EFFECTS OF TIME OF AMMONIUM SULPHATE APPLICATION ON THE GROWTH OF NEWLY TRANSPLANTED COCONUT SEEDLINGS

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ABSTRACT

In a soil known to be deficient in nitrogen and sulphur, the uptake of these elements was studied through applications of ammonium sulphate at different intervals after transplanting. Fertiliser applied at transplanting resulted in increases in sulphur levels within a month of application with uptake reaching its maximum level from fertiliser applied as early as one month after transplanting. Consistent responses, in terms of increases in leaf nitrogen, became evident when fertiliser was applied two months or later after field plantings.

If transplanting methods are similar to those utilised in the trials, fertiliser should be applied first at four to six weeks after transplanting, although a delay of up to 12 *weeks would probably not cause much growth setback.*

Indications were that more frequent or perhaps heavier applications of nitrogen might be necessary for maximum growth while intervals between applications of sulphur could well be prolonged.

The relatively poor growth over the first 12 *months of seedlings transplanted with four to seven leases showed a need for better establishment techniques. Alternative methods are suggested.*

INTRODUCTION

RESPONSES by coconuts to added nutrients in terms of better early growth and earlier bearing have been a common occurrence on a multitude of soil types in the tropics.

The question arises as to whether, using normal plantation establishment techniques, nutrients applied at, or soon after, field planting can be effectively utilised. In the Territory of Papua and New Guinea, as well as in many areas of the Pacific, coconut seedlings are usually transplanted from nurseries at between the 4 and 9 leaf stage of development.

Work by Foale (1968a) in the British Solomon Islands Protectorate indicated that at the stage when transplanting is normally carried out the seedling is deriving most of its growth from its external environment and hence, provided that its absorptive mechanisms are sufficiently effective, responses to fertiliser could be expected. Foale showed that up to four or five months after the commencement of germination (as indicated by the emergence of the shoot through the 'germ pore') the seed supplies most of the seedling's requirements. Thereafter photosynthesis makes substantial contributions to development and by the 11th month 90 per cent of assimilation can be attributed to this source. The author's observations at a number of nurseries in the Gazelle Peninsula, New Britain, showed that symptoms of sulphur deficiency do not generally become evident until the four or five leaf stage (that is, about four to five months after the commencement of germination) where coconut seedlings derived from seednuts with normal sulphur contents are grown in a sulphur deficient soil. This tends to support Foale's findings.

It is common knowledge that traditional methods of transplanting retard subsequent development to varying degrees as the considerable contribution to assimilation from the leaves is drastically reduced by root damage. Root recovery appears to be very gradual and a setback to growth estimated to be as much as six months can result. It would appear likely, therefore, that fertiliser applied at about the time of transplanting could only be taken up in limited amounts initially and could be largely wasted. Indeed, it is conceivable that a premature application may be detrimental in that vigorous weed growth and hence added competition for coconut seedlings could result. On the other hand, it is possible that limited uptake could occur (per-

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haps even through tissue at the base of the seedling or through the foliage) and this might suffice if the nutrients concerned were required in relatively small amounts.

In an attempt to clarify the situation, a set of experiments which varied the time of fertiliser application in relation to transplanting time was conducted on soils where responses to fertiliser had been clearly demonstrated.

On the soils chosen, joint applications of sulphur and nitrogen have been shown to be virtually essential if coconut seedlings are to be brought through to bearing. This requirement is widespread in grassland tracts of the Gazelle Peninsula, New Britain, and responses in nurseries to ammonium sulphate have been observed in seedlings with as few as three or four leaves. As nitrogen and sulphur from ammonium sulphate are usually readily available soon after application, and as seedling tissues appear to be quite sentitive to changes in either nutrient, it was anticipated that any uptake would be readily detected.

EXPERIMENTAL METHODS

Two areas, both of which had previously responded to nitrogen and sulphur, were selected.

Site 1.—The plot selected had a ground cover of kunai (*Imperata cylindrica*) and supported a very sparse stand of old coconuts. The soil was a deep volcanic ash, well supplied with phosphorus and bases, and typical of much of the Gazelle Peninsula. Frequent burning of grass had helped to induce a low nitrogen and sulphur status.

