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TERRITORY OF PAPUA AND NEW GUINEA

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ABSTRACTS

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J. H. SUMBAK. *Papua New Guin. agric. J.*, 22 (1) : 1-5 (1970)

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Observations on coconut palm characteristics and the growth of crops such as young oil palms, cacao and leucaena, together with sunshine recordings, strongly point to insufficient insolation as being the direct cause of poor coconut development in this area.

Insect pests are not considered to be of much importance but fungal diseases, especially White Thread Blight (*Corticium penicillatum*), cause considerable damage. The author suggests that fungal diseases are a secondary cause as they are undoubtedly induced by high rainfall and frequent periods of low sunlight. While unsatisfactory nutrition is sometimes evident, an overriding soil deficiency (or deficiencies) is not the main cause of poor performance. Genetically inferior planting material could be a contributing factor, but this has yet to be tested. Undoubtedly poor drainage for prolonged periods is of some consequence but poor growth is also evident where drainage is satisfactory.

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

J. H. SUMBAK. *Papua New Guin. agric. J.*, 22 (1) : 6-25 (1970)

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.

[*continued overleaf*]

IMPROVED PASTURES FOR PAPUA AND NEW GUINEA

G. D. HILL. *Papua New Guin. agric. J.*, 22 (1) : 31-58 (1970)

These notes are a synthesis of currently available information on pastures in the Territory. They cover certain aspects that are peculiar to the Territory environment, including the problems of maintaining production in the drier season of the year, storage of seed in the lowlands, and the possible need for fertilizers and their efficient use on pastures.

A comprehensive list of pasture grasses and legumes which have been tried in the Territory is included, with recommendations as to the environment to which they are best suited. Brief information is also given on suggested methods of establishment and management.

COFFEE ERADICATION IN A PREVIOUSLY COFFEE RUST INFECTED AREA IN PAPUA

DOROTHY E. SHAW. *Papua New Guin. agric. J.*, 22 (1) : 59-61 (1970)

The results of regular inspections of two areas in Papua from which coffee and coffee rust were eradicated in 1965 are reported. Mature coffee bushes, seedlings and regrowth suckers located at some sites on some inspections were destroyed. No coffee rust was recorded during the surveys.

ERRATA

Papua and New Guinea Agricultural Journal,

Volume 22, No. 1 (1970).

Page 18. In *Table* 12, columns 3, 6 and 9, each of the values given should be preceded by +, thus:

+5.1, +8.1, +20.7, +11.4, +48.5, +56.1
+18.6, +142.7, +243.4

Page 20. In *Table* 16, below columns 6 and 7, read "Interaction not significant".

Page 21. In *Table* 17, column 3, the last line should read 39.8.

Page 22. In *Table* 19, column 7, the last two lines should read 720.0 and 221.6

Page 29. In column 2, 2nd last line, read *Porlutaca oleracea* for *Porlutaca oleraceae*

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CONTENTS

* The *Papua and New Guinea Agricultural Journal* is no longer produced on a regular quarterly basis, but only when sufficient material is available. Volume 22 will include this issue and all issues appearing during 1971. After 1971, each volume will cover one calendar year.

POOR COCONUT GROWTH IN SOUTH-WEST BOUGAINVILLE

J. H. SUMBAK*

ABSTRACT

Possible reasons for unthrifty growth of coconuts in south-west Bougainville were examined.

Observations on coconut palm characteristics and the growth of crops such as young oil palms, cacao and leucaena, together with sunshine recordings, strongly point to insufficient insolation as being the direct cause of poor coconut development in this area.

Insect pests are not considered to be of much importance but fungal diseases, especially White Thread Blight (Corticium penicillatum), *cause considerable damage. The author suggests that fungal diseases are a secondary cause as they are undoubtedly induced by high rainfall and frequent periods of low sunlight. While unsatisfactory nutrition is sometimes evident, an overriding soil deficiency (or deficiencies) is not the main cause of poor performance. Genetically inferior planting material could be a contributing factor, but this has yet to be tested. Undoubtedly poor drainage for prolonged periods is of some consequence but poor growth is also evident where drainage is satisfactory.*

INTRODUCTION

A LARGE area of south-west Bougainville is suffering from poor coconut performance. Broadly speaking the syndrome consists of reasonable early growth, followed by a slowing down of development, tardiness in bearing and very poor production. A survey showed the unthriftiness to be widespread although palms near the coast were somewhat better than those further inland, but generally speaking the majority of palms were poor, characterized by upright fronds, few spathes and even fewer nuts. A few reasonable stands were noted.

The exact areas of numbers of palms affected are not known. An approximate count for the Siwai area (G. D. Hill, pers. comm.) was:—

10,000 palms on the coast;

20,000 palms in the flat hinterland, 5 to 15 miles inland; and

20,000 palms in the mountain areas.

Coconuts were healthy and green up to a mile or so inland and bearing at four and a half years. The coconuts in the hinterland were very poor (80 per cent bearing lightly or not at all) with stems long and thin in the older trees, leaves slightly yellow and tending to dry off prematurely in some cases. Leaves were thin and pointing up instead of being thickly bunched. Patches of better palms were noted. Sixty per cent of the mountain coconuts were reported to be well grown and bearing in six years or so but areas of poor coconuts were also evident.

R. V. Frost (pers. comm.) gave the following approximate figures for the four Census Divisions of the Buin Administrative areas:—

25,000 palms in coastal villages;

55,000 palms from 5 to 15 miles inland (hinterland); and

20,000 palms in mountain villages.

He described palms in the hinterland as very stunted, thin-stemmed with very erect pale green fronds. Isolated areas of healthy palms occurred. The coastal belt was generally better with the palms deeper in colour and approximately half producing by the sixth year. These areas were subject to a very high water table for most of the year. There appeared to be a lower incidence of disease. The mountain area (300 to 500 ft) had less disease but only one or two areas which bore in the sixth year. Palms grew to 30 to 40 ft, had pale green leaves, thin trunks and erect fronds.

Factors that could affect performance are discussed below.

* Agronomist, Lowlands Agricultural Experiment Station, Keravat.

POSSIBLE CAUSES OF POOR GROWTH

Pests and Diseases

Although T. L. Fenner (pers. comm.) found *Axiagastus* present in considerable numbers he concluded that this pest was not a major cause of unthriftiness and that it was equally present in all sections. The author noted little evidence of insect damage and *Axiagastus,* although it had been reported to be a menace from time to time, was not conspicuous. Frost (pers. comm.) noted that rhinoceros beetle and other beetles caused negligible damage and affected less than five per cent of palms. Pests are certainly not a major contributing factor to poor performance.

Most palms suffered seriously from fungal attack. White Thread Blight (*Corticium penicillatum*) was the prevalent disease (T. L. Fenner, pers. comm.). R. V. Frost (pers. comm.) reported in 1969 that more than 50 per cent of palms were affected by White Thread Blight and attributed this to the heavy rainfall (185 inches in the preceding nine-and-a-half months). Leaf spot disease, probably attributable to *Pestalotsiopsis palmarum*, was also noted, mainly on the older fronds. Fungal damage probably contributes to poor performance through reduction in effective photosynthetic area.

Planting Material

Genetically inferior planting material is a possibility. In certain isolated geographical areas palms are probably derived from a limited number of nuts and the resultant population would be inferior if these were, by chance, genetically poor.

For a conclusive test of whether Buin palms are of genetically inferior stock it is intended to plant Buin seednuts and seednuts from other sources (probably New Ireland and Buka) for a comparison of growth of each strain, both at Buin and at the Lowlands Agricultural Experiment Station, Keravat.

Nutrition

Soil and foliar samples have been collected from the area under consideration on a number of occasions. While unsatisfactory nutrition has been noted occasionally, nothing consistently amiss has been detected. *Table* 1 gives details of foliar analyses from samples of fronds collected in November 1965. The samples were fourteenth fronds or oldest fronds in the case of some palms which had fewer than fourteen fronds. Samples came from various sites in the Buin area. In addition, one sample was included from palms with yellowish fronds on the DASF station at Kubu, Sohano (Buka Island).

Table 1.—Analysis of coconut fronds, Buin District, November, 1965

Location	Per cent N	Per cent P	Per cent K	Per cent Ca	Per cent Mg	p.p.m Mn	p.p.m. Fe	p.p.m. Cu	p.p.m. Zn.	p.p.m. B
Malabita No. 1	1.14	0.100	0.34	0.74	0.402	87	439	3.8	144	20.3
Malabita No. 2, owner Mim	1.48	0.144	1.60	0.37	0.120	67	74	4.0	32	19.6
Malabita No. 2, owner Numaman	1.24	0.115	1.44	0.49	0.130	40	57	2.3	39	21.0
Malabita No. 3, owner Perokana	1.50	0.131	1.66	0.30	0.108	52	57	4.0	17	22.0
Musiminoi, village Siwai	1.69	0.167	1.18	0.39	0.090	122	58	5.8	23	15.3
Laguai	1.69	0.146	1.40	0.41	0.091	57	63	9.3	36	16.8
Kangu Government Plantation	1.27	0.110	0.78	0.37	0.167	116	100	6.0	18	16.8
Unanai village, Diwai	1.53	0.144	1.58	0.45	0.116	50	39	4.5	24	20.3
Mava village, Nagovissi	1.46	0.139	0.84	0.59	0.250	139	34	3.3	39	21.0
Sisirvai, Nagovissi	1.32	0.120	1.12	0.51	0.193	164	34	3.3	42	14.8
Loro, Nagovissi	1.54	0.131	1.46	0.61	0.100	198	38	4.3	39	16.0
DASF Sohano (from palms with yellowish fronds)	1.84	0.191	1.86	0.25	0.091	26	34	5.8	23	9.6
Critical levels proposed in T.P.N.G.	1.7	0.12	0.9	0.4	0.25	30	40	2.5	10	10

Nitrogen.—Contents are generally below the critical level. However, a private agricultural consultant, Mr L. A. Bridgland, who had inspected the sampled palms, commented that their appearance did not suggest nitrogen deficiency.

Phosphorus.—Contents are generally adequate with one or two low analyses.

Potassium.—Levels are adequate to high. High potassium levels could be limiting magnesium uptake.

Calcium.—Generally adequate and as calcium contents are affected by the uptake of other nutrients it is not considered that a calcium deficiency exists.

Magnesium.—With two exceptions magnesium levels tend to be somewhat low. This is probably due to high potassium levels limiting magnesium uptake. Note that Malabita No. 1 and Mava Village, Nagovissi, which are highest in magnesium were lowest in potassium. DASF Sohano samples, from yellowish palms were low in magnesium, yet palms there are quite productive. Although magnesium levels tend to be on the low side it is not considered that a magnesium deficiency is an important factor in poor coconut growth.

Trace Eelements.—Contents are very variable but, on the whole, satisfactory. In the Malabita No. 1 sample iron and zinc levels were extraordinarily high; however, contamination is suspected as a later sample from the same area failed to reveal similar levels. Boron levels were somewhat higher than usual but there was no suggestion of toxicity.

All in all, these analyses did not suggest that lack of any nutrient or combination of nutrients was the primary reason for poor growth. Sulphur levels were not determined so sulphur deficiency remained a possibility.

Results of analyses of fronds and nut waters collected in November 1966 on the whole were similar to the 1965 analyses (*Tables* 2 and 3). Nitrogen levels tended to be low but levels in poor palms were similar to those in good palms. The extremely high levels of zinc and iron found in the previous Malabita samples were not repeated. Magnesium was again low and potassium levels high while the sulphur status appeared satisfactory.

Analyses of soil and plant samples collected by a private consultant failed to show any serious nutrient problems.

The good growth of cacao (a shade loving tree) and leucaena tend to suggest that there is little wrong with the nutrient supply in these soils.

The poor growth of oil palms relative to other Territory areas, despite regular fertilizing, suggests that factors aside from nutrition are involved.

Drainage

Poor drainage in some areas would adversely affect growth. At Malabita large planting holes (approx. 3 ft x 3 ft x 3 ft) often remain filled with water to within four to six inches of the surface for five or six months of the year. Obviously the rooting area of the palm would be limited severely and a considerable stress applied

Table 2.—Analysis of coconut fronds, Buin Area, November, 1966

Location	Appearance of Palms	Leaf No.	Per cent N	Per cent P	Per cent K	Per cent Ca	Per cent Mg	p.p.m. S	p.p.m. Mn	p.p.m. Fe	p.p.m. Zn	p.p.m. Cu	p.p.m. B
Kangu	Good	4	1.57	0.153	1.50	0.34	0.171	....	....	....	....	....	....
Kangu	Good	9	1.49	0.157	1.50	0.25	0.162	240	60	29	15.3	4.5	13.0
Kangu	Good	14	1.54	0.153	1.74	0.21	0.140	....	52	28	13.8	....	12.5
Malabita	Poor	4	1.71	0.183	2.40	0.26	0.142	....	34	20	22.8	9.5	9.5
Malabita	Poor	9	1.61	0.183	1.94	0.34	0.182	380	46	26	55.0	7.0	10.0
Malabita	Poor	14	1.50	0.190	1.78	0.40	0.150	....	50	27	27.0	7.0	13.5
Kogu	Good	4	1.66	0.188	1.76	0.27	0.095	....	30	23	35.0	4.8	10.5
Kogu	Good	9	1.74	0.193	1.38	0.46	0.119	360	49	40	39.0	4.8	10.5
Kogu	Good	14	1.80	0.170	1.32	0.50	0.098	....	52	34	24.3	5.0	16.8
Kogu	Poor	4	1.63	0.222	2.18	0.31	0.121	....	39	27	38.9	7.6	....
Kogu	Poor	9	1.65	0.212	1.74	0.40	0.136	450	52	29	31.8	6.3	....
Kogu	Poor	14	1.70	0.203	1.70	0.44	0.121	....	53	24	31.8	4.9	16.8

Table 3.—Analysis of coconut waters, Buin area, November, 1966

Location		Appearance of Palms	K (m-equiv./l)	Comments	p.p.m. S	Comments
Kogu	....	Good	72.9	High	49	High
Malabita	....	Poor	65.5	High	60	High

to the palm. Areas similar to Malabita appeared to be common. Poor palms, however, also occur on well drained sites such as hillsides.

It was concluded that, while bad drainage is not the main factor responsible for poor development in the Buin area, it probably contributes to poor growth in some localities.

Insolation

Heavy and continuous cloud cover might be of importance. Often the amount of bright sunshine was less than two hours a day. As the palm is a heavy light demander, such conditions could restrict development severely. The appearance of poor palms was similar to that of shaded palms attempting to reach light, such as when planted under leucaena shade in mixed coconut and cocoa plantings, or in closely planted groves.

The poor growth of light-demanding crops such as oil palm and coconuts and the excellent growth of shade-loving crops such as cocoa and leucaena (which grows well under full sun but tolerates shade) supports the theory of inadequate insolation. Sago palm development is also reported to be poor in the Buin area.

Sunshine recordings for a limited period are shown in *Table* 4 compared with figures for areas where coconuts and oil palms do well (N. J. Mendham, pers. comm.).

