

COCONUT SEEDLING ESTABLISHMENT AS AFFECTED BY SEEDLING DEVELOPMENT AT TRANSPLANTING AS WELL AS AGRONOMIC PRACTICES

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ABSTRACT

Different physiological ages at transplanting, maintenance systems, depth of planting and fertilizer use were studied in an experiment with three replications in time. The location was a pumice ash soil which had previously been subjected to a period of cropping, on the Gazelle Peninsula of New Britain.

Results were assessed through regular height and frond production measurements and fresh weight of the top growth of the seedlings, determined at various stages. Frond samples for chemical analyses were also collected.

At an equal time from nursery planting, transplants with up to four leaves had made better growth than "crow's beak" transplants with older transplants suffering considerable transplanting shock. Cost factors tend to make growth at an equal time from transplanting more important than that of growth at an equal time from nursery planting and indications were that older seedlings retained their advantage at least partially. A method which appears to combine minimum transplanting shock with relatively low maintenance costs is mentioned.

The importance of controlling weed growth is clearly demonstrated. Indications are that moisture stress and light availability as well as soil nutrients are of utmost importance in seedling establishment and development. Weed competition for sulphur and probably nitrogen is indicated with complete weed control acting as a substitute for fertilizer.

There was a suggestion that shallow planting was preferable under clean weeding and regular slashing, while deeper holes were favoured where infrequent slashing was used; and that "crow's beak" transplants performed better under conditions of deep planting while the older stages preferred shallow planting. These indications were not taken as confirmed.

Rainfall and sunlight subsequent to field planting were shown to be of considerable importance in successful establishment.

INTRODUCTION

Weed Competition

Although it is universally recognized that weed competition retards coconut seedling development there is a lack of quantitative information available on this subject. Cook (1936), in the Philippines, reported that coconut plantings infested with *Imperata cylindrica* reached bearing two years later than others and also that unrestricted growth of weeds or cover crops was de-

leterious. The desirability of maintaining a properly managed leguminous cover crop to minimize weed infestation and improve the nitrogen status of the soil has been frequently expressed.

Weed control by clean weeding was compared with regular and infrequent weed slashing in the present trial.

Planting Depth

Menon and Pandalai (1958) quoted planting depth in India as varying from 0.6 to 0.75 metres, in Ceylon from 20 to 30 centimetres

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while in Malaya the top of the nut is left exposed at ground level. Practices in Papua and New Guinea vary. Many estates favour deep planting, claiming that this stabilizes seedlings as well as reduces the likelihood of palm weevil (*Rhyncophorus bilineatus*) damage by preventing the weevil from entering through exposed rootlets in the "apron" region (Smee 1965). It is probable that deep planting holes are justified in areas of sandy soil or frequent strong winds. Unfortunately planting is often inexpertly conducted without care being taken to surround the seedlings with top soil.

Two depths of planting were compared in the present trial.

Stages of Transplanting

Stages of transplanting vary from region to region and often from plantation to plantation within the same locality. Frequently planting is approached in a rather haphazard manner with little care exercised in controlling the size of seedlings at transplanting. It is a common observation that large seedlings or even those with as few as five to seven fronds suffer considerable shock at transplanting and a subsequent set-back in growth. Different physiological stages of transplanting were compared to ascertain the significance of any transplanting shock.

Fertilizer Use

Fertilizing of seedling coconuts is seldom practised in Papua and New Guinea although beneficial effects have been demonstrated on occasions. It was felt that a response was likely to nitrogen, and possibly sulphur, on the volcanic ash soils of the Gazelle Peninsula of New Britain, especially on those that had undergone previous cropping. A compound fertilizer (NPK) and sulphur were applied.

Climatic Variations

Three replications were planted at three-month intervals to note any effects of climatic variation on seedling establishment.

This paper presents results of a trial at Keravat which studied the importance of the above factors and their interactions. Treatments included three methods of weed control, two planting depths, four transplanting stages, use of fertilizer and the effects of climatic variation on establishment.

A progress report of this trial was presented at the South Pacific Commission Technical Meeting on Coconut Production at Rangiroa, French Polynesia in August 1967 (Sumbak 1968).

EXPERIMENTAL METHODS

Replicates in time (termed series 1, 2 and 3) were field planted in November, 1965, February, 1966 and May, 1966.

Nursery plantings for each series were staggered so as to have ready seedlings at the "crow's beak" (that is, time at which the shoot emerges through the husk), two-leaf stage, four-leaf stage and seven-leaf stage for simultaneous plantings. It was estimated that these respective stages would be reached about 12, 21, 28 and 38 weeks after nursery planting. These stages are abbreviated to CB, 2L, 4L and 7L respectively in the tables of results. A few somewhat anomalous nursery plantings occurred and these will be referred to later.

As the experiment was to last for only about two years, a 15 ft square spacing was thought sufficient to prevent serious inter-seedling competition.

Three maintenance treatments were used. The pretreatment cover consisted mainly of *Sorghum propinquum* and some kunai (*Imperata cylindrica*), both of which were somewhat chlorotic.

Maintenance treatments were as follows:—

- (i) Clean weeding, that is, the ground kept virtually bare of weed growth (this necessitated hand weeding at intervals of about 24 days);
- (ii) Regular grass slashing, that is, grass cutting about every 20 days. This is probably more intensive than the usual practice on well-run estates in Papua and New Guinea; and
- (iii) Infrequent grass slashing, that is grass cutting about every 9 weeks which approximates the practice on most estates and some village groves.

The three maintenance methods will be abbreviated in the tables of results as C.W., R.S., I.S., respectively.

Each series comprised three main plots for comparison of maintenance systems. These maintenance plots were split for comparison of

the four transplanting stages. The transplanting subplots comprised the four possible combinations of two planting depths with and without fertilizer treatments. Each sub-subplot contained four seedlings. The fertilizer treatment (designated +F and -F in the tables of results) consisted of four oz of NPK fertilizer and one oz of sulphur soon after transplanting followed by the same dose three months later. Thereafter an application at double the previous rate was given at six-monthly intervals. Two planting depths were used. In shallow planting, seedlings were planted with the top of the nut just exposed at ground level, while in deep planting, seedlings were set in open holes with the nut just covered with soil but 12 to 15 in below the normal ground surface. No attempt was made to fill the holes in later, although filling tended to occur as the sides of the holes crumbled with time.

