

THE GROWTH OF THE YOUNG COCONUT PALM (*COCOS NUCIFERA* L.)

II. THE INFLUENCE OF NUT SIZE ON SEEDLING GROWTH IN THREE CULTIVARS

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[Manuscript received May 20, 1968]

Summary

The growth of three coconut cultivars of the tall type from germination up to 17 months of age was compared by growth analysis. These cultivars differ considerably in mean nut size. Within each cultivar a comparison was also made between the growth of seedlings from small, medium, and large nuts.

There were considerable differences between cultivars in seedling growth up to 2 months but these differences did not persist. Similarly differences due to nut size within cultivars were recorded at early harvests but had disappeared by 6 months. Thus neither genotype nor nut size had any sustained effect on the plant size.

Consumption of endosperm depended on seed size: evidently a lower, compensating net assimilation rate occurred in plants with large nuts to give a similar total supply of assimilate. This suggests that the potential supply of assimilate was not limiting the growth rate.

Large nuts transfer dry matter from the endosperm more rapidly than do smaller nuts; hence under unfavourable conditions for photosynthesis, larger nuts may produce larger seedlings. It is suggested that any seedling selection should be done in a favourable nursery environment so that emphasis is placed on differences in seedling vigour due to genetic variation.

I. INTRODUCTION

It has been shown (Foale 1968) that the endosperm is the only source of assimilate of the seedling coconut for approximately the first 4 months of growth. Thereafter as leaves develop, the contribution by the endosperm declines, ceasing at about 11 months. The present paper is concerned with differences in early growth due to genetic and phenotypic differences in the size of the nut (seed). Interest in this topic arises from the great differences in nut size both between and within cultivars of the coconut; such difference could influence the practice of seedling selection.

It has been reported from Ceylon (Ceylon Govt. 1951; Liyanage 1953) that faster growth in seedlings is associated with higher copra yields in the mature palms. Workers there recommend that only the most vigorous 50% of a nursery population of 6-month-old seedlings be selected for field planting. It is important to determine

* Part I, *Aust. J. agric. Res.*, 1968, 19, 781.

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whether nut size influences seedling vigour, since this might lead to a further increase in the efficiency of nursery selection, which in the Ceylon experiment raised yields of copra by 12% over unselected plants. Nut size has the very high heritability of 95% (Liyanage and Sakai 1960). If nut size and seedling vigour are associated, then selection for nut size will lead to selection for seedling vigour. On the other hand Liyanage and Abeywardene (1957) found that nut size is not correlated with yield of copra per palm.

The coconut, which has unisexual flowers, is divided into two broad botanical groups, Talls and Dwarfs. On the inflorescence of the Tall palm the male flowers are all shed before the female flowers become receptive to pollen, which encourages out-pollination (Whitehead 1965*a*). This outbreeding leads to considerable genetic diversity among Tall palms, shown in such characters as leaf length, crown (canopy) shape, fruit size and colour, yield of nuts, and total yield of copra (dried endosperm). On Dwarf palm inflorescences the two sexual phases partly coincide, and up to 90% of the seeds are self-pollinated (Jack and Sands 1929; Whitehead 1966*a*). Dwarf populations are consequently much more uniform than Talls.

Of the two types, Talls are much more widely used for copra production, and the present study is concerned with three Tall cultivars, all of which are important in coconut plantations of the British Solomon Islands.

Because the coconut has a very large fruit, containing a single embryo which remains viable for only a few months, the number of individuals distributed into new areas is limited. Consequently coconut palm populations in different geographic regions commonly exhibit distinctive characteristics, especially of the fruit; in the Pacific area distinct populations are sometimes to be found on islands only a few score miles apart. These cultivars can be distinguished by such characters as fruit size, shape, colour, and number. At the pre-bearing age, however, it is difficult to distinguish between Tall cultivars by vegetative characters.