Buin records have been consistently low particularly when compared with Aropa, only some 40 miles away. Oil palm growth at Aropa is much superior to that at Buin.

The existence of better palms or groups of better palms can probably be attributed to a number of factors. Local reports state that rainfall in the immediate vicinity of the coast is somewhat less than inland. If this is so it probably follows that sunshine would also be greater and hence the better performance of coastal palms.

The topography of the country could have some effect on palm performance. As an example it is likely that palms on a slope facing the east would get more sunshine than palms on a western slope as cloud cover could be expected to be greater as the day progresses.

Possibly some palms are better users of available light than others and these would be expected to give better performance. In theory, selection for tolerance to low light conditions could be carried out but the task would take too long to be practicable.

Table 4.—Sunshine at Buin and other locations (Jordan Sunshine Recorder)

Date	Average Daily Sunshine (hours)			
	Buin	Keravat	Aropa	Tigak
September, 1968	....	7.01	....	6.31
October	4.32	5.89	....	5.57
November	2.84	5.47	....	4.79
December	3.69	5.24	....	4.75
January, 1969	2.77	3.15	4.20	4.37
February	3.46	3.50	4.41	5.26
March	3.99	4.49	6.35	4.26
April	4.59	4.24	5.39	4.21
May	4.61	6.01	6.58	6.47
June	4.22	7.20	6.39	5.17
July	3.66	5.93	6.48	3.36
August	2.15	5.08	4.64	4.30
September	2.61	3.86	6.28	3.00
TOTAL	1304*	1825	2055*	1687

* The total hours are only approximate, having been adjusted for missing months.

CONCLUSIONS

Observations of coconut palm characteristics, and growth of oil palm, cocoa and leucaena, together with sunshine recordings, strongly point to insufficient insolation as being the direct cause of poor coconut development in the Buin area.

Fungal disease, inadequate drainage and poor nutrition may be contributing factors, particularly in some locations. Control of disease is not practicable because of cost of fungicides, difficulty of application and lack of persistence under high rainfall conditions, although improved drainage may reduce disease incidence where there is any tendancy to waterlogging. Further attention to the nutritional status of the palms will be given in a planned nutritional survey. Comparison of Buin seedlings with seedlings from other sources will show to what extent poor planting material may be involved.

However, the prospects of finding a practical means of improving coconut growth do not seem good. It is therefore recommended that plantings of coconuts be discouraged in this area and that substitute crops be sought.

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J. H. SUMBAK*

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 deleterious. 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 exercized 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
	CB	4		3		3		10
	2L	3		0		2		5
C.W.	4L	1		1		3		5
	7L	0		1		1		2
	CB	0		3		1		4
R.S.	2L	1		1		0		2
	4L	2		1		6		9
	7L	3		3		2		8
	CB	0		1		1		2
I.S.	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	

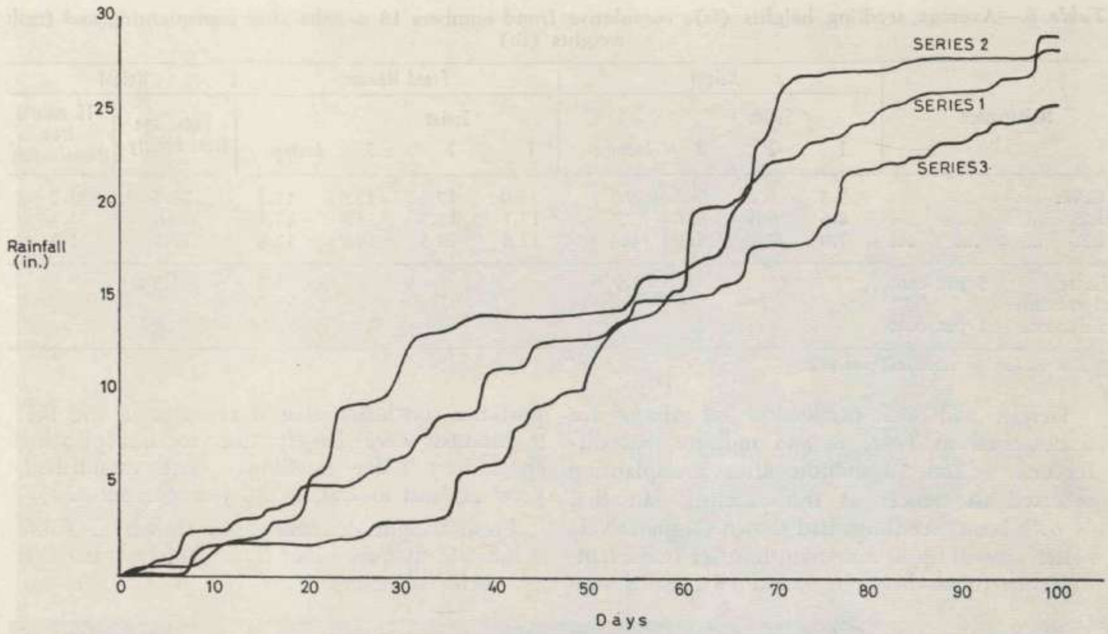

Figure 1.—Cumulative rainfall over first 100 days after transplanting

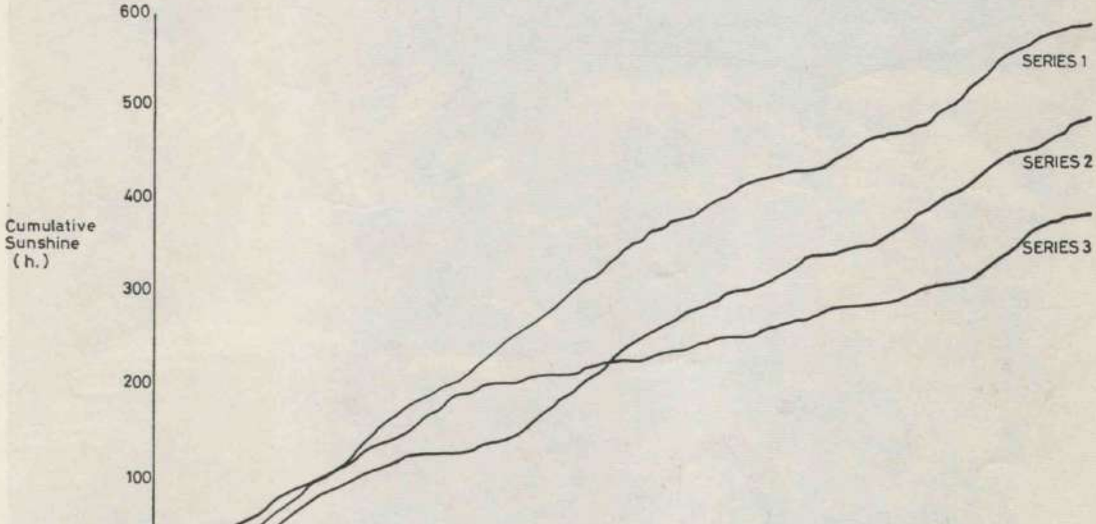

Figure 2.—Cumulative sunshine over first 100 days after transplanting

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	5 per cent				1.9				1.2	31.3	*
difference	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 support 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 onces.

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.

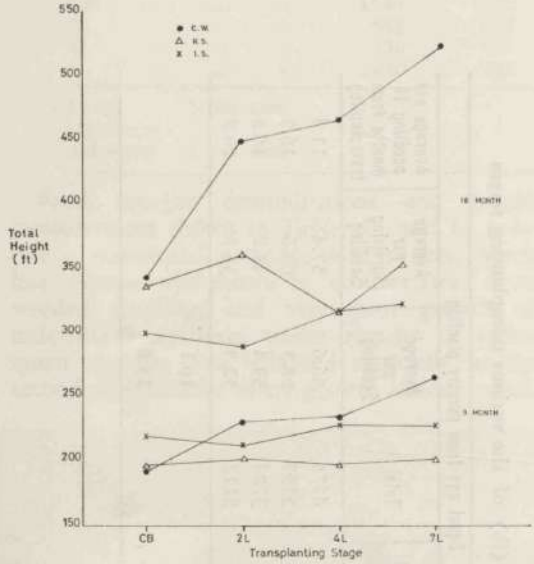

***Figure* 3.—Heights of transplanting stages under various maintenance systems nine and 18 months from field planting**

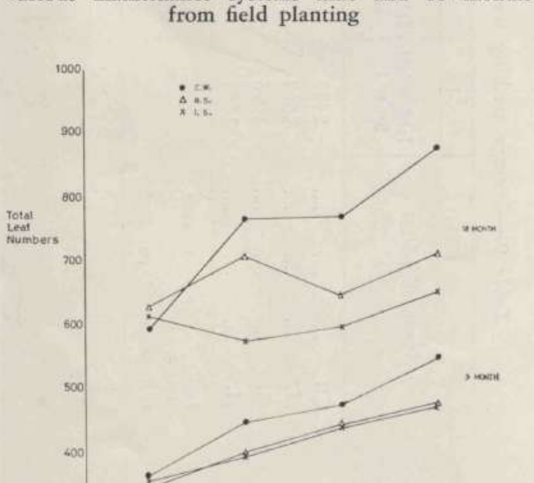

***Figure* 4.—Frond production of transplanting stages under various maintenance systems nine and 18 months from field planting**

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: 9 months +F	Height: 9 months —F	Height: 18 months +F	Height: 18 months —F	Height gain in last 9 months +F	Height gain in last 9 months —F	Frond Production: 9 months +F	Frond Production: 9 months —F	Frond Production: 18 months +F	Frond Production: 18 months —F	Leaf no. in last 9 months +F	Leaf no. in last 9 months —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: +F	Equal age from nursery planting: —F	Equal age from nursery planting: Percentage Response	18 months from transplanting: +F	18 months from transplanting: —F	18 months from transplanting: 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	

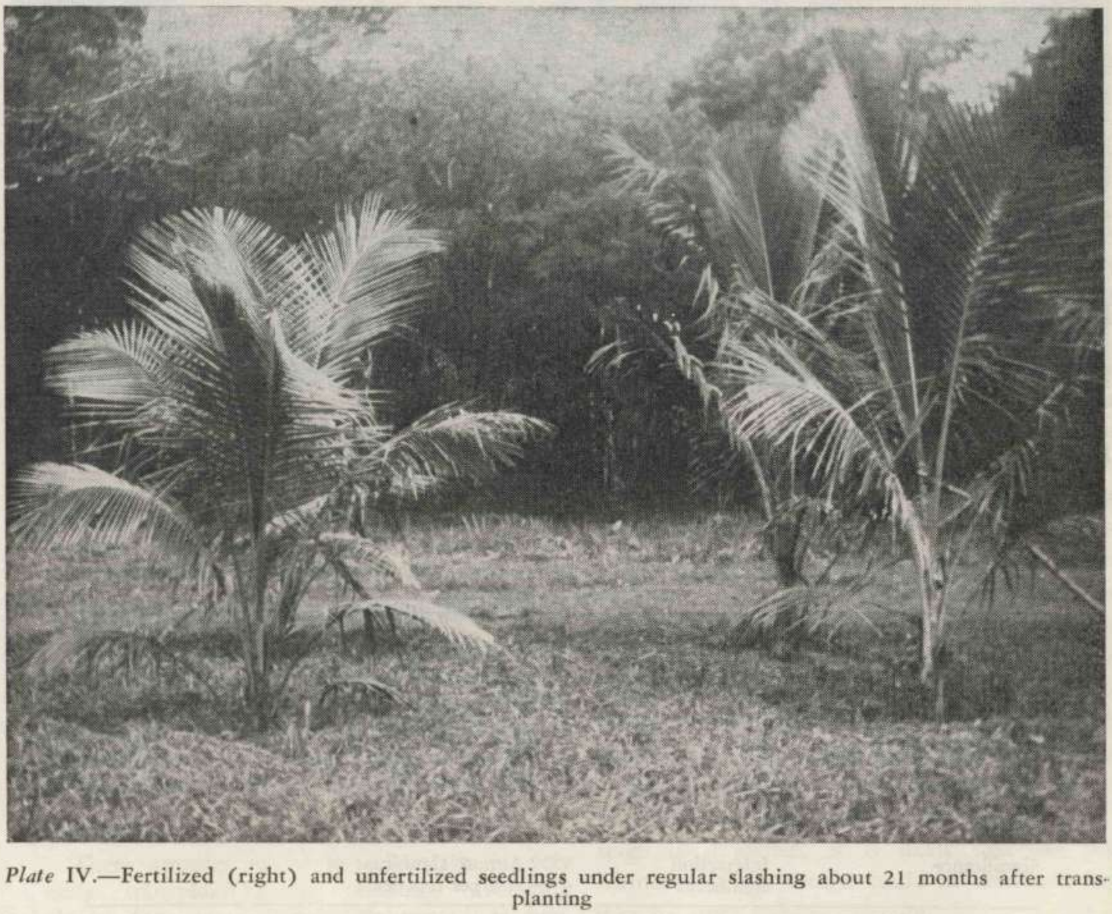

Plate IV.—Fertilized (right) and unfertilized seedlings under regular slashing about 21 months after transplanting

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 competion for nutrients is an important factor, especially under slashing treatments. Soil moisture and light availablity 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. Competion 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 competion 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.

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RESPONSE OF WHITE SPANISH PEANUTS TO APPLIED SULPHUR, INOCULATION AND CAPTAN SPRAYING IN THE WET LOW-LANDS OF NEW GUINEA

G. D. HILL*

ABSTRACT

White Spanish peanuts were sown at Bubia, near Lae with applications of 0, 25, 50 *and* 100 *lb per acre of elemental sulphur. At the same time inoculation and spraying treatments were imposed. There were very highly significant increases in yields of kernels to the applied sulphur up to* 50 *lb per acre. Production of shell increased only slightly. Part of the increased yield can be explained by the significant increase in nut size on sulphur-treated plots. One hundred pounds of sulphur per acre gave a slightly lower yield than* 50 *lb per acre. Responses to inoculation and captan, which both appeared to cause a slight reduction in yield, were not significant.*

INTRODUCTION

FOR some years peanut growers in the Markham Valley have been concerned by reduced yields. Work in Africa (Bockelee-Morvan and Martin 1966) has shown that the application of sulphur at levels of 10 kg per hectare was sufficient to produce significant increases in peanut yields in areas where this element was deficient. Sulphur is believed to increase the oil content of the nuts, and to increase nodulation and the number of nuts remaining attached to the vines (Feakin 1967).

Southern (1967) has reported sulphur deficiency in coconut plantations in three areas near Lae and it is possible that a deficiency of this element could also be influencing peanut yields. An experiment was conducted to determine yield response to sulphur by peanuts. At the same time a check was made on the desirability of inoculation (not commonly practised) and to determine if spraying with a fungicide post emergence could control *Cercospora* leaf spot (*Cercospora personata*).†

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† *Cercospora personata* (Berk. and Curt.) Ellis and Everhart, now *Cercosporidium personatum* (Berk. and Curt.) Deighton (perfect state *Mycosphaerella berkeleyi* W. A. Jenkins).