Seedling heights (height of the newest fully emerged frond) and frond production were recorded regularly for 18 months after transplanting. Fresh weights of the above ground portion of each seedling were measured at an equal age after nursery planting for series 1 and 2 and at 18 months after transplanting for series 3.

Foliar samples from the first and fourth fronds were taken 15 months after transplanting for all series.

RESULTS

General

The various maintenance systems had a definite effect on the botanical composition of the weed population. Clean weeding virtually eliminated grasses except for patches of couch (*Cynodon dactylon*) and gave rise to several types of "soft" weeds. Regular slashing resulted in kunai becoming dominant and centro (*Centrosema pubescens*) common. Infrequent slashing increased the proportion of kunai although *Sorghum propinquum* was still dominant.

Interpretation of results was complicated considerably by the deaths of substantial numbers of seedlings and the weakening of others by fungal infestations. Some of the treatments (for instance the use of fertilizer) may have influenced susceptibility to fungal damage. However, considerable variation in fungal damage between seedlings in the same sub-subplots suggests that genetical make-up is of importance. Subsequent trials (unpublished) have suggested that seedling age influences susceptibility to fungal damage.

Table 1 summarizes numbers of missing seedlings 18 months after transplanting. An overall loss of 11.8 per cent was recorded.

Table 1.—Total numbers of missing seedlings 18 months after transplanting. Each series x maintenance reading represents misses from a total of 16 seedlings

Treatment					Series 1	Series 2		Series 3		Total	
C.W.	CB	....	....	....	4		3		3	10	
	2L	....	....	....	3		0		2	5	
	4L	....	....	....	1		1		3	5	
	7L	....	....	....	0		1		1	2	
R.S.	CB	....	....	....	0		3		1	4	
	2L	....	....	....	1		1		0	2	
	4L	....	....	....	2		1		6	9	
	7L	....	....	....	3		3		2	8	
I.S.	CB	....	....	....	0		1		1	2	
	2L	....	....	....	3		2		2	7	
	4L	....	....	....	2		0		5	7	
	7L	....	....	....	3		0		4	7	
TOTAL		....	....	....	22		16		30	68	
Summary											
	CB				16	C.W.	22	Fertilized	26	Deep	30
	2L				14	R.S.	23	Unfertilized	42	Shallow	38
	4L				21	I.S.	23				
	7L				17						
TOTAL					68		68		68		68

It is difficult to deduce anything concrete from these figures. Series 3 showed the greatest number of misses (15.6 per cent) probably because of less favourable conditions at establishment which may have rendered seedlings more liable to fungal damage. Nothing conclusive can be said about transplanting stages in relation to survival, although it is probable that under poor establishment conditions the more advanced seedlings are more liable to suffer than the younger ones.

Maintenance treatments had no obvious influence on seedling survival. Fertilizer additions appeared to decrease the incidence of deaths and deep planting had a similar effect.

Seedling Growth

Tables 2 and 3 illustrate the more outstanding treatment effects. Individual treatments and their interactions are discussed subsequently in more detail.

Height measurements indicated a good response to clean weeding with a relatively larger response to fertilizer where maintenance was poor. Transplanting shock was considerable but, certainly under clean weeded conditions, less than growth made during additional periods in the nursery. Fresh weights, a better index of growth than height measurements, showed the advantages of good maintenance and indicated a

relatively greater response to fertilizer where maintenance was poor. Generally the longer seedlings are left in the nursery the greater the setback to growth experienced at transplanting. The relatively poor average weights of "crow's beak" seedlings under clean weeding was attributed largely to a high proportion of deaths, apparently unrelated to treatment, under these conditions. The poor average of the fertilized "crow's beak" seedlings in the infrequent slashing treatment was attributed partially to the same cause.

Time of Transplanting

Table 4 shows the actual leaf number and age per seedling at field planting for the three series. Seedlings in series 2 were older than either series 1 or 3 and hence this affected comparisons. It is noted that the actual leaf numbers of treatments designated as two-leaf and four-leaf were considerably higher than planned.

Climatic variations over the period of establishment would appear to have had little influence on leaf production as the considerable differences in leaf number at transplanting between the series persisted.

Although well below series 2 and 3 at transplanting, seedlings in series 1 were, at nine months after transplanting, significantly taller than those in series 2 (Table 5). Records of

Table 2.—Average seedling heights (ft) 18 months after transplanting

Transplanting Stage				Clean Weeding		Regular Slashing		Infrequent Slashing		Average	
				+F	—F	+F	—F	+F	—F	+F	—F
CB	....	....	....	6.7	7.6	8.0	6.0	6.7	5.8	7.1	6.5
2L	....	....	....	9.7	8.5	9.1	5.8	7.8	4.2	8.9	6.2
4L	....	....	....	11.0	8.5	8.8	4.3	8.3	4.9	9.4	5.9
7L	....	....	....	11.7	10.0	7.9	6.7	8.4	5.0	9.3	7.2
Average	....	....	....	9.8	8.7	8.5	5.7	7.8	5.0	8.7	6.5

Table 3.—Average seedling fresh weights (lb) at an equal age from nursery planting

Transplanting Stage				Clean Weeding		Regular Slashing		Infrequent Slashing		Average
				+F	—F	+F	—F	+F	—F	
CB	....	....	....	55.0	72.6	74.3	35.6	16.8	24.4	46.6
2L	....	....	....	102.6	92.2	72.0	28.3	45.2	9.5	58.3
4L	....	....	....	90.6	48.6	48.5	16.9	18.6	13.4	39.4
7L	....	....	....	74.4	44.0	28.3	19.6	19.3	9.0	32.4
Average	....	....	....	80.7	64.3	55.8	25.3	24.9	14.1	....