II. EXPERIMENTAL METHODS

Some aspects of this project have been reported in an earlier paper (Foale 1968). The work here presented was a study of the effect of seed size and genotype on seedling growth using three Tall cultivars grown in the Solomon Islands; these were Solomon Islands Tall, FMS (Federated Malay States), and Rennell. The first of these is widely distributed on the larger islands of the Solomons and is grown in most plantations. The FMS are the progeny of a few hundred palms established from seed imported from Malaya about 50 years ago; the original seed block, only about 8 acres in area, was surrounded by Solomon Islands Tall palms. Owing to out-pollination, the progeny of these original FMS palms contains a proportion of hybrids between FMS and Solomon Islands Tall. Pure FMS palms are generally distinguishable from hybrids through nut size and shape, so that it was possible at the time of seed collection to avoid hybrid palms by selecting typical round FMS nuts. The Rennell cultivar takes its name from an isolated island in the south of the Solomons

group. Rennell nuts are very large, have a distinctive pear shape, and are usually light bronze in colour. This cultivar has become well known only in recent years but is now being planted widely in the Solomons.

Samples of 150 nuts of each variety were collected at random from a large sample and analysed for fresh and dry weight of the component tissues. A further 500 nuts were harvested from about 100 trees of each cultivar, the nuts being at a stage when the husk had just begun to dry, the first sign of nut maturity. These nuts were dehusked, numbered, and weighed, and then three size groups were selected for each variety.

The date of germination of each nut was recorded (Foale 1968) and the seedlings were planted into the field when sufficient nuts of each cultivar had a shoot about 8 cm long.

TABLE I
FRESH AND DRY WEIGHTS OF NUT COMPONENTS AND EMBRYO

Component*	Fresh Weight						Dry Weight					
	Sol. Is.		FMS		Rennell		Sol. Is.		FMS		Rennell	
	g	%	g	%	g	%	g	%	g	%	g	%
Husk	498	44.7	816	43.8	691	34.0	214	43.1	351	44.9	297	34.7
Shell	152	13.6	219	11.7	310	15.2	122	24.6	175	22.4	248	29.0
Solid endosperm	294	26.4	465	24.9	560	27.5	154	31.1	242	30.9	293	34.2
Liquid endosperm	170	15.3	366	19.6	475	23.3	6	1.2	14	1.8	18	2.1
Total	1114	100	1866	100	2036	100	496	100	782	100	856	100
Embryo†	0.133		0.142		0.126		0.027 ±0.006		0.028 ±0.005		0.025 ±0.008	

* Values for components are means of 150 nuts per cultivar. † Mean of 20 nuts per cultivar.

Cultivars were allocated to main plots, which were split into 10 subplots for the 10 harvests. Each subplot contained three planting points to which the three size groups were allocated at random. The overall layout therefore consisted of 3 cultivars × 3 nut size groups × 10 harvests × 7 replicates = 630 palms.

The systematic allocation of subplots to harvests to give a progressive reduction in the plant density, and details of the size and weight measurements made on each harvested plant have been described earlier (Foale 1968).

III. RESULTS

(a) Nut Composition

The fresh and dry weights of the nut components, based on samples of 150 nuts for each cultivar, are shown in Table I. The range of total nut size of Solomon Islands, FMS, and Rennell is very great, with relative dry weights of 58/91/100. Rennell is not only larger but it also has a relatively light husk. The range of dry weight of endosperm (solid + liquid) was 51/82/100.

The embryos were dissected from 20 nuts of each cultivar, and the mean embryo weights are given in Table 1. The embryos are minute in comparison with the endosperm and there was no apparent relationship between embryo size and nut size.

(b) Husked Nut Weights

Of the 500 nuts of each cultivar collected for study, some 50, when the husk was removed, were found to have germinated, and were therefore discarded. The weight distribution of the remaining nuts is shown in Figure 1, which also indicates those parts of each population designated as "small", "medium", and "large" nuts.