MATERIALS AND METHODS

The trial was sown at Bubia on a brown clay loam on the 9th to 11th October, 1968.

The treatments were elemental sulphur at 0, 25, 50 and 100 lb per acre, inoculated and uninoculated, and captan sprayed and not sprayed.

Sulphur and inoculation treatments were fully randomized within blocks. Complete blocks were split for captan spraying. There were four replicates.

The size of each plot was 11.25 ft x 33 ft, each plot comprising five rows of peanuts spaced 2.25 ft apart. Distance between seeds within the row was 4 in. This was the most common row spacing and sowing rate used by commercial growers in the Markham Valley (Vance, pers. comm.). There were 32 plots altogether and the total area occupied by the trial was 90 ft x 147 ft.

The seed used in the trial was obtained from two commercial properties in the Markham Valley and was mixed prior to sowing.

Sulphur Application

To ensure the sulphur did not kill the inoculum because of its fungicidal properties, sulphur was placed at a depth of three inches below the surface of the soil. The seed was sown above it at a depth of one inch. The sulphur was therefore not in direct contact with the germinating seed.

Inoculation

Seed sown in inoculated plots was inoculated with *Rhizobium* strain CB 756 immediately prior to sowing. Uninoculated plots were sown first and precautions were taken to make sure no inoculum or inoculated seed was allowed to fall onto these plots.

Fungicide Application

The fungicide used was captan (N-(trichloromethylthio) cyclohex-4-ene-1,2 dicarboximide). It was applied at the rate of 2 lb per acre in 40 gallons of water using a knapsack spray. The initial application was made three weeks after sowing and further applications were made at two-weekly intervals until harvest.

Harvesting

The trial was harvested on 20th January, 1969. At harvest each plot was split into two subplots 11.25 ft x 15 ft. A guard strip of 3 ft was left between captan-sprayed and unsprayed halves of each block. Within subplots three rows 13 ft long were harvested.

Whole plants were pulled and allowed to dry in the sun for three days. After this nuts were detached from the plants and further sun-dried until the kernel rattled in the shell.

Records collected were:—

(1) Yield of nuts in shell;

(2) Yield of kernels; and

(3) Mean number of kernels per ounce.

This last measurement was determined by taking the weight of five random samples of 100 kernels from each treatment and from this determining the mean number of nuts per ounce. This measurement is of importance as export quality nuts must have no more than 57 kernels per ounce.

RESULTS AND DISCUSSION

Response to Inoculation

No visual response to inoculation was apparent at any stage. Two months after sowing three plants from each treatment were pulled from each treatment block and observations made on the number and size of nodules present. All plants were well nodulated and there was no indication that nodules on inoculated plants were any more efficient than those on uninoculated plants. The mean yield of kernel from inoculated plots was 1836 lb acre and that from uninoculated plots was 1882 lb per acre. Analysis showed that the values were not significantly different.

Response to Fungicide

All plots, sprayed and unsprayed, showed evidence of *Cercospora,* to the extent of two or three spots per leaf. On visual assessment of the incidence of disease it was not possible to separate sprayed and unsprayed split blocks. Bockelee-Morvan and Martin (1966) suggest that the application of sulphur increased the general health of the plants by limiting *Cercospora* attack. This may have occurred in this trial; however plots with no sulphur did not show increased infection within unsprayed subblocks.

The mean yield from sprayed plots was 1843 lb kernels per acre, while that from unsprayed was 1874 lb. The difference between the two treatments was not significant.

Response to Sulphur

(i) *Yield*

The mean yield of nuts in shell and kernel for the various sulphur treatments is shown in the *Table*. Response to the applied sulphur in production of kernels was very highly significant ($P<0.001$). It is also of interest to note that beyond an application of 50 lb of sulphur per acre there was a slight decline in yield. This would indicate that for the soil concerned the applications had gone beyond the region of maximum response.

Fitting of polynomials to the kernel yield showed that the results were best described by a quadratic equation which was:—

$$Y = 1688.216 + 8.708x - 0.0641x^2$$

where Y=yield of kernel and x=lb of sulphur applied. By differentiating the equation when $\frac{dy}{dx} = 0$, the point of theoretical maximum response to sulphur is obtained; this is with an application of 70 lb of sulphur which should give a yield of 1984 lb of kernel. This point is not necessarily the most economic. This will depend on the relative price of sulphur and peanuts.

Apart from the response to sulphur the yield of the no-sulphur plots is also of interest. Vance (pers. comm.) had found that growers' yields had declined from 1200 lb kernel per acre to 600 lb. It was popularly believed by the growers that the seed had suffered "genetic decline". The yields from the control plots indicate that under suitable conditions the seed currently being used by Markham Valley peanut growers still has the potential for high yields. It would appear therefore that the reduced yields were related to factors other than decline of seed quality.

(ii) *Seed size*

The mean number of seeds per ounce for the various sulphur treatments is shown in the *Table*. Analysis indicated that overall sulphur treatments were not significant. However partition of the degrees of freedom to compare S— with the three levels of S+ indicated that the comparison was significant ($P<0.05$). The sulphur treatment had therefore significantly increased the size of the nuts.

(iii) *Threshing percentage*

The threshing percentage for the sulphur treatments is shown in the *Table*. Although the differences appear to be very small, analysis showed the sulphur treatment to be significant ($P<0.05$). Partitioning of the degrees of freedom for the sulphur treatments showed that the comparison S— with S+ was very highly significant ($P<0.001$). This means that, in addition to the increased yield overall, the grower would obtain on average over all sulphur treatments an extra 1.6 lb of kernel per 100 lb of nuts threshed.

It would appear therefore that the increased yield can be explained almost entirely on the basis of increased kernel production, part of which was due to the increase in kernel size with sulphur application. There was only a slight increase in amount of shell produced over all treatments (*Table*).

It is apparent that the results cannot be fully explained on the basis of more nuts remaining attached to the vines as a result of sulphur treatments, as threshing percentage can only be determined on the nuts actually harvested.

CONCLUSIONS

The high yield of peanuts from the control plots indicates it is most unlikely that there has been a "genetic decline" of White Spanish peanuts grown in the Markham Valley. Application of sulphur, even at 25 lb per acre, increased significantly nut size and threshing percentage. Response to sulphur treatment of yield of kernels was very highly significant. Most of this was due to an increase in production of kernel, while production of shell increased only slightly over all treatments.

In this experiment sulphur was applied in the form of powdered elemental sulphur. Further work is required to determine the best form of sulphur to use, and to check if similar responses can be obtained on other soil types in the Markham Valley.

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Table.—Response of White Spanish peanuts to applied sulphur

Sulphur Levels (lb per acre)	Yield (lb per acre)			Threshing Percentage	Nuts per Ounce
	Nuts in Shell	Kernels	Shells		
0	2340	1679	661	71.8	49.69
25	2567	1889	678	73.4	47.44
50	2660	1946	714	73.3	47.88
100	2617	1921	696	73.4	47.19

STUDIES ON THE GROWTH OF LEUCAENA LEUCOCEPHALA

1. EFFECT OF CLEAN WEEDING AND NITROGEN FERTILIZER ON EARLY ESTABLISHMENT

G. D. HILL*

ABSTRACT

Leucaena leucocephala *cv. Peru was sown with a dressing of* 0, 30 *and* 60 *lb of fertilizer nitrogen per acre, plots being weeded or left unweeded. Significant responses to weeding and nitrogen were obtained. On weeded plots there was no increase in production from* 30 *lb of nitrogen to* 60 *lb of nitrogen. Nodulation of nitrogen treated plots was not affected by the levels of nitrogenous fertilizer used.*

INTRODUCTION

LEUCAENA when established from seed makes slow initial growth (Takahashi and Ripperton 1949). Weed competition at establishment causes reduced forage yield (Kinch and Ripperton 1962; CSIRO Aust. 1965).

Edwards (1963) showed that nitrogen (urea) applied at sowing, in pots, increased root growth but reduced nodule dry matter. In another experiment he was unable to detect significant differences between weight of tops, roots or nodules when nitrogen was applied at 0, 2 and 4 mg per pot at sowing or at first nodule formation.

Gates (1970) has shown that for *Stylosanthes humilis* nitrogen applied at sowing stimulated nodule development and increased growth of the whole plant.

An experiment was conducted to study the effects of weed competition and of fertilizer nitrogen at sowing on the early establishment of Leucaena in the field.

MATERIALS AND METHODS

The experiment was sown on a brown clay loam at Bubia on 23rd May, 1968. A factorial design with eight replicates was used.

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The treatments were:—

0 lb nitrogen per acre 30 lb nitrogen per acre 60 lb nitrogen per acre	X	not weeded weeded

Each plot comprised a single row of Leucaena 20 ft long spaced 10 ft from the next plot. Rows 10 ft apart had been found to be suitable for the cultivation of Leucaena in pastures.

The experiment was sown to the Peru strain at a rate of 10 lb per acre. Seed was scarified using the method of Gray (1962) and inoculated with *Rhizobium* strain NGR 8 prior to sowing. Weeded plots were weeded by hand to 3 ft each side of the row at fortnightly intervals from sowing to harvest.

At harvest on 1st August, 1968, the central 15 ft of each row was cut and weighed green, the entire harvest being completed in one day. At the same time three plants in the remaining part of each row were dug up and inspected for nodules.

RESULTS AND DISCUSSION

No visual responses to added nitrogen were observed at any stage. The experiment coincided with the period of day-time rain at Bubia and weed growth on unweeded plots was prolific. Principal weed species present were *Mimosa invisa, Eleusine indica, Portulaca oleraceae* and *Euphorbia geniculata.*

Effect of Nitrogen on Nodulation

No differences among treatments could be detected. All plants pulled were well nodulated and had numerous pink nodules present.

Effect of Treatments on Growth

Production of green forage for the various treatments is shown in the *Table*.

Table.—Production of green forage

Nitrogen (lb per acre)	Production (lb per acre)	
	Unweeded	Weeded
0	666	858
30	736	1473
60	973	1473

Yield responses to added nitrogen and weeding were very highly significant ($P<0.001$). The interaction nitrogen x weeding was highly significant ($P<0.01$). Yield of weeded plots which had received 30 lb of nitrogen per acre and 60 lb per acre was the same.

In unweeded plots there was a continued response to nitrogen up to 60 lb per acre, probably due to competition between the Leucaena and the weeds for the added nitrogen.

CONCLUSIONS

Early growth of Leucaena was assisted by the addition of fertilizer nitrogen and clean weeding, the optimum treatment being clean weeding and 30 lb of nitrogen per acre.

Use of fertilizer nitrogen may also be of value to assist early growth in areas where weeding is not practical because of terrain.

The addition of fertilizer nitrogen at the levels used did not appear to have an adverse effect on nodulation.

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IMPROVED PASTURES FOR PAPUA AND NEW GUINEA

G. D. HILL*

ABSTRACT

These notes are a synthesis of currently available information on pastures in the Territory. They cover certain aspects that are peculiar to the Territory environment, including the problems of maintaining production in the drier season of the year, storage of seed in the lowlands, and the possible need for fertilizers and their efficient use on pastures.

A comprehensive list of pasture grasses and legumes which have been tried in the Territory is included, with recommendations as to the environment to which they are best suited. Brief information is also given on suggested methods of establishment and management.

INTRODUCTION

THE cattle population of the Territory was estimated at 20,213 on 30th June, 1961 (DASF 1965a, p.46). By the same date in 1967 this number had risen to 50,125 (DASF 1969, p.38), a 150 per cent increase in six years. At present most of these animals are grazed on mainly unimproved pastures comprising *Imperata cylindrica* and *Themeda australis*.

The 1965 report of the International Bank for Reconstruction and Development estimated that there were 11 to 12 million acres of native grasslands in the Territory and that, in their unimproved state, these could carry a national herd of two million head. If use of improved pastures increased the stocking rate three-fold, improvement of 25 per cent of this area would allow a herd of three million to be carried. Already in the Northern District, one property is carrying 1,930 head on 1,748 acres of improved pasture, and in the Morobe District, three properties with less than half their area improved are carrying a beast to 1.45 acres (DASF 1969). Obviously results such as these will not be obtainable in all parts of the Territory. However, if the national herd is to reach the levels recommended by the Bank Mission, considerably more improved pastures will need to be sown.

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These notes are an attempted synthesis of the available information on pasture improvement in the Territory. They have been compiled from the results of research on stations of the Divisions of Animal Industry and Research and Surveys, and from the practical experience of graziers throughout the Territory.

NUTRITIVE VALUE OF NATIVE GRASSLANDS

Do we need improved pastures? There is plenty of grass in New Guinea. Why waste time and money planting new grass?

It is true that there is plenty of grass in New Guinea, but its value as pasture is doubtful. Whyte *et al.* (1959) state:

> "Tropical grasses are notoriously low in protein content, even during their optimal stage of growth. For most of the year in monsoonal tropical climates they are little better than cereal straw."

Work in other tropical countries has shown that growing cattle require a diet of 10 per cent crude protein (on a dry matter basis) and that mature cattle require 6 per cent for maintenance. Work in Queensland, Rhodesia and the Sudan has shown that, although at the start of the wet season many tropical pasture grasses may have crude protein contents about these levels, as they reach maturity the level falls rapidly and at maturity may be as low as 2 per cent (Whyte *et al.* 1959).

Work in Queensland on tropical species indicates that digestibility and intake of tropical species is probably less than that of temperate species.

No studies of variation in native pasture quality have been conducted in the Territory but the situation at Goroka, where cattle on native pastures lose condition at certain periods of the year (DASF 1965a, p.45) and at Yambi where cattle on native pastures made no growth in the wet season and slow growth in the dry season (DASF 1965b, p.91) indicate that the low quality of Territory native pastures can result in nutritional problems regardless of the potential of the environment.

Territory native grasslands contain few useful legumes and for that reason pastures require the incorporation of improved legumes to improve their protein content. At the same time, because nitrogen fixed by the legume can be made available to the grass, the quantity of feed produced may also be increased.

ROLE OF IMPROVED SPECIES

If land is to be cultivated to sow legumes, sowing of improved grass species should be considered at the same time. Grasses like Buffel, Elephant and Kazungula Setaria have been selected by rigorous screening to give high yields of forage.

Work on the north coast of New South Wales shows the differing ability of grass species to respond to the incorporation of a legume into the pasture (Swain 1965). *Figure* 1 shows that in all cases the incorporation of the legume considerably increased total dry matter production. In the case of Kikuyu 2,000 lb of this increase was from the grass.

In Hawaii, Whitney and Green (1969) obtained a yield of 3,780 kg $ha^{-1}yr^{-1}$ from a stand of pure Pangola grass. When *Desmodium intortum* was incorporated into the pasture planted at 45 cm between the rows dry matter production rose to 11,960 kg $ha^{-1}yr^{-1}$ and was equivalent to a yield from Pangola grass that had received 525 kg nitrogen $ha^{-1}yr^{-1}$.