Table 4.—Average leaf numbers and age (weeks) at transplanting

Transplanting Stage			Series 1		Series 2		Series 3		Average	
			Age	No.	Age	No.	Age	No.	Age	No.
CB	....	...	12.0	....	16.5	2.15	11.0	....	13.2	0.72
2L	....	....	20.5	3.54	24.0	4.21	22.0	3.90	22.2	3.88
4L	....	....	27.5	4.42	32.0	5.71	29.0	5.56	29.5	5.23
7L	....	....	38.0	7.04	42.0	7.69	39.0	6.60	39.7	7.11

rainfall and sunlight suggest that these factors were of importance in establishment. *Figures 1 and 2* illustrate rainfall and sunlight on a cumulative basis for the first 100 days after transplanting for each series. Relatively high sunlight combined with low rainfall initially would have considerably hindered establishment in series 3. This was followed by a period of very low sunshine from the 35th to the 87th day during which a daily average of only 2.11 hours of sunshine was recorded. It is also noteworthy that the average daily sunlight for series 1, 2 and 3 over the first 100 days was 6.05, 4.93 and 3.93 hours respectively. A good correlation with height is noted.

Soil factors may also have contributed to series differences, as the three series also corresponded to spacial replications.

Maintenance

Table 6 shows average heights, cumulative leaf numbers and seedling weights under the three maintenance systems.

Eighteen months after transplanting, clean weeding was clearly superior while regular grass cutting was substantially ahead of infrequent slashing.

A significant maintenance x series interaction for seedling height nine months after transplanting stemmed mainly from infrequent slashing being ahead of clean weeding in series 3. This

is not considered a real indication and probably resulted from the clean weeded plots having five misses against one for the infrequently slashed, which was probably a chance effect. The trend was reversed in the height measurements at 18 months.

Plates 1, 2 and 3 demonstrate the relative merits of the three maintenance systems.

Transplanting Stages

Significant differences in height increment between the different transplanting stages three months after transplanting are shown in *Table 7*. These figures do not present a true picture of transplanting shock as the vertical growth rate of younger transplants would be faster at this stage regardless of any treatment. Growth rates between the "crow's beak" and seven-leaf stages deduced from records of heights at transplanting are shown. It appears as if transplanting had little effect on the "crow's beak" transplant but considerable effect on older seedlings.

A stages x series interaction occurred through seedlings in series 2 designated as "crow's beak" actually being at the two leaf stage and so showing slower growth and series 3 showing poorer growth than series 1 for all stages except "crow's beak". The poor growth in series 3 can probably be attributed to less favourable conditions following transplanting.

Table 5.—Average seedling heights (ft), cumulative leaf numbers and fresh weights

Series	Height			Leaf Number			Fresh Weight Equal time from nursery planting
	0 months	9 months	18 months	0 months	9 months	18 months	
1	2.01	4.93	8.32	3.74	8.46	12.97	50.5
2	2.90	4.69	7.72	4.94	9.82	15.67	37.9
3	2.41	3.95	6.67	4.02	8.88	13.90	....
Least significant difference	5 per cent	0.47	Not significant		0.44	1.21	Not significant
	1 per cent	0.78			0.73	2.01	