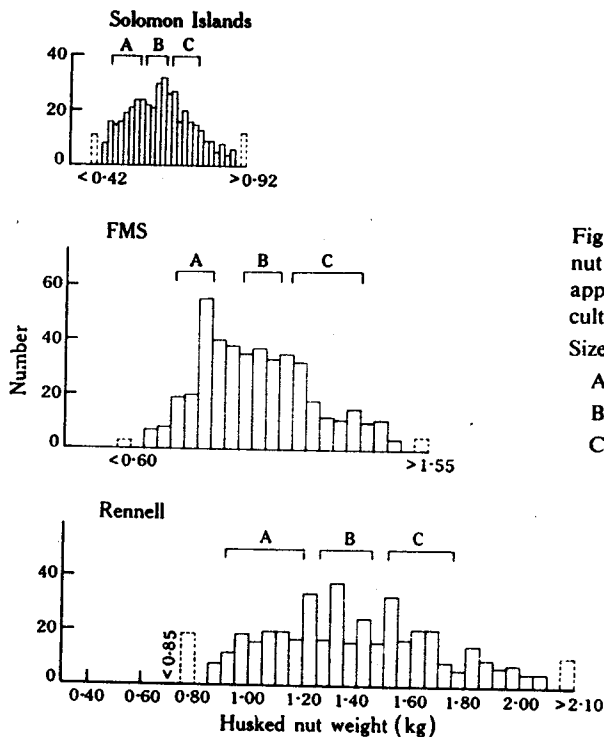


Fig. 1.—Distribution of husked nut weight within populations of approximately 450 nuts of each cultivar.

Size group ranges:

A, small.

B, medium.

C, large.

The means and standard errors of the whole populations, together with the husked weights (i.e. with husk removed) of the nut classes are shown in Table 2.

(c) Germination

The cumulative percentage germination is shown in Figure 2 for cultivars (left) and size classes (right). All time intervals are from the date of collection of the nuts. The commencement of germination was not quite simultaneous for all cultivars, but it is apparent that Rennell had its peak of germination in advance of that of FMS and Solomon Islands. Small nuts commenced germination sooner than larger nuts but thereafter maintained a common rate.

(d) Growth

Total plant weight and endosperm loss are shown in Table 3, for cultivar and nut size treatments.

The initial endosperm weight was estimated by use of a regression on the weight of the husked nut (Foale 1968). This estimated initial weight minus the actual endosperm weight at harvest gave an estimate of endosperm utilized. The losses estimated in this way are erratic at 2 months and to some extent also at 4 months, but thereafter assume a regular pattern. As virtually no photosynthesis took place before 4 months, the endosperm loss up to that time would be expected to exceed the plant weight (tops, roots, and haustorium) by the loss due to respiration, whereas in a few of the comparisons in the first two harvests it is recorded as less.

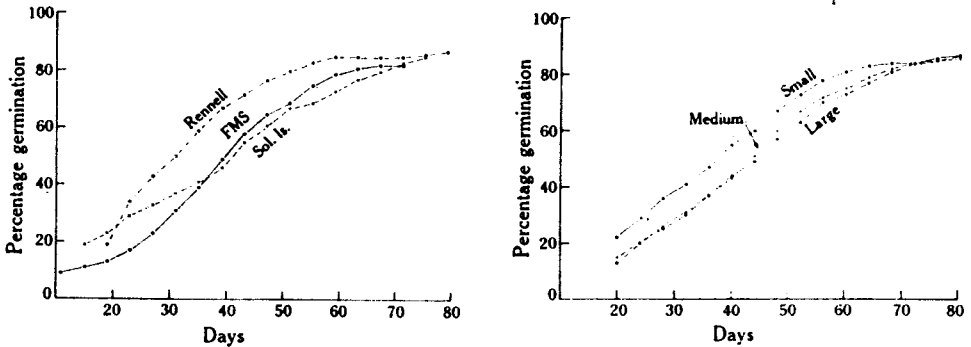


Fig. 2.—Cumulative germination of the three cultivars (*left*) and of the nuts in each of the size classes within varieties (*right*). "Days" indicates interval from harvest of mature nuts from the palms.