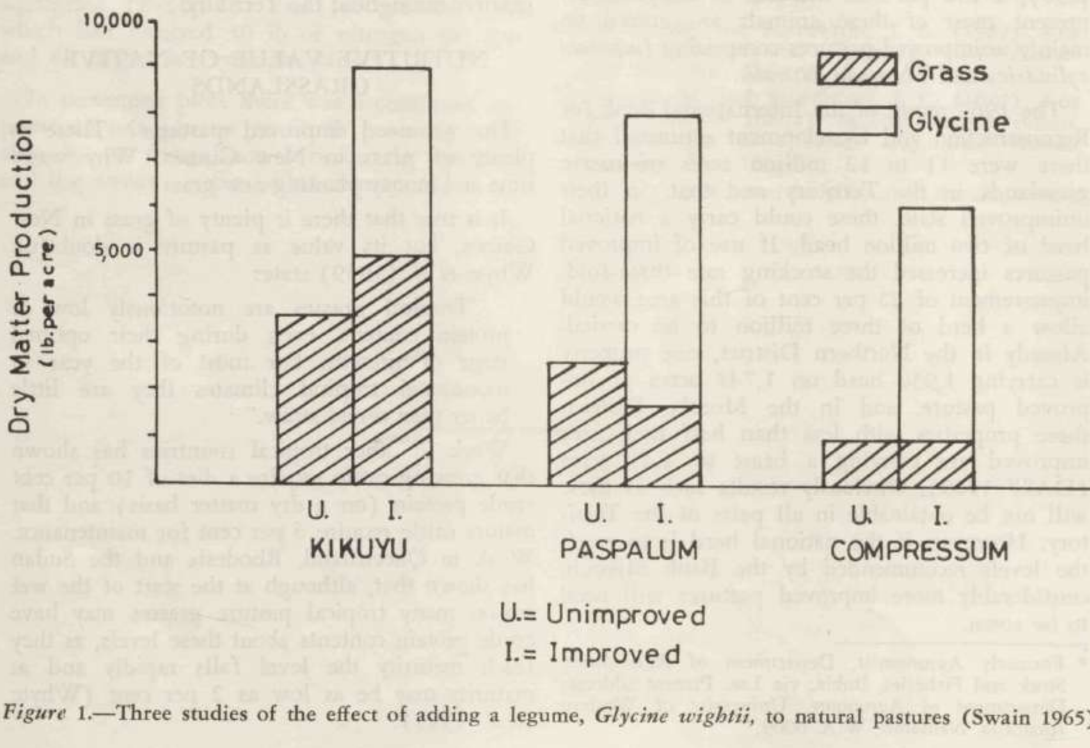

Figure 1.—Three studies of the effect of adding a legume, *Glycine wightii*, to natural pastures (Swain 1965)

In many cases it may not be practical to improve pasture fully. Terrain, lack of machinery, or lack of finance can all be limiting. In these cases sowing of legumes should be attempted. For this purpose it is important to select legume species that can compete with established grasses and are tolerant of poor seed bed preparation.

Stylo and Siratro are legumes of this nature. Good establishment of Siratro into freshly burnt ground in Queensland gave stands of 4,600 plants per acre 48 weeks after sowing, and as not all seed was scarified, plants were still germinating in the second season (CSIRO Aust. 1965a).

Similarly CSIRO workers have sown Siratro by air at a rate of $\frac{1}{2}$ ounce acre^{-1} and were able to find 140 plants acre^{-1} even at this low sowing rate (CSIRO Aust. 1965a).

In Africa, Stylo was established in Hyparrhenia grasslands following light cultivation. The addition of Stylo doubled dry matter production and increased crude protein production five-fold (Smith 1963).

An additional advantage of Stylo is that seed is not damaged by passage through the gut of the grazing animal, and once established it is spread by cattle in dung.

Other tropical legumes are not as tolerant of poor ground preparation and should be sown into a well prepared seed bed if failures are to be avoided.

GRAZING MANAGEMENT

Under Territory conditions, the aim of the grazier is to obtain the maximum production of animal products per acre, while at the same time not destroying his established native and sown pasture. To do this, efficient grazing management is essential. However, what do we know of grazing management? Moore and Biddiscombe (1964) state:

> "Systems of management and utilization of pastures both sown and native have been and still are subject to scientific inquiry and controversy."

While this may be of intense academic interest to scientists working in this field, it is poor consolation to the grazier who is faced with feeding his cattle throughout the year and making a profit.

The best that can be done is to review some of the systems of grazing that can be practised and some of the results that have been obtained from their use in other parts of the world. In the end it is the grazier himself who will have to decide which system is going to be the best for his property. He is the only person with the intimate knowledge of his pastures and his animals and the only one that can decide which are his most important objectives.

Although the Territory lies entirely in the tropics, because of the presence of the highlands considerable climatic diversity exists. From the point of view of pasture production we can consider three types.

1. Wet all year round, rain falls all year with little marked difference from month to month. Lae would be a typical example of this type.

2. A marked wet season from November to April, followed by a drier season, but not really a dry season. Much of the highlands would fall into this category. At Aiyura, February and March are the two wettest months with over ten inches of rain on average. There is however no month of the year that averages less than 3.7 inches.

3. A marked wet season also from November to April followed by a marked dry season. The central coast of Papua and the upper Markham and Ramu Valleys fall into this classification. Although rain may fall outside the wet season it is not dependable. At Erap in 1965 only 148 points of rain fell from the end of June to the end of October. The average for each of these months is above 250 points.

Each of these environments will require a different response from the grazier to obtain maximum utilization of his pasture. In all of them however the basic problem is the same: to keep animals in good condition, and to obtain steady weight gains in animals for sale and in young breeders.

GRAZING SYSTEMS

1. *Continuous Grazing*

In this system a number of animals are placed on an area and remain there for a long period. This method is still used by most cattle properties in the Territory. In spite of a considerable amount of work which has attempted to prove this system to be inferior to rotational grazing, an extensive review of the literature on the subject by Wheeler (1962) found that few experiments had in fact shown higher yields from rotational grazing than from continuous grazing. In cases where a superiority had been shown the experiment had usually been designed in the first place under the assumption that rotational grazing would be better.

2. *Rotational Grazing*

In rotational grazing there are a number of paddocks. Cattle graze each paddock in turn for a short period and are then removed to allow recovery of the pasture. The recommended stocking rate at time of grazing is six to ten cows per acre, the cattle remaining on the pasture for three to seven days and being removed for three to five weeks. This system may be sound on small coastal properties with year-round rainfall, to assist weed control. At this stage, however, it could not be considered a practical proposition for larger properties, because of the requirement for extra fencing, watering points, and labour to move cattle from paddock to paddock.

3. *Strip Grazing*

This method is an even more intensive form of rotational grazing. In this, cattle are only allowed access to as much pasture as they can consume in one day. This is usually achieved by use of electric fencing. The theory behind this method is that there is a more complete utilization of the available pasture. Whyte *et al.* (1959) point out that with this method it is essential that pastures be of a high nutritional value. If the crude protein content of the pasture is allowed to fall below a certain level, making animals eat all available pasture will result in a drop in total production, as animals normally select food of higher nitrogen, phosphate and gross energy content, and lower fibre content, than the average for the food on offer (Arnold 1964).

Whyte *et al.* (1959) suggest that this method may be of use in the tropics as a way of ensuring efficient utilization of restricted areas of high quality fodder legumes and grass legume mixtures.

4. *Deferred Grazing*

In this system, part of the pasture is preserved during the growing season to be fed back at a later period when feed is in short supply. The disadvantage of this system is that generally with maturity comes a loss of quality, and that when the pasture is eventually fed to the cattle. the grazing will not be as good as if utilized when the material is at its prime (Whyte *et al.* 1959). In an experiment with sheep, Lloyd Davies (1968) found that advantage from deferred grazing could only be obtained at stocking rates that were higher than those likely in commercial practice. There are however, certain tropical pasture species that are able to maintain their nutritive value with age and these (which are discussed more fully below) may be of use in Territory pastures to provide supplementary grazing in the dry season.

5. *Zero Grazing*

This system is popular in the United States and in India. In it livestock do not graze the pastures at all. Forage is cut and fed to the animals on feed lots or in bails. It is very high in labour requirements and has the disadvantages that any food not consumed on the day of cutting is wasted, and the choice of forage available to the animal is restricted. This may cause a drop in productivity for the reasons mentioned under strip grazing.

CONSERVATION OF FEED

A possible method of overcoming shortages is conservation of feed under a deferred or zero grazing regime. Problems of conserving forage in the humid tropics have been reviewed by Davies (1965). He concludes that because of high relative humidity and heavy precipitation, hay-making using orthodox methods is seldom practical in such areas. This probably applies equally to most parts of the Territory where fodder conservation is likely to be necessary, the main problem being that cutting of the forage for optimum quality would have to be carried out during the wet season.

The production of silage, using high-yielding species such as forage sorghum is theoretically feasible. Preparation of silage from Guinea grass, Setaria, Elephant grass and cane tops has been practised. Whyte *et al.* (1959) feel that at the time grasses are at the optimum for cutting they are already of low feeding value. The results of Hill (1969a) with unfertilized forage sorghum at Bubia tend to confirm this. Although at eight weeks of age the mean crude protein content was 8.3 per cent, four weeks later this had fallen to 5.8 per cent. In the same period total production increased from 1,900 lb per acre to 5,000 lb per acre.

Quality might be improved by mixing with legumes. To obtain good consolidation of coarse tropical species they should be cut, and also partially wilted in the field to reduce moisture content. Silage has been successfully made in the West Indies and East Africa (Whyte *et. al.* 1959).

Queensland work (CSIRO Aust. 1965a) has shown that good silage can be prepared from *Setaria anceps* at a young stage of growth.

EFFECTS OF GRAZING ON PASTURE COMPOSITION

Unfortunately, besides its effect on total production of animal products, grazing management also affects the composition of pastures. This may under some Territory conditions be more important than considerations of yield. In wet coastal regions intensive rotational grazing is almost obligatory if good pastures are to be maintained. In large set-stocked paddocks cattle are able to be highly selective and will eat palatable species as long as there is no pressure on them to do otherwise. As a result of this, palatable improved species may be eliminated by selective grazing. At the same time unpalatable species, many of them weeds, will come to dominate the pasture. To control this, paddock size must be small enough to ensure that when they are grazed a high stocking density is obtained. Once cattle are removed adequate rest periods must be allowed for the pasture to recover. The extensive presence of *Calopogonium mucunoides* in coastal pastures is probably a reflection of its poor palatability rather than its excellence as a pasture legume.

In drier areas stoloniferous or rhizomatous species are to be preferred because of the good ground cover they provide. Clump-type species when heavily grazed leave large bare patches of soil. In the succeeding wet season cattle will concentrate on the emerging pasture shoots and give weed species an excellent competitive advantage.

OTHER METHODS OF IMPROVING PASTURE PRODUCTIVITY

On what has been said so far it would appear that the carrying capacity of a property is limited to what it can carry at the height of the dry season. However, there are methods of overcoming this, even on properties which are almost devoid of improved pasture.

Urea Supplementation

Work in Australia and South Africa has shown that the addition of urea to poor quality forage considerably increases intake and reduces loss of body weight in the dry season. One farmer in the Territory has used urea as a supplement in dairy cow rations and obtained a considerable increase in milk production (Hamilton, pers. comm.).

In Australia when urea was added to a diet containing 2.3 per cent crude protein intake of roughage by sheep was increased 2.6 times (McInnes and Mangelsdorf 1966).

There are, however, problems with urea. The use of blocks in the Territory is dangerous because of their absorption of water and subsequent disintegration. Urea is toxic and excessive intake can lead to death.

A system has been devised in Queensland to feed urea to cattle and limit intake. It involves the use of a 44 gallon drum in which is placed a 12 gallon drum. The cattle obtain the urea by licking the 12 gallon drum which floats in a urea-molasses mixture. Full details of construction of the lick feeder and suitable mixtures for it can be found in an article by B. E. Moore (1968).

Use of Species Unpalatable When Green

Members of the genus *Stylosanthes* are less palatable to cattle when green. As they dry off, palatability increases and the material is readily eaten. For this reason the use of Stylo as a component in pasture mixes will in effect provide deferred grazing. A possible drawback of its use is that, in the wet season, more palatable species may be grazed very heavily and unless stocking rate is controlled, may be almost entirely grazed out.

Browse Plants

A method of preserving feed for high protein supplementation during the dry season is the planting of leguminous browse shrubs or trees.

These, because of their deep-rooting habits, will remain green long after other pasture species have dried up.

At Erap, *Leucaena leucocephala* is now being used as a shade tree, planted in one-acre blocks. Leucaena is readily accepted by cattle and can be cut to provide a high protein supplement.

Other species that have been used for this purpose in the West Indies have been *Delonix regia* (Poinciana), *Cajanus cajan* (Pigeon Pea), *Albizzia lebbeck* and *Gliricidia sepium*. All these species had a protein content in excess of 10 per cent and gave annual mean dry matter yields of from 5.38 to 6.63 tons per acre over the five years of the trial (Oakes and Skov 1962).

Species of which Intake Does not Decline with Age

As the pasture matures, animals eat less and less of most of the tropical species. However, for some species intake remains constant over a considerable period. Two such species are Rhodes grass (*Chloris gayana*) (*Plate* III) in which intake remained constant up to 170 days, and Siratro (*Phaseolus atropurpureus*) in which intake of 260-day-old material did not decline (*Figure* 2). The use of such species in pastures should help to ensure high intake during the dry season.

Conclusion

It is not suggested that all of these methods will be suited to all graziers, but a combination of one or more of them might well help the grazier to successfully combat the critical period of poor feed quality.

SEED

Storage Problems

In general, seed of pasture species does not store well under lowland conditions in the Territory. For this reason considerable care should be exercised if large quantities of seed are purchased from Australia or are to be stored.

If seed is purchased from Australia the order should specify that seed is to be "tropic packed" and it should be ordered so that it can be sown as soon as possible after arrival. If it has to be held for any length of time on the coast every effort should be made to prevent loss of viability by storage under dry conditions.

This can be done in a number of ways. An air-conditioned room will keep seed in quite good condition. It can also be left in a cool room, one in which the temperature does not fall below freezing point. If only a small quantity of seed is to be stored it should be placed in drums with tight fitting lids, with bags of activated silica gel. All these methods will help to reduce loss and will save money.