Vigorous seedlings with 5 to 6 leaves were selected from a slightly shaded nursery and planted in plots of 20 on a 10 ft square spacing. Four replicates of five treatments in a randomised block design were used. The close spacing was used as the experiments were of only 12 months' duration and hence inter-seedling competition would be expected to be negligible.

Site 2.—Another area of volcanic ash origin supporting a rather chlorotic sward of a *Sorghum* species was utilised. The area tended to be excessively wet on occasion.

Seedlings with 4 to 7 leaves were used from a trial comparing germination and development of partially dehusked nuts with unhusked nuts. Equal numbers of each type were allocated to plots of 16 seedlings and the design was similar to that used on Site 1.

Treatments

Treatments were as follows:

T1 = 4 oz ammonium sulphate at transplanting;

T2 = 4 oz ammonium sulphate 1 month after transplanting;

T3 = 4 oz ammonium sulphate 2 months after transplanting;

T4 = 4 oz ammonium sulphate 3 months after transplanting; and

T5 = Control (unfertilised).

Initial applications were followed by subsequent additions at 3-monthly intervals.

The amount of 4 oz of fertiliser was chosen as this dosage had resulted in good responses in previous experimets and was thought to be adequate at this stage.

Fertiliser was spread evenly over a circle about 3 ft in diameter around the base of the seedling. The fertilised area was clean-weeded every month and the remainder of the plots slashed simultaneously. Seedlings in the unfertilised plots were also clean-weeded and the grass slashed.

Recordings

The following records were taken:

(i) Height at monthly intervals;

(ii) Frond production at 3-monthly intervals; and

(iii) Fresh weights of the above-ground portion of seedlings at the termination of the experiment about 12 months after commencement.

Foliar Samples

Leaf samples from the newest fully opened fronds were collected from each plot at monthly intervals over the first 10 recordings while samples from the first, second, third and fourth youngest fronds were taken over the last two samplings. Replicates for each treatment were bulked in the latter case.

Analyses for sulphur and nitrogen were conducted by the Chemistry Section of the Department of Agriculture, Stock and Fisheries at Port Moresby.

RESULTS

General Observations

In general, unfertilised seedlings showed chlorotic symptoms within three months of transplanting while fertilised seedlings were a normal green colour even though height determinations failed to reveal any differences at that stage. Colour differences had become very obvious after four months when significant height differences between fertilised and unfertilised seedlings were recorded. In some instances a slight chlorosis was noted in the month prior to refertilising suggesting that fertiliser effect was short-lived. Seedlings at Site 1, probably as a consequence of initial growth in a shaded nursery, showed signs of sun scorch soon after transplanting.

Site 1

(i) Height.—Height measurements (as shown in *Table* 1) failed to reveal statistically significant differences between treatments until four months after transplanting, although fertiliser responses, in terms of better colour, were evident prior to this. Six months after transplanting, differences between fertilised and unfertilised seedlings were quite noticeable and seedlings fertilised one month after transplanting were significantly taller than those receiving their initial application either two or three months after field establishment. At 12 months all fertiliser seedlings were vastly superior to the unfertilised ones while differences, although not very marked, were noted between seedlings fertilised one month after transplanting and those fertilised at other times. It was noted that unfertilised seedlings at the completion of the experiment had not shown any growth (in height) over the whole period. This is attributed to severe nitrogen and sulphur deficiency and supports the contention that very few seedlings could be brought through to the bearing stage without adequate fertilising.

(ii) Frond production.—Cumulative frond production recordings shown in *Table* 2 did not show a consistent trend. There appeared to be a positive response to fertiliser 6 and 9 months after transplanting but none after 12 months. Overall frond production for the duration of the trial was lower than at Site 2 with an

Table 1.—Seedling growth at Site 1. Average heights (inches) at intervals after transplanting.