Up to 6 months, large nuts generally gave slightly larger plants than medium nuts, which in turn produced plants slightly larger than those from small nuts. Over the same period Rennell seedlings were generally slightly larger than those of FMS, which were larger than Solomon Islands seedlings. After 6 months the differences between treatments were irregular; there was no consistent relationship to nut size within any cultivar, nor between varieties.

TABLE 2
HUSKED NUT WEIGHTS (KG) OF WHOLE POPULATIONS AND SIZE CLASSES

Cultivar	Mean Weight ± Stand. Error	Coeff. of Variation	Size Class:	(b) Within cultivars and size classes			Mean (%)
				A Small	B Medium	C Large	
Sol. Is.	0.640 ± 0.131	20.5%	Wt. range	0.46–0.56	0.58–0.66	0.68–0.78	0.62 (46)
			Mean wt.	0.51	0.63	0.73	
FMS	1.029 ± 0.211	21.2%	Wt. range	0.71–0.85	0.96–1.10	1.14–1.40	1.03 (76)
			Mean wt.	0.80	1.03	1.25	
Rennell	1.400 ± 0.330	23.5%	Wt. range	0.91–1.20	1.26–1.45	1.51–1.75	1.34 (100)
			Mean wt.	1.06	1.35	1.61	

It appears that from 6 months onwards, when the estimate of endosperm loss was probably fairly accurate, the Solomon Islands cultivar was transferring less dry matter from the endosperm to the seedling than were the other cultivars. This is

illustrated more clearly in Figures 3 and 4, in which endosperm loss, both absolute and as a percentage, is plotted against time for the three cultivars and the three size groups. Absolute loss increases with the nut size of the cultivar (Rennell > FMS > Solomon Islands), but a greater proportion of endosperm was consumed in the cultivar Solomon Islands, with the smallest nuts. Similarly the greatest absolute loss occurred in the large nut class, while the reverse was true of the percentage loss.

TABLE 3
PLANT WEIGHT, AND ESTIMATED LOSS IN WEIGHT OF ENDOSPERM (G) SINCE GERMINATION

Date of Harvest	Cultivar: Nut Size Class:*	Solomon Is.			FMS			Rennell		
		S	M	L	S	M	L	S	M	L
2 months	Plant weight	8.5	8.9	7.2	11.9	10.4	14.6	15.5	16.3	17.4
	Total endosperm loss†	14.8	21.0	8.4	23.2	22.8	22.4	23.8	13.6	10.3
	Liquid endosperm loss	2.8	3.0	2.4	3.2	2.8	6.4	3.8	4.6	7.3
4 months	Plant weight	54.4	55.5	57.5	59.3	59.2	61.3	54.0	68.2	66.9
	Total endosperm loss	54.9	56.9	69.8	73.3	54.5	57.4	84.2	86.7	74.6
	Liquid endosperm loss	4.9	5.9	7.8	8.3	12.5	16.4	11.2	15.7	21.6
5 months	Plant weight	72.3	74.3	78.7	77.6	74.3	74.7	79.7	89.6	96.2
	Endosperm loss	55.9	67.0	79.9	92.3	60.1	107.1	96.0	100.4	98.4
6 months	Plant weight	86	101	106	93	123	111	110	140	143
	Endosperm loss	59	88	81	87	103	129	103	113	135
7 months	Plant weight	138	133	140	156	149	147	160	147	147
	Endosperm loss	73	91	91	111	114	124	139	120	132
9 months	Plant weight	242	216	280	241	175	232	221	253	313
	Endosperm loss	93	115	133	119	138	173	155	168	168
11 months	Plant weight	683	579	617	547	632	746	813	604	747
	Endosperm loss	101	134	134	163	145	189	206	191	209
13 months	Plant weight	1175	1262	1263	1174	1083	1243	1172	1069	1324
	Endosperm loss	122	142	142	160	186	201	188	‡	218
15 months	Plant weight	1809	1402	2452	2291	2070	2703	2171	2246	2161
	Endosperm loss	122	150	158	176	166	205	205	257	201
17 months	Plant weight	3322	3296	2965	3287	3445	3152	2705	2930	2671
	Endosperm loss	‡	‡	163	190	167	255	227	‡	260