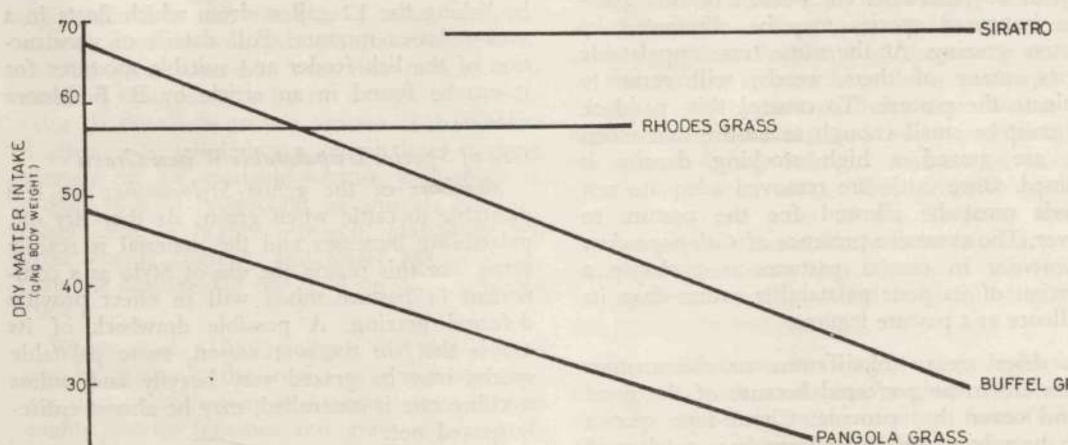

Figure 2.—Relation between consumption and age of four tropical pasture species (CSIRO Aust. 1965b)

If seed is harvested in large quantities and is to be held over for the next season's sowing, arrangements should be made to store it in the highlands or in the special seed store of the Department of Agriculture, Stock and Fisheries at Lae.

SCARIFICATION OF HARD LEGUME SEED

Many legumes have very hard seed coats which are impermeable to water. This characteristic has advantages in allowing the plant to survive from season to season, should a very dry season kill all plants that germinate in that year. However, when it is desired to establish a pasture, unless steps are taken to break down the seed coat the result is a very patchy germination. Tropical legumes are no exception and for this reason some form of scarification prior to sowing is essential.

Broadly there are three methods of doing this:—

(1) Mechanical;

(2) Chemical; and

(3) Heat treatment.

Some seed supplied from Australia is scarified prior to packing. It is therefore a good idea to test seed prior to treatment. About 200 seeds should be placed on a sheet of blotting paper and kept moist. If more than 50 per cent of these seeds germinate within a week it is safe to assume that they have already been scarified and no further treatment should be applied.

Mechanical Methods

If only small quantities of seed are to be dealt with, the easiest method for large seeds is to remove a small piece of the testa by nicking with a pair of scissors. For small seeds rubbing between two boards on which emery paper or coarse glass paper has been stuck will usually be sufficient.

For large quantities of seed, shaking the seed with an abrasive material is satisfactory. An example would be the use of coarse sand mixed with the seed in a cement mixer. In tests in Hawaii, shaking two parts of Leucaena seed with one part of sand for 20 minutes gave a germination of 96.6 per cent after 14 days compared to a control in which 17.9 per cent germinated (Akamine 1942).

Chemical Methods

These involve the use of concentrated sulphuric acid. The acid supplied to battery manufacturers is quite suitable. It should be poured over the seed using 4 volumes of acid to 100 volumes of seed. The whole should be stirred very well and allowed to stand for 20 minutes. Following this the seed should be washed to remove all traces of the acid. Experiments in Hawaii on Leucaena gave a germination of 98 per cent after seven days (Akamine 1942) and, with Siratro at Bubia of 92 per cent over the same period.

This method should only be used by qualified staff, firstly because of the dangers associated with the handling of the acid, and secondly because, unless all traces of the acid are removed in the washing process, the subsequent inoculation of the seed will be impaired.

Heat Treatment

This usually involves immersion of the seed for varying periods in hot water. Particular care should be taken to ensure that the water temperatures recommended and the duration of immersion are not exceeded or seed will be killed.

With Leucaena, immersion in water at 80 degrees C for two minutes is sufficient to break down hard-seededness (Gray 1962); for Siratro, immersion in water at 65 degrees C, the seed being placed in the water and allowed to cool, gives good germination (Edwards, pers. comm.).

Wycherley (1960) was able to improve the germination of Calopogonium, Centrosema and Pueraria by immersing the seed in glycerine at 50 degrees C for various periods.

INOCULATION

For the efficient fixation of nitrogen, legumes need to be inoculated. Many of the tropical pasture legumes are promiscuous and will nodulate from native cow pea Rhizobium, whether inoculated prior to sowing or not. On the other hand, certain of the tropical legumes are highly specific in their Rhizobium requirements, and if not inoculated will almost certainly fail. However, even for the promiscuous species, inoculation prior to sowing should be carried out because a species may be infected by a strain of Rhizobium which may be infective but not efficient. This means that the production of the plant is limited because it has an inefficient Rhizobium strain in association with it.

The strains of Rhizobium distributed by the Soil Microbiology Section of the Department of Agriculture, Stock and Fisheries have been selected by research as most suitable for the legumes concerned. Inoculum is supplied free by the Department and inoculation takes very little time. Therefore as an insurance policy, all legumes should be inoculated at sowing. In return for this service the Department asks growers to give a simple report on the results of inoculation.

Table 1, adapted from Norris (1967), shows inoculum requirements for tropical pasture legumes.

Technique

Rhizobium cultures in the Territory are supplied by the Plant Pathology Section of DASF at Konedobu. Orders for inoculum should specify the species to be inoculated and the amount of seed to be sown. Inoculum is supplied on nutrient-agar slopes in bottles. The amount of inoculum needed for any seed lot depends on the size of the seed of the particular species.

When received, the inoculum, if not used at once, should be stored in a refrigerator or a cold dark place, but should not be frozen. Inoculum should not be kept more than four or five weeks; after this time the bacteria will have died.

The inoculum in the bottle is in the form of a scum growing on the surface of the agar slope. This should be washed off using a 10 per cent sugar solution, shaking the bottle each time to ensure complete removal of the inoculum. If ants are a problem in the area, wash off with water instead of sugar solution.

Place seed to be inoculated in a shady place on a flat surface, and pour the suspension of inoculum over it, making sure that all seed is moistened. Then spread the seed out to dry in the shade. Once dry, sow as soon as possible. Do not inoculate more seed than can be sown in one day; in fact it is probably better to inoculate twice a day to ensure survival of bacteria.

Table 1.—**Guide to inoculum requirements of legumes used in tropical pastures**

Legume Species	Common Name	Inoculum Requirement
Calopogonium mucunoides	Calopo	Cowpea*
Centrosema pubescens	Centro	Specific
Desmodium intortum	Greenleaf Desmodium	Desmodium
Desmodium uncinatum	Silverleaf Desmodium	Desmodium
Dolichos axillaris	Archer Dolichos	Cowpea*
Dolichos biflorus	Leichhardt Dolichos	Cowpea*
Dolichos lablab	Rongai Dolichos	Cowpea
Glycine wightii	Cooper, Clarence or Tinaroo Glycine	Cowpea
Leucaena leucocephala	Peru Leucaena	Specific
Lotononis bainesii	Miles Lotononis	Specific
Medicago sativa	Lucerne	Lucerne
Phaseolus atropurpureus	Siratro	Cowpea*
Phaseolus aureus	Golden Gram	Cowpea*
Phaseolus lathyroides	Phasey Bean	Cowpea*
Phaseolus mungo	Mung Bean	Cowpea*
Pueraria phaseoloides	Tropical Kudzu	Cowpea*
Stylosanthes guyanensis	Schofield Stylo	Cowpea*
Stylosanthes guyanensis	Oxley Fine-stem Stylo	Specific
Stylosanthes humilis	Townsville Stylo	Cowpea*
Trifolium repens	White Clover	Clover
Trifolium semipilosum	Kenya White Clover	Specific
Vigna luteola	Dalrymple Vigna	Cowpea*
Vigna sinensis	Cowpea	Cowpea*

*Indicates a promiscuous species which will normally nodulate from native cowpea Rhizobium even if not inoculated.

A check on the efficiency of inoculation can be made by carefully lifting the plants from the soil from time to time after sowing; nodules are attached to the fine rootlets. On crushing, they should be pink in colour.

Henzell (1968) has estimated that in Queensland the rate of nitrogen fixation for an average legume is 20 to 160 lb N per acre per year and for a good legume 260 lb N per acre per year. *Table* 2 shows the equivalent amounts of urea or sulphate of ammonia that would have to be applied to obtain the same amount of nitrogen.

Table 2.—Equivalent amounts of nitrogenous fertilizer required to provide the same amount of nitrogen as a legume

Nitrogen (lb)	Ammonium Sulphate (lb)	Urea (lb)
20	95	44
160	762	348
260	1238	565

FERTILIZER

Territory soils, compared with those in Australia, are relatively fertile; the application of fertilizers is therefore in most districts not essential for growth of pastures. This does not mean that increased forage production would not be obtained from fertilizer application. However, before applications are made, the economics should be carefully considered.

Soil Requirements

The Land Utilization Section of the Department carries out surveys in many districts of the Territory and soil analyses are made in conjunction with these surveys. Although they do not provide the complete answer, some indication is obtained as to whether major deficiencies occur.

Similarly, the Chemical Section has carried out analyses of soils from many parts of the Territory on behalf of individuals and companies. Therefore, before any fertilizers are applied, information should be sought from the Department on soil analyses in your area.

Nitrogenous Fertilizer

Henzell (1968) has estimated that in Queensland price per unit of nitrogen would have to drop to 2 cents a lb before the use of fertilizer nitrogen would be better than legumes. Current Australian prices are 7 cents a lb for aqua ammonia, and 9 cents a lb for urea. The current chances of the cost of nitrogen fertilizer falling as low as this in the immediate future in the Territory are not high. Therefore the use of nitrogen except in special circumstances is probably not economic. Remember that in order to get legume nitrogen pastures must contain legumes that are nodulated and efficiently fixing nitrogen. Pastures without legumes will almost certainly be lacking in nitrogen.

Which Fertilizers to Use

The department is not in the position to conduct fertilizer trials on every property in the Territory. For this reason probably the quickest way to get an answer to what fertilizer, other than nitrogen, is required is to lay down a small test of your own. An Australian company* markets a kit which allows a non-replicated omission trial to be laid down in an area of 14 yards x 57 yards. This test will allow a visual estimation of what major and minor elements are lacking. One point about this test is that it is based on the assumption that all land will receive an annual application of superphosphate, thus it will not show whether sulphur is deficient (superphosphate is 25 to 32 per cent sulphate). This could be important as sulphur has been found to be deficient in several areas of the Territory (Southern 1967).

Rates of Application

If trace elements are deficient, such deficiencies can usually be corrected by a few pounds of the deficient element per acre. As such, correction would be economic, even in the most remote highland areas. However, if major nutrients are deficient, fertilizing may not be economic because of high freight costs. In general, if a property is not fully stocked and there is adequate feed at all times, fertilizing will not be economic.

As the property comes up to its full carrying capacity without fertilizers, further stocking will only be achieved by their use.

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* Horticultural Industries, Pty. Ltd., 27 Fitzpatrick Street, Revesby, N.S.W.

Spectacular increases in production have been achieved by use of fertilizers on pastures. In Hawaii (Younge and Plucknett 1965) on soils that normally produced 30 lb beef per acre per year obtained the following responses to the application of phosphorus:—

250 lb P per acre—630 lb beef per acre;

500 lb P per acre—900 lb beef per acre; and

1500 lb P per acre—1164 lb beef per acre.

In Australia at Rodds Bay, unfertilized native pasture gave 29 lb beef per acre per year; application of fertilizer increased production to 75 lb; a fully improved fertilized pasture gave a yield of 276 lb per acre per year (Bryan 1965).

Composition of Fertilizers

Having decided to apply fertilizer, careful consideration of the analysis of the fertilizer will allow a calculation of the cost of the element you are applying. There is no point in applying a compound fertilizer if you only require one element. Details of the analysis of fertilizers normally sold in the Territory can be obtained from the Chemical Section of DASF. This information together with a current fertilizer price list, will allow you to determine the cheapest way of applying the element or elements that you require. In the highlands cost of freight from the coast will also have to be considered.

WEEDS

Weeds in pastures can be a problem for two reasons.

Firstly, the weed species present may be toxic and as a result of their ingestion, losses of livestock occur. In this case there is little alternative to complete eradication. Examples of such weed species in the Territory are *Cycas circinalis*, *Solanum mammosum* and *Asclepias currassica*. Generally, to ensure complete eradication, hand methods are preferable. This should not be too large a problem if infestations are discovered before becoming well established.

The other weeds which are a problem are those that because of their vigour and unpalatability come to dominate pastures and compete with planted pasture species for nutrients and moisture, reducing forage yields and production per acre. Examples of this type of weed are ferns on the coast and *Digitaria insularis* and *Sida cordifolia* in the drier regions of the Markham Valley.

At current costs in the Territory, spraying for broad acre weed control is not economic. In general it is better to keep weeds under control by sowing highly competitive pasture species and by management. Species such as *Dolichos lablab*, Para grass and Buffel grass are all good competitors against weeds because of the good ground cover they provide.

In all cases a weed infestation should be attacked before it becomes a problem of major importance. To this end correct identification of the species present is essential. Identification can be obtained from the Herbarium of the Division of Botany, Department of Forests, in Lae.

For accurate identification a fully representative sample of the plant must be submitted. It is essential that flowers and seed pods or heads be sent, as well as leaves and stems. If specimens are to arrive in good condition they should be pressed between sheets of newspaper prior to dispatch.

For complete details on the submission of specimens write to the Division of Botany.

PASTURE GRASSES

The information on the performance of grasses and the section on legumes that follow are based upon information from a variety of sources. In some cases the species discussed have only been grown in observation plots, there is therefore no information in some cases as to their response to grazing. In others the species are already in use in pasture mixtures or are already naturalized in the Territory. Naturally recommendations concerning the former should be treated with some caution.

Brachiaria brizantha

This grass is somewhat similar in appearance to *B. ruziziensis*. In introduction plots at Aiyura it has performed somewhat better than *B. ruziziensis*. At this stage there is no information as to its potential for the lowlands.

Limited supplies of planting material are obtainable from Aiyura.

Brachiaria decumbens

This grass, illustrated in *Plate* I, is an upright perennial which tends to fall to the ground as clumps become enlarged. It is difficult to establish from cuttings and does not root freely from the nodes, It is a member of the same family as Para grass, but it is not covered with the fine hairs that are a characteristic of that grass.

B. decumbens, in spite of difficulty of establishment and slow initial growth, is worth consideration because in trials at Bubia it maintained high protein levels when not fertilized.

Seed is now obtainable from Australian seed merchants and limited supplies of cuttings can be obtained from Bubia. It is suitable for the lowlands.

Brachiaria dictyoneura (Koronivia Grass)

This grass is a dark green rhizomatous perennial which grows to a height of about two feet. It establishes easily from runners and rapidly provides good ground cover. It was introduced into the Territory from Fiji where it is a common pasture grass. It has grown well in introduction plots at Bubia and should be suitable for wet lowland situations where erosion could be a problem.

