monthly mean maximum and minimum temperatures for two sites

Site	Jan.	Feb.	Mar.	Apr.	May	June	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Mean
Maximum temperatures, degC													
Keravat													
1969		30.6	30.9	30.9	32.5	32.1	31.4	31.0	30.8	32.2	31.9	28.0	31.1
1970	31.0	31.1	31.1	31.4	32.0	31.5	31.1	31.7	31.6	31.8	32.0	30.9	31.4
Bisianumu													
1969		27.8	28.9	27.8	29.5	27.8	27.8	29.5	28.9	29.5	30.6	28.9	28.8
1970	30.0	28.9	29.5	30.0	28.9	28.9	27.8	28.4	29.5	29.5	30.0	28.4	29.1
Minimum temperatures, degC													
Keravat													
1969		22.7	22.9	23.0	22.4	22.0	21.8	20.9	21.5	21.2	21.7	22.3	22.0
1970	21.7	22.6	22.6	22.5	22.1	21.7	21.0	20.8	21.4	22.0	21.6	22.3	21.9
Bisianumu													
1969		21.1	21.1	21.7	21.7	21.1	19.5	20.0	20.0	21.1	20.6	21.1	20.8
1970	21.1	21.1	21.1	21.1	21.1	20.0	19.5	20.6	21.1	21.1	21.1	21.1	20.8