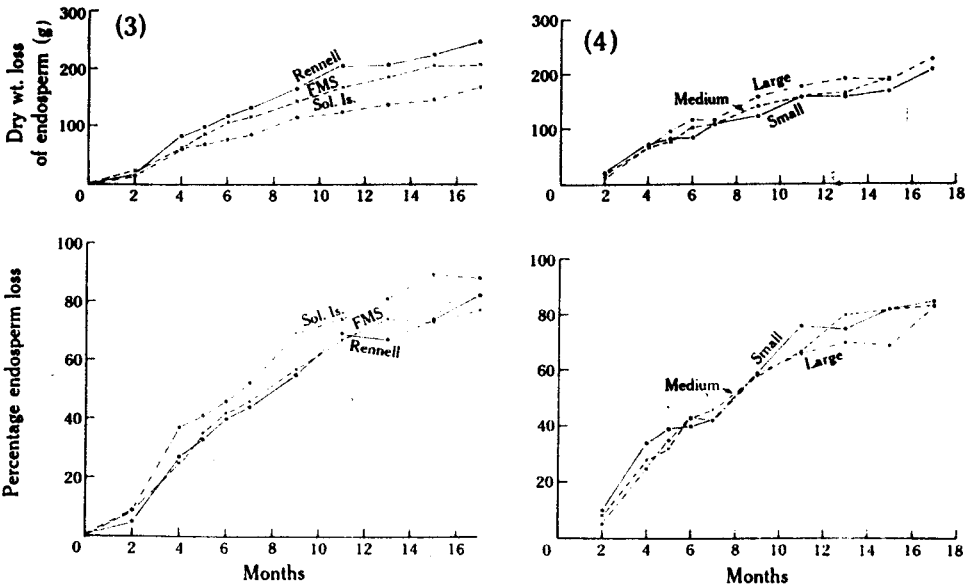
* S, small. M, medium. L, large.

† Errors in the estimation of solid endosperm loss, which were determined by difference from estimated pre-germination endosperm weight based on nut weight, were high in the early harvests, leading to erratic values in harvest 1 and to a lesser degree in harvest 2.

‡ No data available as all haustoria and residual endosperm in these groups were rotten.

The haustorium weight is shown in Figure 5, which illustrates a consistent relationship between size of nut and haustorium. The haustorium usually fills the vacuole completely and thereafter expands as the endosperm is progressively absorbed.

Statistical analysis of the natural logarithms of shoot dry weight, root dry weight, and leaf area was carried out for each harvest separately. The design was treated as a randomized block arrangement, as preliminary analysis showed that the split



Figs. 3 and 4.—Absolute endosperm loss (*above*) and endosperm loss as a percentage of total initial endosperm (*below*), for the three cultivars (Fig. 3) and for the nut size groups (Fig. 4).

plot arrangement of size groups within the cultivar main plots was ineffective (i.e. there was generally no worth-while reduction in subplot error compared with main-plot error). The significant differences for the three cultivars and three nut sizes are presented in Table 4.