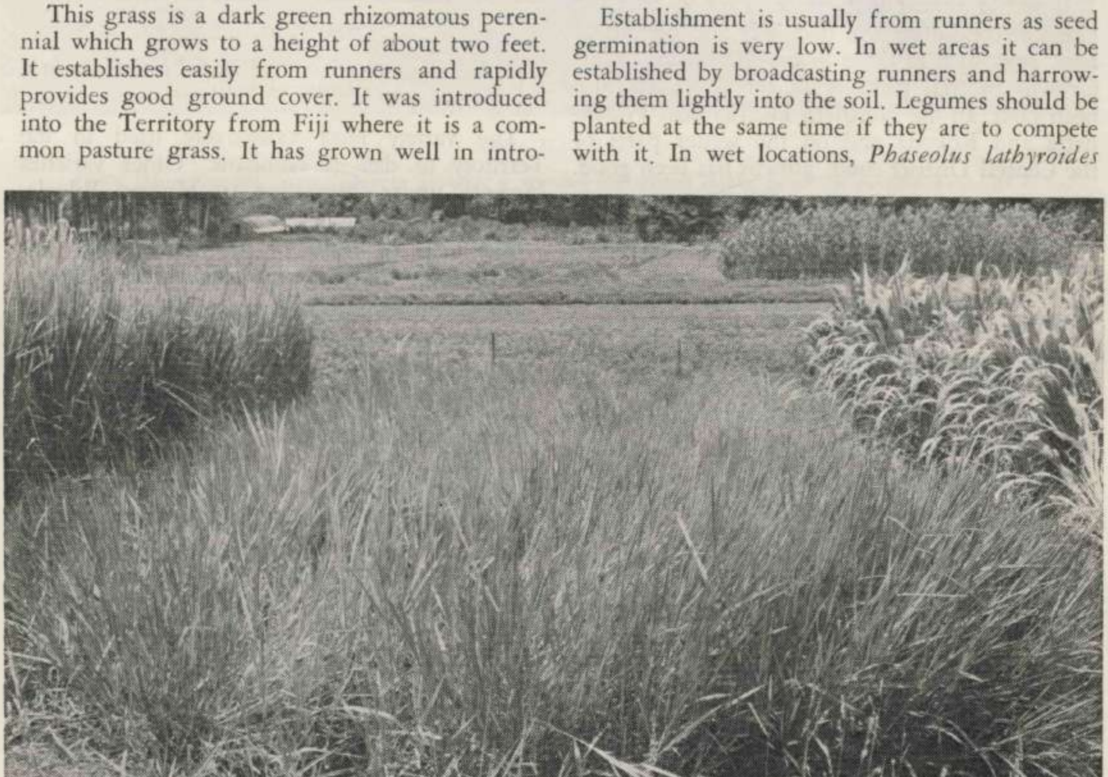
Limited supplies of planting material can be obtained from Bubia.

Brachiaria mutica (Para grass)

Para grass is a vigorous prostrate creeping perennial which grows to a height of three feet. Its leaves and runners are covered in fine white hairs, which gives it a faint bluish-white appearance.

Para is well adapted to a wide range of Territory environments, but thrives best in wet areas. In such areas it may be difficult to maintain balanced grass-legumes swards because of the growth of Para.

Establishment is usually from runners as seed germination is very low. In wet areas it can be established by broadcasting runners and harrowing them lightly into the soil. Legumes should be planted at the same time if they are to compete with it. In wet locations, *Phaseolus lathyroides*



(Photo D.I.E.S.)

Plate I.—***Brachiaria decumbens*** **has shown itself capable of maintaining high crude protein levels when not fertilized**

(Phasey bean), is the legume of choice. In drier areas, *P. atropurpureus* (Siratro) or *Stylosanthes guyanensis* (Stylo) will associate well.

Planting material of Para can be obtained from road verges and creek and river banks in many parts of the Territory.

Brachiaria ruziziensis

This grass has a similar growth habit to Para. It has shiny dark green leaves and is not as hairy as Para. It roots freely at the nodes and thus can be easily established from runners. It may also be established from seed; recommended sowing rate is 2 to 3 lb per acre. In areas to which it is suited, growth is very vigorous and careful management will be required to maintain legumes in the sward.

It would appear that, unlike Para, it does not like wet conditions and that it is not tolerant of basic soils such as those in the Markham Valley. Growth in trial plots at Baiyer River has also been poor. In the Northern District near Popondetta and Kokoda and on the wetter parts of the Central District coast, growth has been good.

Limited suplies of planting material may be obtained from DASF, Popondetta, and seed from Australian seed merchants.

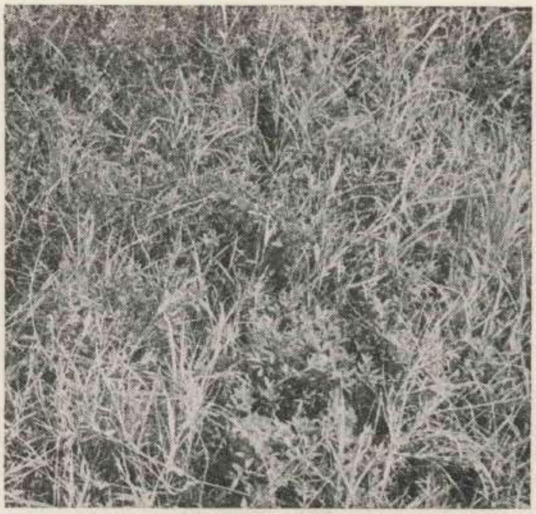
Cenchrus ciliaris (Buffel Grass)

Buffel grass is a prostrate creeping perennial which grows very rapidly providing a good ground cover. It grows to a height of two feet under Territory conditions.

The main advantage of Buffel is its ability to withstand dry conditions. For this reason it can be recommended for areas that have a marked dry season. It grows particularly well at Erap in the Markham Valley. Buffel associates well with *Stylosanthes guyanensis* (*Plate* II).

It should be sown at ½ to 4 lb per acre. Because of its fluffy seed, sowing through a drill may be difficult, but rate of flow can be improved by mixing with damp sawdust or cracked grain.

Buffel grass seeds freely in the Territory. Seed should not be sown in the year of collection; seed from Erap had a zero germination immediately after harvest. After dry storage for three months, germination increased to 33 per cent.



(Photo G. D. Hill.)

***Plate* II.—A good mixture of Buffel and Stylo in a pasture at Erap**

The variety most extensively used in the Territory to date is Nunbank. Other varieties currently under observation are Molopo, Biloela, Tarrewinnabar and Gayndah.

The role of Buffel grass in Australia has recently been reviewed by Humphreys (1967).

Seed can be obtained from Australian seed merchants.

Chloris gayana (Rhodes Grass)

Rhodes grass is a tufted perennial with some tendency to form runners (*Plate* III). It grows to a height of about four feet. It has not been tested extensively in the Territory, but it made satisfactory growth in introduction plots at Bubia.

In Australia it is recommended for areas with a 25 to 50 in rainfall. It is tolerant of fire, and is suitable in areas where erosion may be a problem. It should be sown at ½ to 6 lb per acre at a depth of ¼ to ½ in. Cultivars currently available are Callide, Samford and Katambora.

Seed would have to be purchased from Australia.

For a recent review see Bogdan (1969).

Digitaria decumbens (Pangola Grass)

This grass is a fine-leafed, fine-stemmed, creeping perennial, somewhat similar in appearance to couch. It does not set seed and must be

(Photo D.I.E.S.)

Plate III.—Rhodes grass, *Chloris gayana*, a species for which intake does not decline with age

propagated by runners. In Australia it has produced yields of over 20,000 lb of dry matter per acre per annum (Bryan and Sharpe 1965).

In trials at Bubia, it rapidly became stunted, gave poor growth, and under grazing, virtually disappeared from trial plots. Poor growth was also obtained at Aiyura and Erap. Investigation failed to isolate the virus suspected of causing the symptoms. They could be reduced by application of very high levels of fertilizer nitrogen, up to 600 lb per acre. It would appear that the species is not suited to the Markham Valley. In other areas a small observation plot should be planted to observe performance. If the grass is suited to the environment this can then be used as a source of planting material.

Limited supplies of runners should be obtainable for planting from Bereina.

More information on this species can be found in the paper by Nestel and Creek (1962).

Digitaria spp.

Three new *Digitaria* introductions have been made as possible substitutes for *D. decumbens* (Pangola).

All are somewhat similar in growth and appearance to Pangola. *D. milanjiana* and *D. pentzii* have to be propagated from runners while *D. smutsii* sets some viable seed. All three appear to be promising in introduction plots at Aiyura and limited supplies of planting material can be obtained from that station.

Hyparrhenia rufa (Jaragua)

Jaragua is a densely tufted perennial which forms thick clumps up to six feet high when ungrazed. When young is it quite leafy, but if allowed to seed it becomes very stemmy.

It is widely distributed in tropical Africa—its origin—and is a popular pasture species in South America, where it is known as Jaragua grass. As yet it has not gained any acceptance as a pasture species in Australia.

In trial plots at Bubia and in pastures at Aiyura it has grown well. Indications from Aiyura are that cattle do not find it highly palatable, for in mixed pastures it is the last species to be grazed.

It can be sown from seed at 15 to 20 lb per acre and lightly disced into the soil. Because seed is awned, sowing with a drill is difficult.

Establishment is also possible from cuttings. If kept well grazed it will provide good ground cover.

Because it is not grown in Australia seed is not commercially obtainable. Small quantities of planting material can be obtained from Bubia or Aiyura.

Other *Hyparrhenia* species that have been introduced are *H. cymbaria* and *H. hirta;* they are similar to *H. rufa.*

Melinis minutiflora (Molasses Grass)

Molasses grass is a tufty perennial especially adapted to the highlands. In the Wau valley and around Mount Hagen, extensive naturalized stands can be seen in flower in May.

It has showy purple seed heads and is also distinguished by a sweet molasses-like smell.

It is probably best regarded as a pioneer species, because it does not produce a large amount of forage and is easily grazed out if over-stocked. A further disadvantage under Territory conditions is that it burns very well when dry. However it is very suitable for steep areas which are difficult to cultivate, and in Queensland is recommended because of its ability to compete with weeds on new land (Douglas and Luck 1964).

It should be sown at 2 to 4 lb per acre. Seed may be collected in areas where the grass is naturalized or purchased from Australia.

Panicum maximum (Guinea Grass)

Guinea grass is a tall perennial bunch-type grass which produces long showy seed panicles, up to five feet high. It can be seen growing extensively on road verges outside Port Moresby and near Lae.

Guinea grass is well suited to areas that receive a good all-year-round rainfall. In areas that have a long dry season because of its growth habit large bare patches of soil occur. In the following wet season rapid weed emergence from these will cause problems.

Two varieties that show greater promise because of taller growth and greater drought resistance are Coloniao, which grows up to 12 ft tall, introduced from Brazil, and Hamil, which was selected in Queensland and is also larger and more robust than common Guinea.

A subspecies of *P. maximum* var. *trichoglume* (Green Panic) has been successfully grown under coconuts in the Markham Valley at Maralumi (Hill 1969b).

With Guinea grass, as with Elephant, care must be taken to prevent the stand becoming too coarse. To this end, intensive rotational grazing and a yearly slashing back to 6 in are recommended. It is unlikely that cattle will be able to control actively growing Guinea grass in the wet season.

Guinea grass should be sown from seed at 2 to 3 lb per acre no deeper than a $\frac{1}{4}$ in. A vigorous climbing legume such as Siratro, Stylo or *Dolichos lablab* should be sown at the same time. Planting from cuttings can also be carried out but has a high labour requirement. Planting material can be obtained from road verges in many parts of the Territory, or seed can be purchased from Australia.

Paspalum conjugatum

This grass is a perennial spreading stoloniferous grass which occurs commonly as a volunteer in coastal coconut and cacao plantations. On several coastal cattle properties near Lae, this grass in association with Calopo is carrying a beast to the acre (Hill 1969b). In a trial at Bubia, where production was compared with introduced species dry matter yields and protein levels were quite satisfactory.

If this species is already present there is little point in eliminating it to replant other species. In such a situation a legume component only need be planted. Sod seeding after heavy grazing or a set-back with Grammoxone at $\frac{1}{2}$ pint per acre, or both, or sowing of the legume in cultivated strips 5 to 6 feet apart, should provide a well-balanced pasture mix.

Paspalum plicatulum

Two cultivars of this grass have been released in Australia: Rodds Bay, which comes from Guatemala, and Hartley from Brazil.

Both varieties are highly palatable to cattle and in Australia have produced up to 11 tons of dry matter per acre per annum (Shaw *et al.* 1965).

These varieties are good pioneer species and can grow well in areas of reasonably low fertility. However, like most other crops, they respond well to added fertilizer.

Both cultivars seed freely in the Territory and seed is easy to harvest. Some spraying for insects may be necessary to protect immature seed from damage.

Paspalum plicatulum associates well with Glycine, Siratro and *Desmodium* spp. It should be sown from seed at 3 to 4 lb per acre and should be grazed lightly in its initial stages to allow the legume component of the pasture to become well established. Seed can be purchased from Australian seed merchants.

Pennisetum clandestinum (Kikuyu)

This grass species is a native of East Africa at elevations of 6,500 to 9,000 ft (Mears 1970). Because of its equatorial highland origin it is well suited to the New Guinea highlands. It is a vigorous rhizomatus perennial which produces a dense mat of vegetation. Because of this it should be considered in any area where erosion may be a problem.

Establishment is from runners which should be harrowed into the soil. Kikuyu associates well with clover (above 6,000 ft) and at lower elevation should combine with the *Desmodium* spp. and with *Glycine* spp.

If allowed to become sod-bound, growth will diminish and the stand should be renovated from time to time following severe grazing. Kikuyu because of its vigorus growth, will respond well to fertilizers.

For a recent comprehensive review on Kikuyu see Mears (1970).

Planting material should be obtainable from various highland centres.

Pennisetum purpureum (Elephant Grass, Napier Grass)

Elephant grass is a tall upright perennial which, under Territory conditions, will grow to a height of 12 ft. It has broad leaves which are borne on canes that may be up to $\frac{3}{4}$ in in diameter.

Elephant grass appears well adapted to many Territory environments ranging from Port Moresby to the highlands. It is capable of producing a vast bulk of material, but requires careful management to obtain maximum utilization. In general it should not be allowed to grow to a height of more than four feet before grazing. If it is, cattle will only eat back to the tough unpalatable stalks and when the pasture regenerates, shooting will come from the internodes on the stalk rather than from the ground. At least once a year it should be cut back to about one foot above ground level with a slasher.

For fuller information on the management of Elephant grass and its potential see Takahashi *et al.* (1966).

Because of its tall growth habit any legume planted in association with Elephant grass will need to be a vigorous climber, or it will be rapidly shaded out.

Elephant grass can be established from seed; however, under Territory conditions establishment from cuttings is probably easier. A modified cane planter is ideal for the job. Canes are planted in furrows two to four feet apart, depending upon the amount of planting material available.

Because of its wide distribution, cuttings of Elephant grass should be relatively easy to obtain anywhere in the Territory.

Pennisetum typhoides (Katherine Pearl Millet)

In the Northern Territory, this species was found to be highly efficient in extracting nitrogen from the soil. Plants were able to extract nitrogen from a depth of five feet whereas Sudan grass was only able to extract nitrogen from the top two feet (Norman 1962).

In the same experiment it was found that millet was, under severe and frequent defoliation, able to give yields of forage comparable with any other forage plant, and that under a light cutting regime it was outstanding. In grazing trials, beef cattle at one beast per acre gained 223 lb per head in 20 weeks starting four to six weeks after sowing.