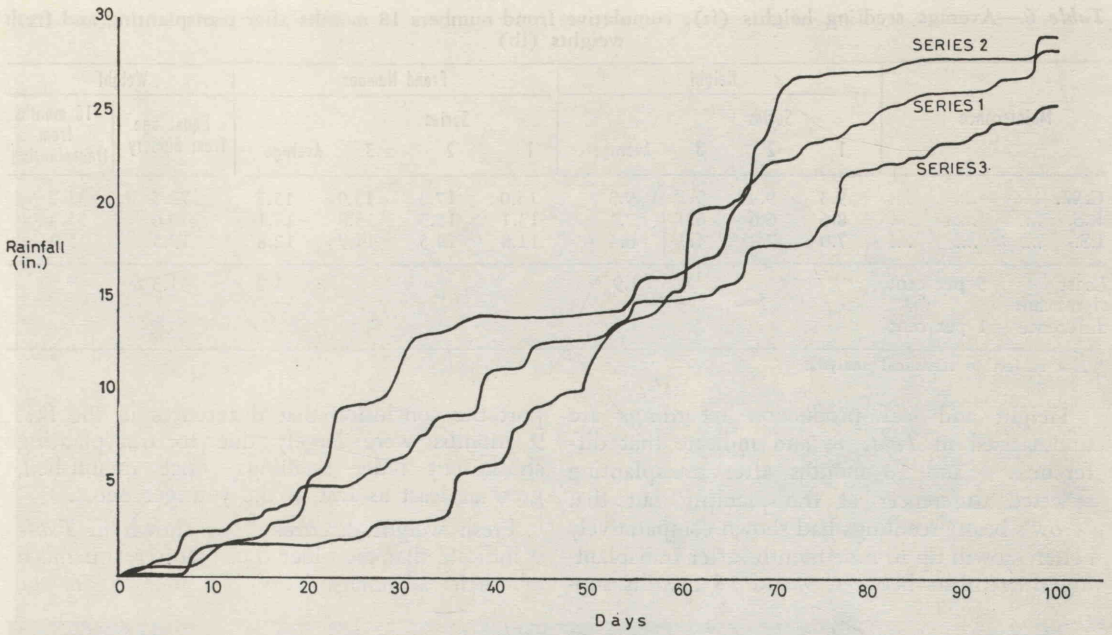


Figure 1.—Cumulative rainfall over first 100 days after transplanting

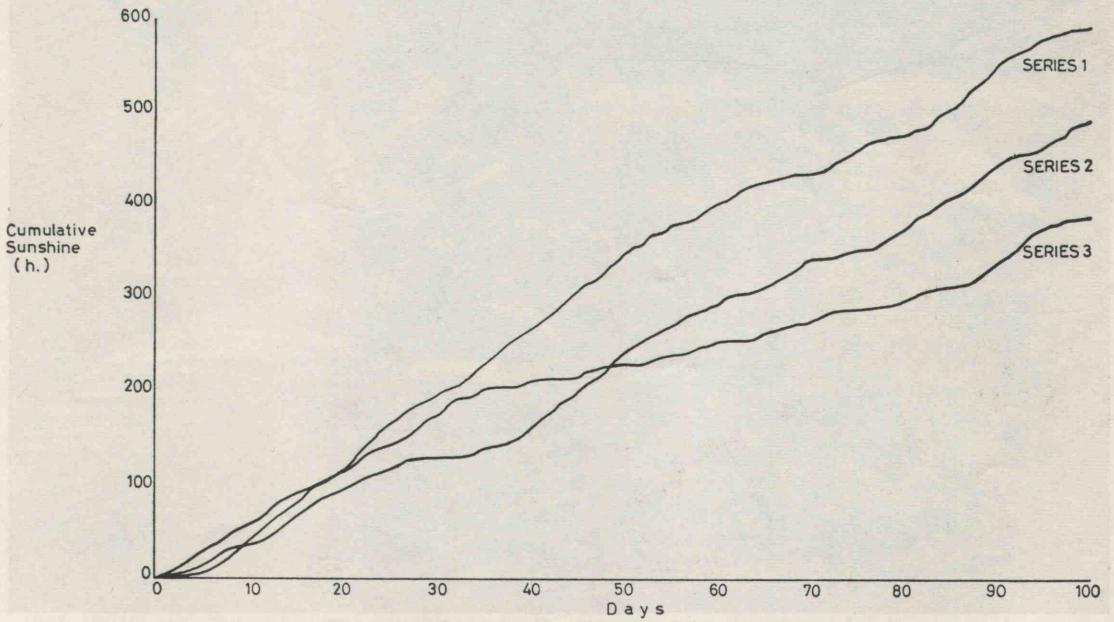


Figure 2.—Cumulative sunshine over first 100 days after transplanting

Table 6.—Average seedling heights (ft), cumulative frond numbers 18 months after transplanting and fresh weights (lb)

Maintenance				Height				Frond Number				Weight	
				Series				Series				Equal age from nursery	18 months from transplanting
				1	2	3	Average	1	2	3	Average		
C.W.	....	....	....	9.3	9.4	9.1	9.3	14.0	17.3	15.9	15.7	72.5	31.7
R.S.	....	....	....	8.6	6.6	6.0	7.1	13.1	15.3	13.8	14.1	40.6	11.4
I.S.	....	....	....	7.0	7.2	4.9	6.4	11.8	14.5	11.9	12.8	19.5	5.9
Least significant difference	5 per cent						1.9				1.2	31.3	*
	1 per cent						3.1				2.0	72.2	

* Not subject to statistical analysis.

Height and leaf production recordings are summarized in Table 8, and indicate that differences 9 and 18 months after transplanting reflected differences at transplanting but that "crow's beak" seedlings had shown comparatively better growth up to nine months after transplanting. Increments between 9 and 18 months sup-

port the conclusion that differences in the first 9 months were largely due to transplanting shock but older seedlings, once established, grew at least as fast as the younger ones.

Fresh weight determinations shown in Table 9 indicate that the older transplants retain much of their advantage after 18 months in the



Plate I.—Clean-weeded seedlings (right) and regulary slashed seedlings about 16 months after transplanting



Plate II.—Regularly slashed seedlings (right) and infrequently slashed seedlings about 16 months after transplanting

field while recordings of the various transplanting stages at equal ages from nursery planting effectively revealed the extent of set-back at transplanting. At first glance the apparent better performance of the two-leaf transplants over the "crow's beak" ones is surprising. However, the large number of deaths in the latter transplants particularly under clean weeding where the best growth could have been expected largely explains the discrepancy. *Table 9* also shows average weights of surviving seedlings for the various transplanting stages.

Figures 3 and 4 illustrate a stages x maintenance interaction. The relatively poor performance of "crow's beak" transplants under clean weeding could largely be attributed to about 20 per cent misses in this treatment combination. It appeared that only under clean weeding was

transplanting shock sufficiently slight for the more advanced stages to retain much of the lead they had attained in the nursery. Nothing concrete could be determined by examining growth in the second nine months after transplanting except that clean weeding gave best growth and regular slashing was superior to infrequent slashing.

Fertilizer

As expected, there was no detectable response to fertilizer three months after transplanting. *Table 10* shows that most of the response to fertilizer occurred in the second nine months after transplanting.

Although a response to fertilizer was evident nine months after transplanting, a much greater response was shown in the second nine months.

Table 7.—Total and average height increments (inches) three months after transplanting and estimates of growth in the nursery for the same period

Transplanting Stage				Series 1	Series 2	Series 3	Total	Average per Seedling	Average per Seedling in Nursery
CB	....	....	....	1340	997	1593	3930	27.3	32.5
2L	....	....	....	588	349	162	1099	7.6	16.2
4L	....	....	....	340	187	154	681	4.7	11.2
7L	....	....	....	280	80	91	451	3.1	N.A.
Least significant difference	5 per cent						622	4.3	
	1 per cent						852	5.9	

Fresh weight determinations and height measurements shown in *Tables 11 and 12* indicate a substantial response to fertilizer. Much less response was shown to fertilizer from clean weeded seedlings and very poor growth of unfertilized seedlings under regular or infrequent slashing was indicated especially in the second nine months where growth almost ceased.

Height measurements shown in *Table 13* indicated a fertilizer x stages interaction which stemmed from the "crow's beak" stages' failure to respond to fertilizer. A response in the second nine months would be expected and this is indicated when growth in this period is considered. Weight determinations shown in *Table 14* failed to show any interaction between fertilizer and



Plate III.—Clean-weeded seedlings (right) and infrequently slashed seedlings about 19 months after transplanting

Table 8.—Average seedling heights (ft) and leaf numbers

Transplanting Stage			Height			Growth			Number of Fronds			Growth		
			1*	2*	3*	4*	5*	6*	1*	2*	3*	4*	5*	6*
CB	....	....	0.5	4.2	6.8	3.7	6.3	2.6	0.72	7.51	12.82	6.79	12.10	5.31
2L	....	....	2.5	4.5	7.6	2.0	5.1	3.1	3.88	8.76	14.28	4.88	10.40	5.52
4L	....	....	3.1	4.6	7.6	1.5	4.5	3.0	5.23	9.53	14.03	4.31	8.81	4.50
7L	....	....	3.7	4.8	8.3	1.1	4.6	3.5	7.10	10.42	15.59	3.32	8.49	5.17
Least significant difference	5 per cent		0.3	Not significant					0.33		0.97			
	1 per cent		0.5						0.46		1.35			

* 1 = at transplanting.

2 = 9 months after transplanting.

3 = 18 months after transplanting.

4 = growth between transplanting and 9 months.

5 = growth between transplanting and 18 months.

6 = growth between 9 and 18 months after transplanting.