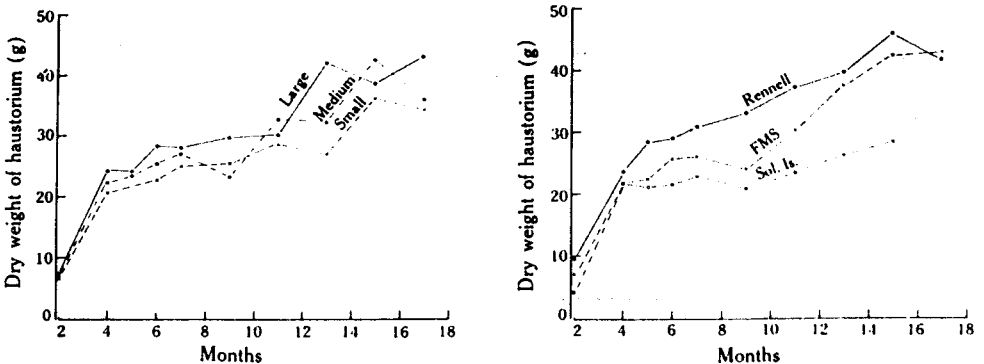


Fig. 5.—Haustorium weight of the three nut size groups (*left*) and the three cultivars (*right*).

In all, 12 significant differences between cultivars were recorded; of these, 11 conform to the pattern Solomon Islands < FMS < Rennell. But the differences are neither substantial (except as between cultivars at 2 months) nor consistent between harvests.

Large nuts gave significantly greater values for shoot weight and leaf area than medium-sized nuts at 9, 11, and 15 months, but in all these instances the small-sized nuts gave intermediate values.

TABLE 4

SIGNIFICANT DIFFERENCE BETWEEN CULTIVARS AND BETWEEN SIZE GROUPS FOR NATURAL LOGARITHM OF SHOOT AND ROOT WEIGHT (G) AND LEAF AREA (M²)

Letters indicate which treatments, within each group of three, are significantly different from each other. Cultivars: S, Solomon Island Tall; F, FMS; R, Rennell. Nut sizes: A, small; B, medium; C, large. Dashes indicate that no data were available for analysis

Harvest (months):	2	4	5	6	7	9	11	13	15	17
Shoot weight: Cultivars	**			*					**	
Size groups	S < F < R			F < R S < R					S < F	
Root weight: Cultivars	***				*				—	—
Size groups	S < F < R			A < B					—	—
Leaf area: Cultivars	—				*				*	*
Size groups	—				S < F R < F				S < F S < R	B < C

* Significant at 5% level.

** At 1% level.

*** At 0.1% level.

The interaction between varieties and size groups did not achieve statistical significance. It was also found that there was no overall regression of plant weight on nut size independent of genotype. That is, if the nine treatments were regarded as nine separate size groups without regard to cultivar, no significant effect of nut size on growth was demonstrated.

IV. DISCUSSION

Little is known of the factors which influence germination in the coconut, though differences in germination behaviour have long been recognized for different varieties (Jack and Sands 1929; Whitehead 1965*b*, 1966*b*). Coconut germination requires further investigation, as many non-genetic factors, such as degree of maturity at the time of harvest from the palm, and differences in temperature and humidity between harvest and germination, probably affect the speed of germination. Coconut nursery

management would be greatly simplified if the germination of a batch of nuts could be manipulated by means of environmental control as is done with oil palms (Rees 1959).

With regard to seedling growth, larger nuts have been shown within Rennell and FMS, and between cultivars, to produce a larger seedling at 2 months of age (Table 3), even though the initial embryo size was similar for all genotypes. The early differences in plant weight both between and within cultivars may be related to the different amounts of liquid endosperm utilized up to 2 months. The haustorium in nuts of greater size developed more rapidly (Fig. 5) and absorbed the liquid endosperm at a faster absolute rate. Liquid endosperm had been completely consumed in most nuts by 4 months and at this stage the early treatment differences had disappeared. There were also large differences between cultivars in the absolute amount of endosperm utilized, Rennell using most and Solomon Islands least (Fig. 3).

Figure 4 shows that larger nuts transferred more endosperm to the seedling from the fourth month onwards. Both in size groups and cultivars there is a correlation between the rate of utilization of the solid endosperm and the size of the haustorium (Figs. 3, 4, 5). There is, however, some reduction in the efficiency of absorption in larger nuts, and the percentage of the endosperm absorbed was generally greatest for Solomon Islands nuts and for the small-sized nuts. This could be due to the longer time taken for the haustorium to develop to full size in large nuts. The maximum rate of utilization of endosperm would presumably be achieved only when the haustorium completely filled the vacuole. It was found, however, that in the largest nuts the development of the haustorium stopped short of completely filling the vacuole; that part of the endosperm not in contact with the haustorium was only slowly absorbed.