In a cutting trial as Bubia (Hill 1969a) Katherine Pearl Millet produced 5,000 lb of dry matter at 12 weeks and did not produce as well as any of the forage sorghums evaluated at the same time. However, among its advantages as a short term forage are its freedom from prussic acid, and its apparent freedom from fungal attack.

It should be sown in drills 14 in apart at 10 to 15 lb per acre or broadcast at 20 to 30 lb per acre. Graze when plants reach 18 in high and do not graze below 6 in.

Seed is available from Australian seed firms.

Phalaris sp.

A Phalaris hybrid (NG 6115) which is a cross between *Phalaris tuberosa* (CPI 1483) and *P. arundinacea* (CPI 10446) has performed exceptionally well at the high altitude station at Tambul (7,000 ft). It is an erect clump type grass.

This grass has not yet been generally released and seed is not available. Limited supplies of planting material are obtainable from Aiyura and Tambul.

Saccharum officinarum (Cow Cane)

In many areas of Queensland farmers plant areas of sugar cane (*Plate* IV) as a standing drought fodder reserve. It could be considered for drier areas in the Territory. Sugar cane is planted from three node setts in furrows 4 ft 6 in to 4 ft 9 in apart.

Sugar cane is able to stand flooding provided the soil is well drained, and could be considered for areas where streams have a tendency to overwash their banks.

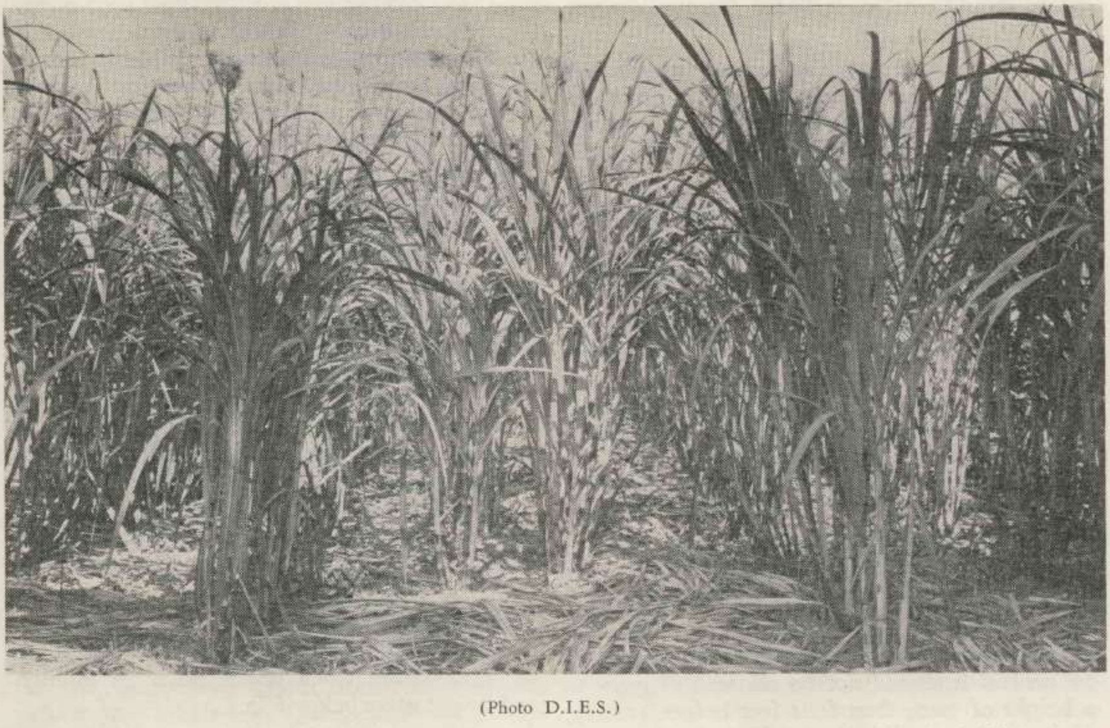
It must be remembered that sugar cane is predominantly carbohydrate and because of this it should not be used as a sole fodder for cattle for long periods.

Best results from cane will be obtained if it is cut and fed. If treated well, it will yield several ratoon crops and is thus capable of producing a large bulk of forage from a small area. After cutting, interrows should be cultivated and nitrogen fertilizer applied. If cut material is removed from the field for feeding, potassium may also be required after some years.

Pindar and Q58 are two varieties recommended in New South Wales and limited supplies of planting material of these varieties can be obtained from Bubia. There is no reason, however, why native varieties of cane should not be quite suitable.

Setaria anceps

The taxonomy of the African *Setaria* spp. is complex. Hacker and Jones (1969) recently concluded that the two commercially released



(Photo D.I.E.S.)

Plate IV.—***Saccharum officinarum.*** A small area of sugar cane can provide a useful drought fodder reserve

Setaria cultivars Kazungula and Nandi are of the species *S. anceps* not *S. sphacelata* as was previously thought.

Both these grasses come from Africa where they occur from sea level to 10,000 ft. Of the two, Kazungula (*Plate* V) is the more vigorous, growing to a height of four feet. Both cultivars are tufted perennials, clumps of which thicken very rapidly. The foliage has a blue-green appearance. Setaria sets viable seed in the Territory, and plant can be found growing at considerable distances from established plots.

At Bubia this species seems to maintain growth in the wetter season of the year (May to September) when most other species show diminished yields.

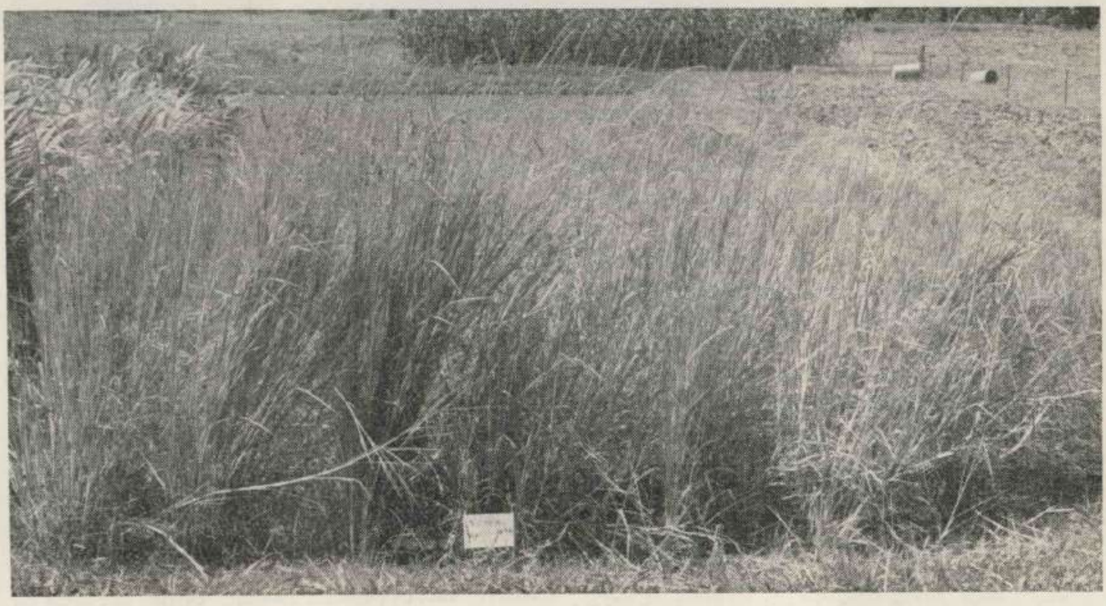
Setaria seed should be planted at 1 to 2 lb per acre. In the lowlands it associates well with Siratro, and at Aiyura is growing well in association with Green and Silverleaf Desmodium. Limited supplies of planting material are available from Bubia and seed may be obtained from Australia.

Sorghum sp. (Forage Sorghum)

In recent years a large variety of forage sorghums (*Plate* VI) have been bred for high forage yield and low prussic acid content. Most Australian seed firms market one or more of these hybrids: Trudan, Sudax, Suhy 5, Bonanza, Zulu and Forager are now all available in Australia. In Australia most farmers who have grown these hybrids have been surprised by the bulk of forage produced. In a trial at Bubia, Sudax at 12 weeks produced 12,000 lb per acre of dry matter and had a crude protein content of 7.9 per cent. Bonanza and Calala both produced more than 10,000 lb of dry matter per acre in the same period (Hill 1969a).

Another recent sorghum introduction of interest is Krish (*Plate* VII). This cultivar was developed by CSIRO. It is perennial and is a cross between *S. halepense* and *S. roxburghii*. In observation plots at Bubia and Erap it was slow to establish but appeared to give reasonable growth when mature.

Recommended sowing rate is 4 to 7 lb per acre in drills 14 in to 42 in apart. The crop should be grazed when 2.5 to 3 ft high



(Photo D.I.E.S.)

Plate V.—Kazungula Setaria. This grass seeds well and in spite of its upright growth habit rapidly provides good ground cover

(Photo D.I.E.S.)

Plate VI.—Young forage sorghums growing at Bubia. In trials at Bubia they yielded 12,000 lb dry matter per acre in 12 weeks

and high stocking density should be used to graze back to 6 in. Thirty head of cattle per acre is recommended in Australia. Stock should then be removed and the stand allowed to regenerate. Seeding should be prevented at all costs and the stocking density increased if necessary to prevent it.

A possible short-term pasture for use in rotations in cropping is a mixture of forage sorghum and *Dolichos lablab, Dolichos* being sown in the interrows at 10 lb per acre.

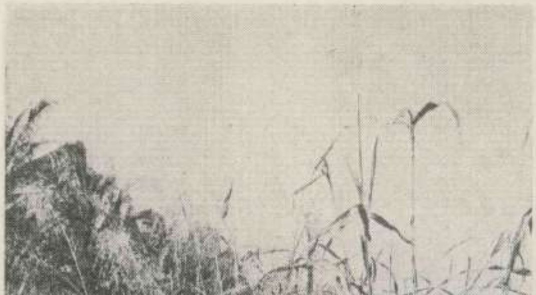
Because young actively growing sorghum contains prussic acid, to prevent loss of stock do not graze sorghum when it is less than 18 in high or when showing signs of wilting due to water stress.

Tripsacum laxum (Guatemala Grass)

Guatemala grass (*Plate* VIII) is a tall upright perennial which grows up to 15 ft in height, and looks, because of its very broad leaves, not unlike a maize plant. It thrives in well watered lowland environments. Growth in the highlands by comparison has been disappointing. Propagation is by cuttings and it is planted in a similar way to sugar cane.

It has a reputation for not standing up well to grazing. However, at Koitaki it appears to be persisting under a regime of high density stocking combined with rotational grazing. It could have uses where cattle are being fed in a bail to provide extra feed in situations such as native cattle projects where cattle are fenced in a small area overnight.

Supplies of planting material can be obtained from Bubia or Aiyura.



(Photo G. D. Hill.)

Plate VII.—Krish, a perennial forage sorghum introduced from India

PASTURE LEGUMES

Cajanus cajan (Pigeon Pea)

Pigeon pea is a tall, fast-growing shrub, the leaf of which is not highly palatable. However, it seeds freely and cattle readily eat the seed pods.

While not suggested as a major component of pasture, it could be of use for planting around fence lines to provide an emergency high protein fodder reserve.

Seed is obtainable from Australian seed merchants.

Calopogonium mucunoides (Calopo)

This legume is naturalized in many coastal areas of the Territory and can commonly be found growing in coconut plantations.

It produces long sprawling runners and is somewhat hairy. Cattle appear to find it relatively unpalatable. If already established it should not be eliminated until replaced by a better species, but it is not recommended for sowing as improved pasture.

Centrosema pubescens (Centro)

Centro is well adapted to many parts of the Territory. It can be seen growing extensively over dredge waste heaps in the Bulolo Valley and grows well in the upper Markham Valley.

Unfortunately, however, when planted in the lowlands, it is prone to Centrosema mosaic virus, which manifests itself as a yellow mottling of the leaves and causes reduced growth (*Plate* IX). For this reason Centro can only be recommended as a short-term pasture component. If used, it should be drilled at 3 to 4 lb per acre or broadcast at 4 to 6 lb per acre. Establishment is slow. Because seed is easy to obtain, it should be considered for sowing with more expensive legumes such as Siratro or Stylo. By the time the Centro ceases to make a significant contribution the other legume should be well established.

Seed is obtainable from the Department of Agriculture.

Clitoria ternatea

A slender perennial plant from tropical Asia which has showy bright blue flowers. It has a reputation for not withstanding heavy grazing.

Seed is not commercially available.

Clitoria rubiginosa

This is a twining prostrate legume with light-green waxy leaves and runners growing out to a length of about four feet.

It has performed well in introduction plots at Aiyura. It has a large seed which is covered in a mucilaginous coating which makes sowing by mechanical means extremely difficult.

Limited suplies of seed may be obtained from Aiyura.

Desmodium canum (Kaimi Clover)

This is a small perennial legume with a dual growth habit. Flowers are borne on upright stems that carry lanceolate trifoliate leaves with white markings in the centre. It also carries

(Photo D.I.E.S.)

Plate VIII.—Guatemala grass does not stand up to grazing but is a good source of green chop

prostrate sterile branches which carry oval unmarked trifoliate leaves. Under grazing the prostrate runners develop strongly and root at the nodes if the soil is moist.

It does not produce a large bulk of forage. It is favoured in pastures in Hawaii because of its persistence and nitrogen-fixing ability (Younge *et al.* 1964). In the Territory it appears to be suited to highland environments. It is growing in pastures at Zenag and has grown well in introduction plots at Aiyura. As areas in which it would grow would also suit *D. intortum* and *D. uncinatum,* these latter legumes should probably be planted instead because of their greater forage production.

Seed is not commercially available.

Desmodium intortum (Greenleaf Desmodium)

Although not generally suited to the lowlands, this trailing perennial legume grows well in the highlands and at Aiyura has performed very well in pastures.

When established from seed it should be sown into a well prepared seed bed at 1 to 3 lb per acre, at a depth of no more than 1 in. Initial grazings should be light until it is well established.

In Hawaii (Younge *et al.* 1964) and in the highlands, considerable success has been obtained from establishing this legume from cuttings. In Hawaii bands are cultivated in existing grasslands and cuttings placed in the furrows. Provided that the plants are protected from weed competition during establishment it is capable of growing across a strip 20 to 30 ft wide.

Limited supplies of cuttings are obtainable from Aiyura and seed from Australian seed merchants.

Desmodium uncinatum (Silverleaf Desmodium)

Silverleaf can be distinguished from Greenleaf by a light central patch in the leaves, which is somewhat silver in appearance. Like Greenleaf it is most suited to the highlands and has done well in pastures at Aiyura.

It can be sown at 1 to 2 lb per acre or can be planted from runners in the same way as Greenleaf.

For a comprehensive review on Greenleaf and Silverleaf, see Bryan (1969).