Table 9.—Average seedling weights (lb) of the various transplanting stages

Transplanting Stage				Equal age from nursery planting					
				Total weight Series 1	Total weight Series 2	Total	Average per Seedling	Average per Surviving Seedling	Average per seedling 18 months from transplanting
CB	....	....	....	2429	2046	4475	46.6	57.4	11.4
2L	....	....	....	3622	1975	5597	58.3	65.6	16.3
4L	....	....	....	1996	1788	3784	39.4	43.2	16.8
7L	....	....	....	1642	1470	3112	32.4	36.3	20.9
Least significant difference				5 per cent			10.1		
				1 per cent			13.6		

transplanting stage but response to fertilizer in the "crow's beak" transplants was considerably less than for other stages.

Plates 4 and 5 show fertilized and unfertilized seedlings.

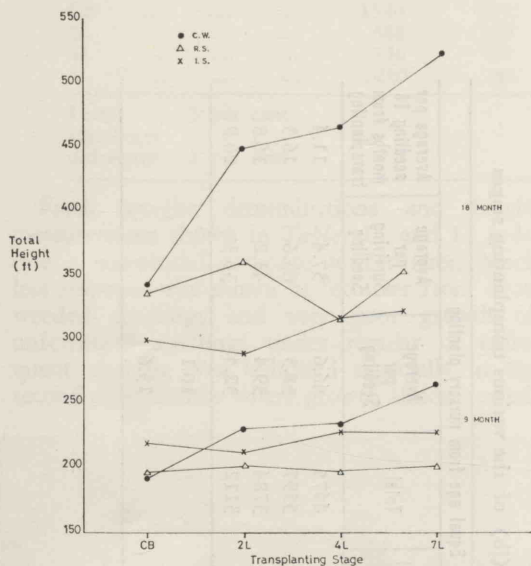


Figure 3.—Heights of transplanting stages under various maintenance systems nine and 18 months from field planting

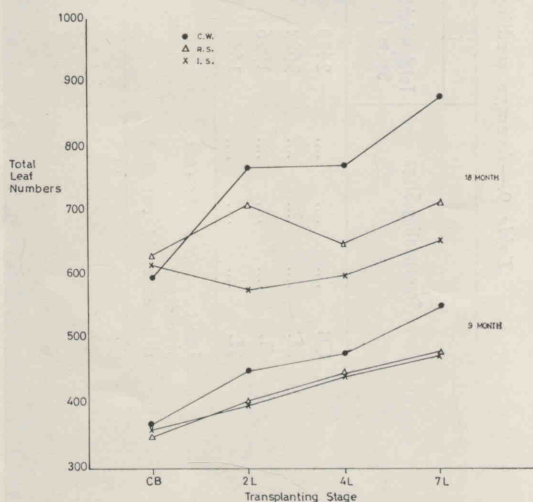


Figure 4.—Fron production of transplanting stages under various maintenance systems nine and 18 months from field planting

Planting Depth

A number of interactions was evident. Table 15 shows shallow planting to be ahead of deep planting under clean weeding and regular slashing with the reverse applying under infrequent slashing nine months after transplanting. However, this was not substantiated by later recordings.

Height measurements and fresh weight determinations shown in Tables 16 and 17 respectively, suggest that "crow's beak" had performed better under conditions of deep planting than when shallow planted while the reverse applied to the other stages. Heights, particularly nine months after transplanting indicated that stages were about equal under deep planting but ran in order of age under shallow planting—this suggests that the former treatment had favoured "crow's beak" transplants and hindered the other stages. However, the apparent poorer performance of shallow planted "crow's beak" seedlings can largely be attributed to more misses under this treatment.

Chemical Analyses

Tables 18, 19 and 20 show chemical analyses for the first and fourth (youngest) fronds sampled 15 months after transplanting for series 1, 2 and 3 respectively. The N, P, K, Ca and Mg determinations are on a percentage of dry matter basis while S, Mn, Fe, Cu and B are in parts per million.

The main beneficial effects of added nutrients apparently have occurred through an improvement in nitrogen and sulphur status of the seedlings. Growth measurements showed a response to fertilizer in most instances and this is reflected in the nitrogen levels of fertilized and unfertilized seedlings. Although there were exceptions, the nitrogen status, especially of the first fronds, was higher in fertilized than in unfertilized seedlings. It is pointed out that, especially for a mobile element such as nitrogen, measurements of absolute levels in a particular frond do not give a full picture of uptake, as much of the element may have been translocated and actual uptake masked by additional growth. In case of seedlings in infrequently slashed plots levels of fertilized seedlings were often lower than unfertilized ones.

Table 10.—Average seedling heights (ft) and cumulative leaf production

Series	Height								Frond Production					
	9 months		18 months		Height gain in last 9 months			9 months		18 months		Leaf no. in last 9 months		
	+F	—F	+F	—F	+F	—F		+F	—F	+F	—F	+F	—F	
1	....	....	5.3	4.6	9.6	7.1	4.3	2.5	8.65	8.27	13.83	12.11	5.18	3.84
2	....	....	4.9	4.5	8.7	6.8	3.8	2.3	9.75	9.90	16.23	15.11	6.58	5.21
3	....	....	4.1	3.8	7.8	5.6	3.7	1.8	8.99	8.77	14.93	12.86	5.94	4.09
Average	....	....	4.8	4.3	8.7	6.5	3.9	2.2	9.13	8.98	15.00	13.36	5.90	4.38
Least significant difference	5 per cent	0.22			0.64				Not significant			1.16		
	1 per cent	0.29			0.84							1.53		

Table 11.—Average seedling fresh weights (lb) with and without fertilizer under the various maintenance systems

Treatment			Equal age from nursery planting			18 months from transplanting		
			+F	—F	Percentage Response	+F	—F	Percentage Response
C.W.	....	....	80.7	64.3	25.4	33.6	29.9	11.2
R.S.	....	....	55.8	25.3	120.2	14.8	7.9	87.4
I.S.	....	....	24.9	14.1	77.1	8.5	3.3	154.2
Average	....	....	53.8	34.6	....	19.0	13.7	....
Least significant difference	5 per cent			10.0		Not subject to statistical analysis		
	1 per cent			13.6				

Table 12.—Average seedling height (ft) with and without fertilizer under the various maintenance systems