Yet though there were large differences between size groups and cultivars in absolute uptake of dry matter from the endosperm, growth differences after 4 months were small. There was evidently a compensating depression of the net assimilation rate so that the total dry matter supplied both by assimilation and by the endosperm was equal for different-sized nuts. This suggests that, under the conditions of the experiment, growth within each genotype was limited not by the supply of assimilate but by the growth capacity of the single apical bud and of the roots.

It is possible that the effects of nut size and cultivar would be greater if water were limiting during the stage of seedling growth when an appreciable proportion of assimilate is coming from the leaves. Foale (1968) suggested that transfer of material from the endosperm to the shoot would be less dependent on moisture supply than is photosynthesis. If lack of water reduced leaf assimilation, the rate of transfer of dry matter from the endosperm to the plant would presumably have a greater influence on growth rate, larger nuts giving faster growth. This view is supported by a result obtained in 1960 (Foale, unpublished data) when the heavier 50% of nuts (in this case with husk still attached) in each of four cultivars was observed to produce significantly taller seedlings at 4-5 months of age. No irrigation was used in that trial, and although rainfall during the 5 month period was 46 inches there were several dry spells during which soil moisture deficit was undoubtedly of an intensity to affect net assimilation rate.

In coconut nursery management it is generally accepted that selection of the most vigorous seedlings will give higher-yielding palms than unselected seedlings. This practice is based on the results of the Ceylon studies (Liyanage 1953) in which it was concluded that seedlings should be selected for "vigour"—which includes earliness of germination, rapidity of growth, sturdiness, and freedom from "legginess".

The nature of seedling vigour is queried by Charles (1961), who speculated as to whether the variation might be based on genetic differences. There do appear to be several aspects of seedling growth where genetic effects could be involved in differences between seedlings. For example the size of the embryo and of the growing point, the number of roots, the rate of production of leaf surface area, and the net assimilation rate could be genetically controlled. It seems reasonable to expect that genetically rather than environmentally determined superiority of a seedling would maintain the stronger influence on the plant in later years when it is producing copra.

In the present experiment a maximum degree of standardization of the environment was attempted, with careful soil preparation and the application of irrigation water. Even so the coefficient of variability of the natural logarithm of shoot weight was considerable, which suggested that genetic factors may have had an important effect on seedling vigour. Even greater variability might have occurred if growth were limited by a shortage of water or nutrients, since under those conditions nut size might exert a direct influence on growth when photosynthesis was checked.

It is considered, therefore, that the best test of genetically controlled seedling vigour will be given with a non-limiting water and nutrient supply. That is to say, nursery soil should be maintained at high fertility, and irrigation water applied as required to supplement natural rainfall. This would lead to selection of a greater proportion of genetically superior seedlings, with a potential increase in the mean vigour of the adult palms. The degree of improvement in copra yield to be secured from a particular level of seedling selection, however, cannot be predicted without further experimentation on the relationship of nursery selection to the subsequent yield of copra for different cultivars in various environments.

V. ACKNOWLEDGMENTS

Thanks are due to Professor C. M. Donald and Dr. R. Knight of the Waite Agricultural Research Institute, Adelaide, and to Mr. G. N. Wilkinson, Division of Mathematical Statistics, CSIRO, for their help with the design, analysis and interpretation of the experiment and the preparation of the manuscript. Thanks are also due to Mr. A. H. Green of Unilever Plantations Group for discussion regarding the design and the manuscript. This paper is published with the permission of the British Solomon Islands Protectorate Government and of Unilever Plantations Group, which collaborate in a Joint Coconut Research Scheme.

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