Treatment		3 Months	4 Months	6 Months	9 Months	12 Months
T1		45.4	49.4	51.6	57.5	60.7
T2		44.2	47.0	53.1	60.8	65.1
T3		44.9	46.5	50.0	59.5	60.8
T4		44.0	46.1	49.6	54.4	59.9
T5		44.1	40.6	38.8	41.0	43.8
Least significant difference	5%	Not significant	3.27	3.11	4.44	4.52
	1%		4.58	4.37	6.22	6.34

Table 2.—Seedling growth at Site 1. Average cumulative frond production at intervals after transplanting.

Treatment		3 Months	6 Months	9 Months	12 Months
T1		1.38	3.74	6.45	8.27
T2		1.43	3.80	6.57	8.46
T3		1.43	3.78	6.97	8.68
T4		1.41	3.95	7.86	9.91
T5		1.34	3.08	6.45	9.10
Least significant difference	5%	Not significant	0.36	0.83	Not significant
	1%		0.51	1.16	

average of 8.88 fronds per seedling produced over the 12-month period. This is possibly a reflection of periods of moisture stress.

(iii) Fresh weights.—The good response obtained from fertiliser application is shown in *Table* 3. Treated seedlings were about twice as heavy as untreated ones. Again an initial fertiliser application one month after transplanting appeared to produce the best response although differences between the four fertiliser treatments were barely significant.

Table 3.—**Seedling growth at Site 1. Average fresh weight 12 months after transplanting.**

Treatment		Weight (lb)
T1		5.06
T2		6.12
T3		5.69
T4		5.36
T5		3.10
Least significant difference	5%	1.00
	1%	1.40

Site 2

(i) Height.—Height measurements shown in *Table* 4 showed less definite differences than those at the other site. Significant differences between fertiliser treatments and controls were evident six and nine months after transplanting but not at 12 months. The lack of statistical significance was possibly a consequence of large experimenetal error arising mainly from variations in soil moisture although Site 2 was probably also less deficient than Site 1 as the control increased in height as much as fertilised treatments at Site 1.

(ii) Frond production.—Frond production comparisons (*Table* 5) failed to reveal any treatment effects. Overall frond production was slightly higher than at Site 1 with an average of 9.59 fronds being produced in 12 months.

Table 4.—**Seedling growth at Site 2. Average heights (inches) at intervals after transplanting.**

Treatment		3 Months	6 Months	9 Months	12 Months
T1		33.6	39.5	47.7	65.9
T2		34.8	40.1	43.3	66.3
T3		35.8	40.8	48.5	66.6
T4		34.0	40.4	47.2	69.9
T5		34.0	33.4	36.5	50.1
Least significant difference	5%	Not significant	4.19	7.82	Not significant
	1%		5.88	10.97	

Table 5.—**Seedling growth at Site 2. Average cumulative frond production at intervals after transplanting.**

Treatment	3 Months	6 Months	9 Months	12 Months
T1	1.57	3.66	7.43	10.17
T2	1.59	3.89	6.73	9.39
T3	1.56	3.84	6.84	9.39
T4	1.39	3.80	6.82	9.54
T5	1.61	3.55	6.80	9.47
Least significant difference	Not significant	Not significant	Not significant	Not significant

(iii) Fresh weights.—Fresh weight determinations (*Table* 6) showed a good response to fertiliser but failed to reveal any effects of time of initial applications.

Table 6.—**Seedling growth at Site 2. Average fresh weights 12 months after transplanting.**

Treatment		Weight (lb)
T1		6.34
T2		6.45
T3		5.95
T4		6.32
T5		3.31
Least significant difference	5%	2.15
	1%	3.02

Chemical Analyses

Nitrogen levels for Sites 1 and 2 are shown in *Tables* 7 and 8 respectively.

Levels varied greatly with time, from 2.04 to 1.48 per cent in unfertilised seedlings at Site 1, while 2.05 and 1.40 per cent were the corresponding values for Site 2.

In terms of leaf nitrogen, Site 2 showed slight uptake of nitrogen applied at transplanting but no uptake of nitrogen applied a month later. Site 1 failed to reveal uptake at the first two samplings. Uptake of nitrogen applied as ammonium sulphate within a month of transplanting appears to be very limited. At both sites weather conditions following application appeared to be suitable for uptake.