Treatment			9 months			18 months			Growth between 9 and 18 months		
			+F	—F	Percentage Response	+F	—F	Percentage Response	+F	—F	Percentage Response
C.W.	....	....	4.9	4.7	5.1	9.8	8.8	11.4	4.9	4.1	18.6
R.S.	....	....	4.3	4.0	8.1	8.5	5.7	48.5	4.2	1.7	142.7
I.S.	....	....	5.1	4.2	20.7	7.8	5.0	56.1	2.7	0.8	243.4
Average	....	....	4.8	4.3	....	8.7	6.5	....	....	....	....
Significance			Interaction not significant			Interaction significant					

Table 13.—Average seedling height (ft) with and without fertilizer under the various transplanting stages

Transplanting Stage			9 months			18 months			Growth between 9 and 18 months		
			+F	—F	Percentage Response	+F	—F	Percentage Response	+F	—F	Percentage Response
CB	....	....	4.2	4.3	—3.2	7.1	6.5	+10.3	3.0	2.2	+37.7
2L	....	....	4.9	4.1	+18.7	8.6	6.4	+39.4	4.0	2.3	+77.3
4L	....	....	5.0	4.1	+22.2	9.4	5.9	+59.7	4.3	1.7	+148.9
7L	....	....	5.0	4.6	+8.1	9.3	7.3	+28.5	4.3	2.6	+64.0
Average	....	....	4.8	4.3	....	8.7	6.5	....	3.9	2.2	....
Significance			Interaction not significant			Interaction significant					

Table 14.—Average seedling fresh weights (lb) with and without fertilizer under the various transplanting stages

Transplanting Stage			Equal age from nursery planting			18 months from transplanting		
			+F	—F	Percentage Response	+F	—F	Percentage Response
CB	....	....	48.7	44.5	+9.3	11.0	11.8	—6.0
2L	....	....	73.3	43.3	+69.1	20.1	12.5	+61.0
4L	....	....	52.6	26.3	+100.1	22.5	11.0	+104.9
7L	....	....	40.7	24.2	+68.0	22.2	19.6	+13.2
Average	....	....	53.8	34.6	....	19.0	13.7	....
Significance			Interaction not significant			Not subject to statistical analysis		

Table 15.—Average seedling heights (ft) under shallow and deep planting in the various maintenance systems.

Treatment	9 months		18 months	
	Shallow	Deep	Shallow	Deep
C.W.	4.9	4.7	9.9	8.7
R.S.	4.3	4.0	7.3	6.8
I.S.	4.5	4.8	6.4	6.4
Average	4.6	4.5	7.9	7.3
Significance	Interaction significant		Interaction not significant	



Plate IV.—Fertilized (right) and unfertilized seedlings under regular slashing about 21 months after trans-planting



Plate V.—Fertilized (background) and unfertilized seedlings under infrequent slashing about 16 months after transplanting. Typical sulphur deficiency symptoms are evident

Table 16.—Average seedling heights (ft) under shallow and deep planting in the various transplanting treatments

Transplanting Stage	9 months		18 months		Growth between 9 and 18 months	
	Shallow	Deep	Shallow	Deep	Shallow	Deep
CB	4.0	4.5	6.4	7.2	2.4	2.7
2L	4.4	4.5	7.9	7.3	3.5	2.8
4L	4.8	4.4	8.4	6.8	3.6	2.4
7L	5.1	4.6	8.7	7.9	3.6	3.3
Average	4.6	4.5	7.9	7.3	....	....
Significance	Interaction significant		Almost significant at 5 per cent level			

Table 17.—Average seedling fresh weights (lb) under shallow and deep planting in the various transplanting treatments

Transplanting Stage				Shallow	Deep
CB	....	....	....	39.1	54.2
2L	....	....	....	70.9	45.7
4L	....	....	....	46.8	32.0
7L	....	....	....	37.5	27.4
Average	....	....	....	48.6	....
Significance				Interaction significant	

It is considered that nitrogen uptake may have occurred and levels may have been diluted through extra assimilate production.

Sulphur is the other element involved. Unfortunately analyses for series 1 were not carried out but sulphur figures for the other series are quite revealing. Levels in the two slashing treatments were low and responded well to added sulphur while sulphur levels in the clean weeded plots were probably adequate without the addition of fertilizer.

Fertilizer application also raised manganese levels quite substantially. This effect has been observed elsewhere and is possibly due to an acidifying effect of fertilizer increasing the availability of manganese.

In series 1 and 2, phosphorus levels in the infrequently slashed plots were somewhat lower than under the other treatments but still probably adequate, while potassium levels were generally quite high. Calcium and magnesium levels were satisfactory as were levels of iron and zinc although in series 3 there was a suggestion of fertilizer depressing zinc uptake. Levels of copper and boron were satisfactory.

DISCUSSION AND CONCLUSIONS

Despite fungal attacks causing the death of a substantial number of seedlings and adversely affecting the performance of others, useful information was obtained on the significance of physiological age at transplanting, in the use of fertilizer and the importance of weed control.

Transplanting Stages

There appears to be no advantage in very early transplanting as seedlings averaging almost four leaves (those designated as two-

leaf) produced larger seedlings than the "crow's beak" transplants at an equal age from nursery planting. This indication is of considerable practical importance as maintenance costs are reduced by long periods spent in the nursery and transplanting at the four-leaf stage allows for more effective nursery selection. Transplanting at the three or four-leaf stage would enable selection on vigour and appearance to be made and seedlings displaying poor vigour or showing any abnormalities could be rogued out, thus raising the quality of planting material reaching the field. Foale (1968a) showed that a coconut seedling is largely dependent on its endosperm reserves for dry matter production until four to five months after germination after which its development becomes more dependent on external sources. This largely explains the good performance of seedlings transplanted at about the four-leaf stage and the poorer growth for the same period of time for the more advanced transplants.

The poorer overall performance of the "crow's beak" transplants can probably be attributed to nursery selection being limited to early germination and the greater number of deaths in that treatment. For the "crow's beak" stage in each series the first 48 seedlings to germinate were transplanted while for the other stages any obviously abnormal seedlings were rejected although under the conditions of the trial early germination was the main basis for selection. An examination of seedling mortality showed that "crow's beak" transplants suffered most to the same age from nursery planting. Respective mortality percentages for the "crow's beak", two-leaf, four-leaf and seven-leaf transplants were 18.8, 10.4, 9.4 and 10.4 per cent. Most of the deaths in the "crow's beak" transplants had occurred under conditions of clean weeding where best growth could be expected and if these deaths are accepted as being unrelated to treatment the "crow's beak" average weights would have been unduly penalized. Even if the apparent superiority of the transplants with up to four leaves over those at the "crow's beak" stage is accidental, it is likely that the performance of the former could be enhanced further by strict nursery selection.