In most cases nitrogen applied two months or more after transplanting appears to have been absorbed in considerable amounts. Although absolute increases in nitrogen level did not always follow application, levels were maintained, suggesting that additional growth had balanced uptake, since levels in unfertilised seedlings decreased in the same interval.

At Site 2, fertiliser applied 4, 7 and 11 months after transplanting failed to affect nitrogen levels by comparison with levels in unfertilised seedlings. It was noted that rainfalls between the times of these applications and the next sampling were some of the lowest recorded. In absolute terms, however, the rainfalls received at Site 2 on these occasions were higher than those recorded on Site 1 on five occasions. On those five occasions nitrogen levels remained quite high. It is probable that sometimes a study of leaf content alone fails to elucidate the situation unless combined with a knowledge of assimilate production. Nitrogen may well have been absorbed but leaf levels only maintained or lowered through extra growth.

Responses to nitrogen fertiliser appear to be of relatively short duration. Three months after application, nitrogen levels in many cases had dropped considerably, occasionally to below that of unfertilised seedlings. The appearance of mild chlorotic symptoms at these stages points to inadequate nitrogen availability.

The position of the leaf sampled can affect levels, as illustrated in *Table* 9. One of the aims of analysing the four different positions was to determine if recently applied fertiliser was taken up into older leaves as well and whether levels in older leaves might remain higher for longer after fertilising than in young leaves. The two samplings, however, showed little sign of uptake of recent fertiliser, so little was achieved.

Generally, contents appeared to increase from the newest leaf to the third and to decrease in the fourth. There were exceptions, however, as with the eleventh determination at Site 1 where there was no consistent trend.

Tables 10 and 11 show sulphur levels for Sites 1 and 2 respectively.

As with nitrogen, levels of sulphur fluctuated considerably with time. The maximum and minimum levels for controls at Site 1 were 251 and 50 p.p.m. respectively while the corresponding figures for Site 2 were 245 and 45.

A definite, although suboptimal, uptake of sulphur applied at transplanting was evident at both sites. Applications of fertiliser a month after transplanting and thereafter resulted in high sulphur levels being attained. Only one application (10 months after transplanting at Site 1) showed a relative low sulphur level a month later.

In most instances, levels of sulphur were still high 3 months after application and longer intervals between applications may be warranted.

There appears to be little consistent relationship between sulphur levels and the positions of young fronds, as shown in *Table* 12.

Table 7.—Average nitrogen levels (percentage dry matter) of first fronds at Site 1.

Treatment	Transplanting	Time from transplanting (months) 1	2	3	4	5	6	7	8	9	10	11	12
T1	*	1.99	1.84	1.86*	1.92	1.90	1.93*	2.00	1.64	1.97*	2.09	1.94	1.70
T2		1.97*	1.89	1.92	1.54*	1.95	2.37	2.13*	1.82	2.13	1.76*	1.96	1.89
T3		1.96	1.75*	2.05	1.69	1.62*	2.30	2.29	1.82*	2.04	2.05	1.76*	1.69
T4		2.02	1.81	1.89*	2.01†	2.05	1.90*	1.84	1.58	1.87*	2.08	1.84	1.72
T5		2.04	1.82	1.80	1.61	1.59	1.86	1.75	1.64	1.91	1.88	1.78	1.48

* Denotes fertiliser application

† Average of three replicates

Table 8.—Average nitrogen levels (percentage dry matter) of first fronds at Site 2.

Treatment	Transplanting	Time from transplanting (months) 1	2	3	4	5	6	7	8	9	10	11	12
T1	*	1.90	2.11	1.90*	1.91	1.83	1.78*	2.17	1.86	2.00*	2.09	1.85	1.59
T2		1.79*	2.17	1.83	1.64*†	1.62	1.84	1.56*	1.26	1.66	1.76*	1.94	1.65
T3		1.80	2.06*	2.12	1.80	1.70*	2.35	2.00	1.61*	2.08	2.05	2.01*	1.49
T4		1.77	1.99†	1.80*	1.98	1.97	1.87*	2.15	1.90	1.99*	2.08	1.86	1.69
T5		1.80	2.05	1.76	1.76	1.89	1.82	1.59	1.40	1.87	1.88	1.57	1.47

Table 9.—Nitrogen levels (percentage dry matter) of four youngest fronds.

Treatment	Time from transplanting: 11 months, Frond 1	2	3	4	12 months, Frond 1	2	3	4
Site 1								
T1	1.94	1.96	1.93	2.07	1.70	1.87	1.94	1.86
T2	1.96	1.91	2.42	1.88	1.89	1.93	2.00	1.89
T3	1.76	1.96	2.02	2.04	1.69	1.78	2.05	1.89
T4	1.84	1.38	1.87	2.01	1.72	1.94	1.96	1.86
T5	1.78	1.74	....	1.60	1.48	1.61	1.85	1.77
Mean	1.86	1.79	2.06	1.92	1.69	1.83	1.96	1.85
Site 2								
T1	1.85	1.99	1.96	1.87	1.59	1.63	1.73	1.47
T2	1.94	2.01	2.12	2.06	1.65	1.79	2.00	1.76
T3	2.01	2.04	2.11	1.74	1.49	1.58	1.58	1.38
T4	1.86	2.02	2.11	1.93	1.69	1.83	1.72	1.39
T5	1.57	1.76	1.75	1.60	1.47	1.54	1.55	1.37
Mean	1.85	1.96	2.01	1.84	1.58	1.67	1.72	1.47

Table 10.—Average sulphur levels (p.p.m.) of first fronds at Site 1.

Treatment	Trans-planting	Time from transplanting in months 1	2	3	4	5	6	7	8	9	10	11	12
T1	*	185	361	334*	420	413	571*	673	693	713*	750	320	600
T2		96*	396	459	304*	510	624	651*	740	770	481*	228	560
T3		93	153*	470	353	313*	550	344	538*	634	800	570*	310
T4		98	158	171*	272†	300	541*	474	589	576*	765	735	250
T5		101	170	181	50	108	251	145	210	123	235	220	180

* Denotes fertiliser application

† Average of three replicates

Table 11.—Average sulphur levels (p.p.m.) of first fronds at Site 2.

Treatment	Trans-planting	Time from transplanting in months 1	2	3	4	5	6	7	8	9	10	11	12
T1	*	149	324	305*	433	395	628*	473	575	674*	750	860	644
T2		71*	669	633	360*†	785	526	508*	501	440	481*	455	415
T3		81	168*	791	455	433*	560	526	684*	685	800	955*	725
T4		79	133	164*	378	550	718*	605	489	749*	765	745	675
T5		68	158	189	45	75	219	185	202	219	235	180	245

* Denotes fertiliser application

† Average of three replicates

Table 12.—Sulphur levels (p.p.m.) of four youngest fronds.

Treatment	Time from transplanting: 11 months, Frond 1	2	3	4	12 months, Frond 1	2	3	4
Site 1								
T1	320	970	710	835	600	655	405	590
T2	288	810	945	430	560	655	500	735
T3	570	520	645	470	310	600	365	540
T4	735	655	195	580	250	470	230	510
T5	220	225	....	190	180	95	180	110
Mean	427	638	624	501	380	495	336	497
Site 2								
T1	860	1005	1085	640	644	710	760	587
T2	455	530	445	770	415	550	530	540
T3	955	830	770	675	725	600	620	570
T4	745	1040	820	945	675	620	590	613
T5	180	....	230	205	245	210	180	245
Mean	639	851	662	647	541	538	536	511

DISCUSSION AND CONCLUSIONS

Chemical analyses of the youngest frond demonstrated that coconut seedlings transplanted with 4 to 7 leaves can absorb sulphur and nitrogen quite soon after field planting. Ammonuim sulphate applied at transplanting resulted in significant increases in sulphur levels within a month of application, while responses, in terms of increases in leaf nitrogen, became consistently evident when fertiliser was applied two months or later after field planting. Uptake of sulphur reached its maximum level from sulphate of ammonia applied as early as one month after transplanting.