Table 18.—Series 1. March, 1967

Treatment	Frond	N	P	K	Ca	Mg	S	Mn	Fe	Zn	Cu	B
C.W.	1st	1.69	0.211	2.64	0.26	0.308	—	22.0	39.	15.7	5.25	20.9
C.W. +F	"	1.83	0.218	2.42	0.28	0.322	—	25.3	40.	13.9	4.78	21.2
R.S.	"	1.90	0.235	2.44	0.25	0.322	—	13.5	40.	15.4	5.25	18.3
R.S. +F	"	2.00	0.230	2.46	0.27	0.580	—	25.3	35.	14.3	5.25	17.2
I.S.	"	1.63	0.185	2.22	0.35	0.368	—	35.0	41.	16.4	4.45	19.3
I.S. +F	"	1.63	0.198	2.24	0.36	0.382	—	53.8	40.	14.9	4.55	21.8
Average +F	"	1.82	0.215	2.37	0.30	0.428	—	34.8	38.	14.3	4.86	20.0
Average —F	"	1.74	0.210	2.43	0.28	0.332	—	23.5	40.	15.8	4.98	19.5
C.W.	4th	1.76	0.181	2.00	0.49	0.422	—	53.5	75.	15.1	3.68	18.5
C.W. +F	"	1.93	0.171	1.94	0.52	0.402	—	74.0	97.	13.9	3.35	21.8
R.S.	"	1.92	0.178	1.72	0.50	0.430	—	30.3	69.	19.4	3.00	15.6
R.S. +F	"	1.94	0.181	1.76	0.57	0.422	—	68.3	70.	16.5	3.25	14.4
I.S.	"	1.37	0.129	1.64	0.56	0.422	—	50.3	82.	16.2	2.70	18.0
I.S. +F	"	1.50	0.137	1.58	0.63	0.368	—	97.0	78.	14.7	2.85	15.6
Average +F	"	1.79	0.163	1.76	0.57	0.397	—	79.7	81.	15.0	3.15	17.2
Average —F	"	1.68	0.162	1.78	0.51	0.424	—	44.7	75.	16.9	3.12	17.3

Table 19.—Series 2. May, 1967

Treatment	Frond	N	P	K	Ca	Mg	S	Mn	Fe	Zn	Cu	B
C.W.	1st	1.84	0.223	2.40	0.23	0.255	465	26.0	55.6	15.8	4.95	18.4
C.W. +F	"	2.00	0.223	2.44	0.23	0.250	575	41.0	49.0	15.5	3.70	19.6
R.S.	"	1.81	0.236	2.42	0.30	0.253	100	14.84	42.0	17.7	4.40	15.9
R.S. +F	"	1.76	0.235	2.30	0.28	0.263	685	23.0	57.0	17.3	4.05	17.1
I.S.	"	1.56	0.231	2.74	0.30	0.297	200	24.0	53.0	15.6	4.70	15.8
I.S. +F	"	1.50	0.212	2.48	0.27	0.297	695	38.5	44.0	15.8	4.40	18.0
Average +F	"	1.75	0.223	2.40	0.26	0.270	652	34.2	50.1	16.2	4.05	18.2
Average —F	"	1.73	0.230	2.52	0.28	0.268	255	21.6	50.2	16.3	4.68	16.7
C.W.	4th	1.84	0.178	2.00	0.45	0.245	325	58.0	121.0	15.2	3.70	14.5
C.W. +F	"	1.78	0.178	1.94	0.50	0.257	670	56.0	88.0	14.9	4.20	14.7
R.S.	"	1.69	0.162	1.88	0.51	0.238	90	24.0	84.0	15.5	2.45	13.9
R.S. +F	"	1.97	0.195	2.12	0.58	0.219	745	64.5	116.0	17.0	3.58	14.5
I.S.	"	1.45	0.137	1.68	0.71	0.335	250	43.3	98.0	18.1	2.58	15.4
I.S. +F	"	1.65	0.157	1.86	0.64	0.274	745	105.0	100.0	12.8	3.10	12.6
Average +F	"	1.80	0.176	1.97	0.57	0.250	720.	75.1	101.3	14.9	3.62	13.9
Average —F	"	1.66	0.159	1.85	0.55	0.272	221.	41.7	101.0	16.2	2.91	14.6

Table 20.—Series 3. September, 1967

Treatment	Frond	N	P	K	Ca	Mg	S	Mn	Fe	Zn	Cu	B
C.W.	1st	1.89	0.193	1.86	0.26	0.240	307	21.5	62.0	15.2	4.9	14.5
C.W. +F	"	2.24	0.164	1.97	0.40	0.220	565	32.8	74.0	10.8	4.9	13.6
R.S.	"	1.96	0.213	2.01	0.28	0.240	257	22.0	40.0	15.7	5.2	15.3
R.S. +F	"	1.73	0.170	1.95	0.32	0.200	390	41.0	46.0	10.8	3.68	12.8
I.S.	"	1.94	0.190	2.00	0.32	0.330	105	21.0	60.0	26.0	5.2	13.8
I.S. +F	"	1.65	0.174	2.07	0.32	0.205	512	40.0	34.0	11.9	3.3	13.8
Average +F	"	1.87	0.169	2.00	0.34	0.208	489	37.9	51.3	11.2	3.96	13.4
Average —F	"	1.93	0.198	1.95	0.28	0.270	223	21.5	54.0	18.9	5.1	14.5
C.W.	4th	1.64	0.170	1.37	0.54	0.21	242	32.8	96.0	18.2	4.4	12.6
C.W. +F	"	1.73	0.180	1.50	0.86	0.22	672	56.0	146.0	13.0	3.25	12.7
R.S.	"	1.81	0.180	1.53	0.48	0.23	180	32.8	88.0	15.7	3.7	12.4
R.S. +F	"	1.74	0.180	1.55	0.61	0.19	492	70.8	97.0	10.8	3.1	11.5
I.S.	"	1.77	0.180	1.65	0.41	0.25	50	29.2	88.0	16.7	3.3	14.5
I.S. +F	"	1.50	0.200	1.90	0.63	0.22	590	82.0	80.0	11.9	2.4	13.4
Average +F	"	1.65	0.190	1.65	0.70	0.20	584.6	49.6	107.6	11.9	2.91	12.5
Average —F	"	1.74	0.180	1.51	0.48	0.23	157.3	31.6	90.6	16.8	3.8	13.2