It would appear that, despite damage to the seedlings' absorptive system at transplanting, added nutrients can be utilised in substantial quantities when applied as early as two months after transplanting and can be absorbed in limited quantities even sooner. The greater early response to sulphur is probably a consequence of its being required in much smaller quantities than nitrogen and the readily available form in which it was applied.

The occasional apparent lack of response in terms of leaf nitrogen content subsequent to fertiliser application could have a number of explanations. It is difficult to ascertain uptake in such cases, unless growth responses are known, preferably in terms of dry matter produced, as uptake may be utilised in extra assimilate production. In such cases leaf levels may remain constant or even decrease. Apart from this consideration, fluctuations in apparent response will also depend on nutrient availability following application, losses through leaching, and the capacity of the seedling to absorb and utilise nutrients. Large fluctuations in nutrient levels of unfertilised seedlings from month to month were obviously tied up with variations in environmental conditions, soil moisture probably being dominant although consistent simple relationships between rainfall and leaf nutrient levels were not evident. A survey of literature by Richards and Wadleigh (1952) appeared to indicate that plants grown at low moisture contents are relatively high in nitrogen, low in potassium, and sometimes low and at other times high in phosphorus, calcium and magnesium. Apparently insufficient moisture supply limits utilisation of nitrogen more than is does uptake. This phenomenon may offer a partial explanation for the substantial variation in nutrient levels in unfertilised seedlings as well as occasional anomalies in the response to fertiliser application.

The dangers of relying on single or limited samplings of young fronds as indicators of nitrogen status, especially without appropriate field descriptions, are demonstrated by analyses of unfertilised seedlings. Unfertilised seedlings, however, served as a useful basis for assessing uptake of fertiliser. For instance, the uptake of a nitrogen application two months after transplanting is indicated by comparing unfertilised levels which, although high at the time of fertilisation, had dropped sharply by the following month, with fertilised levels, which remained about constant.

The relatively short effect of ammonium sulphate as a source of nitrogen was noted. Levels often dropped within three months of application, suggesting the need for more frequent or heavier applications or preferably a fertiliser capable of releasing nitrogen gradually. This contention was supported by the frequent appearance of chlorotic symptoms within three months of fertiliser application. Sulphur levels appeared to be maintained at adequate levels for a considerable time suggesting that less frequent applications of sulphur would suffice. This would be particularly true if sulphur were supplied as granular elemental sulphur.

There was substantial agreement between indications from chemical analyses and growth measurements. The superiority of seedlings fertilised initially one month after transplanting at Site 1, as indicated by height and fresh weight determinations, resulted probably from sulphur uptake preventing the occurrence of a deficiency. The appearance of deficiency symptoms within three months of transplanting in the absence of fertiliser points to a need for added nutrients at a relatively early stage on deficient soils. An initial fertiliser application is recommended four to six weeks after transplanting under conditions similar to those described. However, the absence of outstanding differences in growth between seedlings receiving first fertiliser applications at varying intervals up to three months from transplanting suggests that as long as applications are made within three months growth is not greatly retarded.

Despite the ability of seedlings in these experiments to utilise supplementary nutrients relatively soon after transplanting, growth in the first 12 months was relatively poor. The destruction of much of the seedlings' root systems at transplanting was followed by a slow regeneration and an obvious retardation of growth. Alternative methods of transplanting are needed.

One approach would be to transplant at a stage where most growth needs are still derived from internal sources so that root damage at field planting would have only a minor effect on growth. A quick regeneration of roots could be expected and hence hindrance to nutrient and moisture uptake should be minimised. Fertiliser could then be applied effectively when needed. This method has its drawbacks in that it lessens the efficiency of nursery selection based on seedling vigour as well as necessitating a longer maintenance period in the field, with a resulting increase in costs.

A suggested technique is the growing of seedlings in earth-filled bags, as is done successfully with oil palms and has been shown to be promising by Foale (1968b) with coconut seedlings. Seedlings are germinated, then transferred and set upright in 'polybags' (tough polythene bags) where they are grown for a prolonged period before transfer to the field. Details of optimum bag sizes, fertiliser requirements and ideal stage for transplanting need to be worked out.

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