From a practical point of view, unless the planter is particularly anxious to obtain the earliest possible returns (which may not be justified on a cost basis) it might be better to leave seedlings in the nursery for some time. The much greater cost of maintenance in the field than in the nursery would tend to prohibit very early transplanting. There is no doubt that transplanting shock with older seedlings is considerable but growth at an equal age after transplanting is probably more important than growth at an equal age from nursery planting. In this regard absolute growth appears generally to rank in the same order as age at transplanting. Older seedlings did retain some advantages and the situation may best be summarized by noting that although the more advanced seedlings suffered greater shock at transplanting the retardation in growth was not as great as the growth made during the extra period in the nursery. Transplanting up to the seven-leaf stage appeared to give satisfactory results under conditions experienced in this particular experiment. It is possible that transplanting shock might be much more severe if a long dry spell were experienced after transplanting.

The situation where better growth achieved through early field planting is nullified by higher maintenance costs may possibly be overcome by a method described by Foale (1968b) in the British Solomon Islands Protectorate. The use of large earth-filled polythene bags enabled seedlings in a fairly advanced stage to be transplanted with apparently little hindrance to growth. Additional work in this field is under way.

Maintenance

Complete control of weeds was much superior to regular slashing which, in turn, was better than irregular slashing. It is doubtful whether, under Gazelle Peninsula conditions in particular, many seedlings could be brought to bearing under irregular slashing without the use of fertilizer.

It appears that competition for nutrients is an important factor, especially under slashing treatments. Soil moisture and light availability are also undoubtedly important, as fertilizer additions failed to raise seedlings in the regularly slashed plots to the standard of the unfertilized

seedlings in the clean weeded plots. These findings were substantiated by chemical analyses. Sulphur levels were low in the regularly slashed plots and very low in the infrequently slashed ones. Fertilizer raised levels to adequacy while it was considered that levels in unfertilized clean weeded plots were adequate on the whole. Competition for nitrogen is probably also of considerable significance especially under infrequent slashing.

The importance of moisture and sunlight was indicated in studies of growth after transplanting in the three series. Competition for both is certainly accentuated under conditions of weed infestation.

Another factor which may prove detrimental in weed infested areas is direct mechanical damage to seedling roots near the surface by kunai runners. This possibility is being investigated.

Complete clean weeding without some sort of mulch could be detrimental in the long run as well as impractical at this stage. The usefulness of limited clean weeding with and without fertilizer is under investigation. At present it is recommended that a circular area about 4 ft in diameter be hand weeded until about a year after transplanting and that this circle be extended to 8 ft later. Weeding with spades is condemned as the damage this practice can do to seedlings' roots may exceed the detrimental effect of weed competition. Clean weeded areas should also, where possible, be mulched, as this should improve moisture availability and lessen the frequency of weeding. A leguminous cover crop is also desirable although a better practice in terms of cash return per acre would be intercropping. It is likely that the competitive effect of the intercrop may be less than that of weed growth.

Fertilizer

Fertilizer responses in terms of height were noted nine months after transplanting and were quite pronounced when fresh weights were determined at an equal age from nursery planting for the various transplanting stages, and also after 18 months in the field. A subjective assessment indicated a colour response to fertilizer in the more advanced transplants as early

as five months after transplanting where maintenance consisted of either regular or infrequent slashing. A much greater response to fertilizer was noticed in the second nine months after establishment.

As expected, "crow's beak" transplants showed no response to fertilizer nine months after transplanting as seedling requirements to this stage would still be quite small. There was a lack of a significant response in terms of height 18 months after transplanting but a response was noted in the second nine months after transplanting. The relative response to fertilizer under regular and infrequent slashing was much greater than that under conditions of clean weeding. At no time, however, did fertilized seedlings under the slashing systems of maintenance equal growth in the unfertilized clean weeded plots. Responses are probably limited by competition for light and moisture in the former cases.

Height measurements 18 months after transplanting in clean weeded plots failed to reveal a significant response to fertilizer. The response at an equal age from transplanting was slight and it is probable that clean weeding had more or less substituted for fertilizer.

Depth of Planting

The experiment was of insufficient duration to determine if the beneficial effects often ascribed to deep planting did apply. Palm weevil damage had not become evident and it was not really possible to say whether the shallow planted seedlings were less stable than the deeper planted ones. Four seedlings in all were blown over during a brief squall. Strangely enough, three were planted in deep holes and only one at ground level.

At nine months after transplanting height measurements indicated that shallow planting was preferable to deep planting under clean weeding and regular slashing but the reverse was true under infrequent slashing. It is possible that the deeper holes may have afforded seedlings a degree of protection from the competitive effects of weeds in the poorest maintenance treatment and this was of benefit immediately after transplanting. This effect would disappear as the holes crumbled later.

There is some evidence to indicate that "crow's beak" transplants had performed better under conditions of deep planting and other stages better under shallow planting. It was noted that at 18 months from transplanting 12 shallow-planted seedlings from the "crow's beak" stage had died as against four in the deeper planted plots. As few of the deaths occurred soon after transplanting, actual smothering of the surface-planted seedlings was not a direct cause of death although it may conceivably have weakened seedlings. Even if only the average weight of surviving seedlings is considered, deeper plantings are ahead of surface plantings. The effect may well be real but will need confirmation before it is accepted. It is unlikely to be of any practical importance as the use of "crow's beak" transplants is not recommended. The indication, however, is puzzling.

ACKNOWLEDGEMENTS

Gratitude is expressed for the assistance provided by Mr A. E. Charles, Chief Agronomist, DASF, Port Moresby in the planning and analysis of this experiment and his helpful comments on this paper. Mr P. J. Southern, formerly Senior Chemist, DASF, Port Moresby kindly organized the chemical analyses.

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(Accepted for publication July, 1970.)