Runners of Silverleaf can be obtained from Aiyura or seed purchased from Australia.

Dolichos axillaris

This legume is a member of the same genus as the larger *Dolichos lablab*. Unlike that species, however, it is a perennial.

The plant has smallish, shining green leaves borne on long runners. A feature of the plant is its deep root-sytem and its ability to withstand drought. In Queensland it has shown promise in areas with rainfall as low as 25 in.

Because of its large seed size it will tolerate a relatively poorly prepared seed bed but will respond to good ground preparation. It should be sown at 3 to 5 lb per acre, broadcast and lightly harrowed or drilled to a depth of no more than 1 in. In Queensland, because of its agressive growth, it is recommended for areas where weeds or erosion may be a problem.

This legume has not been extensively tried in the Territory but grew well in observation plots at Bubia.

Seed is obtainable from Australian seed merchants.

Dolichos lablab

Dolichos (*Plate* X) is a vigorous, weakly perennial large-leafed legume. It is large-seeded and makes very rapid growth after sowing; it therefore has a special role in areas where weeds are a problem.

(Photo D.I.E.S.)

Plate **IX.—Centrosema plant showing symptoms of mosaic virus infection**

(Photo G. D. Hill.)

Plate X.—*Dolichos lablab* provides rapid ground cover and is an excellent suppressor of weeds

Dolichos may not flower in certain lowland Territory environments (Hill 1967), but this should not detract from its value as an excellent forage legume, as seed is cheap.

It should be drilled into a well prepared seed bed at 10 lb per acre, in rows two feet apart or broadcast at 15 to 20 lb per acre and lightly harrowed into the soil.

Because of its non-perennial habit, Dolichos is of use in ley farming systems. A mixture of the legume with maize, forage sorghum, or pearl millet would provide a well balanced pasture which could easily be grazed out or ploughed in as green manure when the land was required for other use. It is also sometimes used as a nurse crop in the establishment of slower growing perennial legumes like Siratro and Glycine.

Care should be exercised when grazing Dolichos to ensure that cattle do not extensively damage the runners, leading to rapid grazing out. With good grazing management a stand at Munum near Lae lasted two years (Hill 1969b). Care should also be taken because Dolichos is the first tropical pasture legume from which a case of bloat has been recorded (Hamilton and Ruth 1968).

Seed can be obtained in small quantities from the Department, or from Australia.

Glycine wightii (syn. *G. javanica*)

Glycine is a relative of the soybean, but unlike that plant it has a prostrate creeping growth habit and is perennial. Under Territory conditions initial growth is slow, although once established it forms quite satisfactory swards (*Plate* XI).

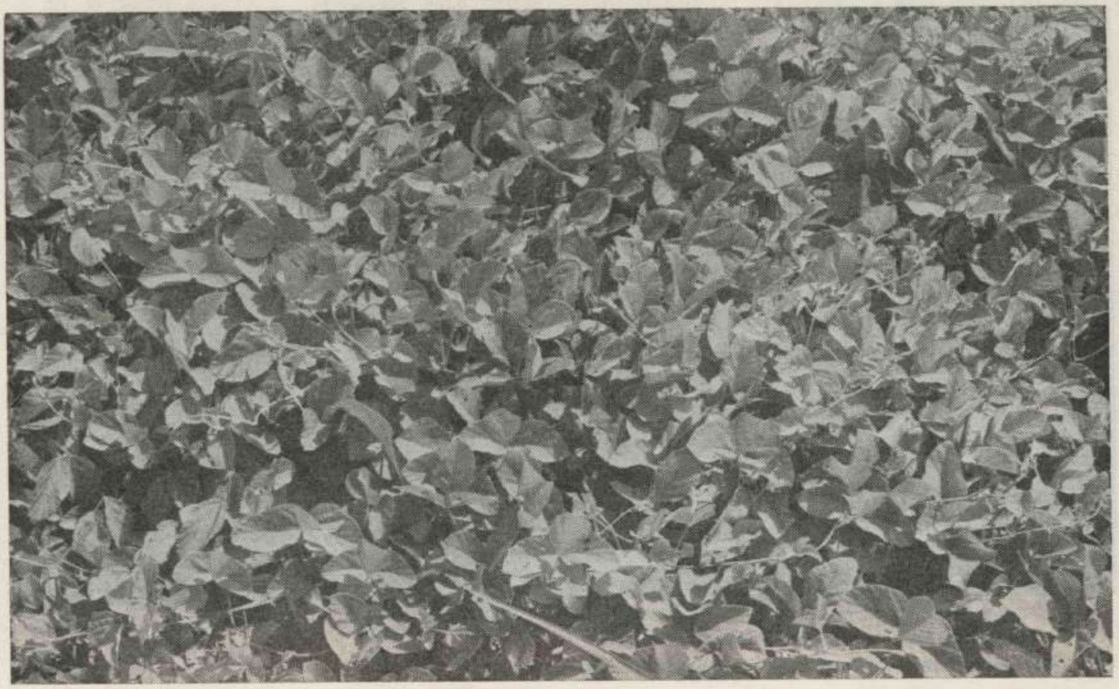
Glycine requires fertile soil and should not be sown elsewhere. It is very deep-rooting and is thus relatively tolerant of drought. It should be sown into a well prepared seed bed at 4 to 8 lb per acre at a depth of 1 in. In Australia, it is often sown into maize crops during the final interrow cultivation, the maize providing some protection for the young seedlings. It is also sometimes sown in association with *Dolichos lablab* at 5 to 7 lb per acre, the Dolichos providing protection for the more slowly growing Glycine. Once established it is able to compete with regrowth of ferns or kunai.

Three varieties are commercially obtainable in Australia—Cooper, Clarence and Tinaroo. As frost is not a problem in the Territory there is probably little to choose between them, although Cooper is reputed to be more hardy and drought resistant.

Leucaena leucocephala (syn. *L. glauca*)

Leucaena is so extensively grown in the Territory that it needs little introduction. For pastures, the introduced Peru strain is recommended. Leucaena, if properly managed, is capable of producing a large bulk of nutritious forage with a crude protein content of up to 30 per cent. In a grazing trial at Erap production of the Peru strain of Leucaena was estimated at 11,000 lb of dry matter per acre over a nine-month period (Hill 1969c).

Leucaena should be sown in rows 10 ft apart at 10 lb per acre. In its early growth it does not compete well with weeds and one or two cultivations may be necessary. The plants should be allowed to grow to a height of 10 to 12 ft, by which time a thick hedge should be formed. At this stage cattle can be admitted to graze off the bulk of the leaf within their reach, and the rows cut back to 3 to 4 ft



(Photo D.I.E.S.)

Plate XI.—A dense sward of *Glycine wightii* at Bubia

in height. *Plates* XII and XIII show a Leucaena pasture established in a coconut plantation near Lae before and after grazing.

Because of its high palatability Leucaena will be grazed in preference to most other plants. For this reason good management requires small paddocks and intensive rotational grazing.

Leucaena contains an amino acid, mimosine, which causes hair loss in monogastric and young ruminant animals. Cattle which are not accustomed to this forage may also lose some hair when it is first grazed, but they rapidly build up rumen micro-organisms which detoxicate the mimosine. Any effect on cattle should therefore be only temporary.

Limited supplies of Peru Leucaena seed are available from Bubia Plant Industry Centre.

Lotononis bainesii

This is a fine-stemmed legume introduced from southern Africa. In Australia it grows well on sandy soils; in the Territory, although slow to establish, it has grown reasonably well in experimental plots near Popondetta in the Northern District. It is not likely to persist on soils that are prone to waterlogging and, because of its unpredictable growth habits, in Australia is usually sown in combination with another legume.

It requires a well prepared seed bed and because of small seed size should be sown at very shallow depth. Once established it should be kept well grazed to prevent its being overgrown by companion grass species.

Lupinus spp.

Several species of this legume have been introduced into the highlands from Western Australia. Most varieties flower and set seed in the highlands. The plants are generally annuals which grow to a height of about 3 ft, leaves are usually palmate, flowers are borne in a terminal raceme, and may be blue, yellow or white depending on the variety sown. The outstanding feature of this species is the very high crude protein content of the seed which can range from 34 to 42 per cent.

(Photo D.I.E.S.)

Plate XII.—Leucaena planted under coconuts at Narakapor near Lae, cut back into hedges before grazing

(Photo D.I.E.S.)

Plate XIII.—Leucaena at Narakapor after grazing, showing the amount of material removed by cattle

In Western Australia, lupins are used extensively to improve fertility on poor sandy soils and are usually reserved for summer grazing. The seed has been used as a protein concentrate in pig and poultry rations in Germany and South Africa replacing part of the animal protein in the ration. Limited suplies of seed of varieties of the following species may be obtained from Aiyura: *Lupinus cosentini, L. angustifolius* and *L. luteus*. Seed of commercially released cultivars may be obtainable from Western Australian seed merchants.

For a recent comprehensive review on the utilization of lupins see Gladstones (1970).

Ornithopus spp.

Two species of *Ornithopus* have been introduced to Aiyura from Western Australia. The plants are prostrate annual legumes with a spreading growth habit. They have slender stems covered with many pinnate leaves. Seeds are borne in long pods which shatter into segments. They are hard and extremely difficult to remove from the remains of the pod. Under Aiyura conditions production is highly seasonal.

The two species are *Ornithopus compressus*, which has yellow flowers, and *O. sativus*, which has pink flowers. *O. sativus* appears to give the best production under highland conditions. It could be of use in the highlands in short term pasture rotations. Limited supplies of seed may be obtained from Aiyura, and it may also be obtained from Australian seed merchants.

Further details on Ornithopus are contained in a paper by Barrett-Lennard and Gladstones (1964).

Phaseolus atropurpureus (Siratro)

Siratro was bred by the CSIRO Division of Tropical Pastures from two plants of this species obtained from Mexico (Hutton 1962).

It is a stoloniferous perennial legume which roots freely at the nodes, producing a dense mat of foliage. It has good climbing ability and is able to climb over obstructions and to overgrow kunai. It has large leaves which are dark green on the upper surface and silvery underneath.

In the Territory, Siratro grows well over a wide range of environments and seeds well in the lowlands.

It should be sown into a well prepared seed bed at 2 lb per acre at a depth of no more than 1 in. Should the price of seed fall, or local supplies be obtainable, advantage could be taken of the ability of Siratro to establish in burnt kunai. This would have obvious application in areas which are too steep for cultivation.

There is a limited supply of seed now available from the Markham Valley.

Phaseolus lathyroides (Phasey Bean)

This is a quick-growing pioneer legume species with an erect growth habit, belonging to the same genus as Siratro.

It is virtually an annual under Territory conditions, but this is compensated for by its prolific seed set. As it is reasonably tolerant of wet conditions, it can be grown in wet locations in association with Para grass. It is also of use for sowing with slower-growing legumes such as Siratro or Glycine to rapidly provide a legume component in the pasture. Once this legume has been sown in an area, plants will be found coming up sporadically for a considerable period.

It should be sown into a well-prepared seed bed at 2 to 6 lb per acre; lesser quantities can be used if it is sown with another legume. At best, apart from in combination with Para grass, it should be regarded as a pioneer species.

Phasey bean is being grown in many locations in the Territory and small supplies of seed could be obtained from them. Larger quantities would have to be purchased from Australia.

Pueraria phaseoloides (Puero)

This legume is used extensively as a cover crop in coastal coconut plantations. As such it is often grazed in those areas where cattle are carried under coconuts.

It is a perennial and produces a dense tangled mat of foliage. It has large, somewhat hairy leaves and may produce runners up to 25 ft in length. In Australia it has a reputation of being grazed out if overgrazed, at least one local producer has had a similar experience (Hill 1969b). It is tolerant of waterlogging, and requires warm conditions. For these reasons it is probably best suited to those areas in the Territory where it has been utilized as a cover crop.

It should be sown at 2 to 4 lb per acre into a reasonably prepared seed bed. On the coast it will probably associate best with Para grass. Puero is susceptible to fire damage and is not tolerant of heavy grazing when young.

Seed in limited quantity can be obtained from the Department. It is also available from Australian seed merchants.

Stylosanthes guyanensis (syn. *S. gracilis*) (Stylo, Brazilian Lucerne)

This legume is well adapted to a wide range of Territory environments and provides a thick mat of prolifically branched runners which may under suitable conditions be up to 3 ft deep. It is perennial and was originally from Brazil.

It was introduced to Zenag some years ago and has naturalized well in that area. It can be found now growing along road verges and stream banks right down to the Bulolo Valley. It also grows well in the drier regions of the Markham Valley and at Baiyer River.

In the wet lowlands under good conditions there are probably better legumes than Stylo; however, for certain areas it is outstanding. These are areas of shallow, gravelly soil such as are found in the Markham Valley, and steep hillslopes covered in native grasses which are too difficult to cultivate. At Erap, it has colonized gravel ridges which, under Centrosema Guinea grass pastures, remained bare all year round. At Zenag it has shown its ability to invade native grasslands.

Stylo is reasonably tolerant of low soil fertility, but like most species will respond well to better soils or added fertilizer.

Stylo is reputed to be relatively unpalatable to stock when green, Observations on Territory properties would appear to indicate that when cattle have green Stylo on offer at all times that it is readily accepted.

In the lowlands it should be sown into a well prepared seed bed at 2 to 4 lb per acre to obtain rapid establishment. On hill slopes it can be either broadcast at 2 lb per acre following a burn, or in the highlands where it seeds freely, small patches can be cultivated allowing the seed to be spread by the cattle.

More comprehensive information on Stylo can be found in the recent review by Tuley (1968).

There is some seed now being produced in the upper Markham Valley.

Stylosanthes humilis (Townsville Stylo, or Lucerne)

This species was accidentally introduced into the Townsville area of Queensland about 1900. It is currently enjoying considerable popularity in tropical pasture improvement programmes in Australia. Unfortunately, currently available varieties from Australia do not produce a large amount of dry matter under Territory conditions. It is an annual which flowers rapidly under the relatively short day lengths in the Territory. Once it has flowered, the plant ceases to make further active growth. For that reason it cannot at present be recommended. However, the Queensland Department of Primary Industries at South Johnstone, and the CSIRO at Townsville (CSIRO Aust. 1965b) are currently screening a large number of selections and varieties suitable for the Territory may become available at a later date.

Trifolium spp.

Several Trifolium species have been introduced to the Territory highlands from the highlands of East Africa. They are *Trifolium ruppellianum*, *T. usambarense*, *T. semipilosum* and *T. burchellianum*.

All make satisfactory growth under Territory highland conditions although production is very seasonal; *T. ruppellianum* has become naturalized at Aiyura and is spreading over the station. All these clovers are highly Rhizobium-specific and will not survive unless inoculated with the correct strain at sowing.

Seed is not generally available but small quantities can be obtained from Aiyura.

Vigna luteola

This is a vigorous leafy perennial legume which roots freely along its runners. It is well adapted to wet environments and grows well near the sea. It should be considered for inclusion in pasture mixtures on coastal plantations where cattle are run.

Although its soft green leaves are attacked heavily by insects under Territory conditions, it still produces a good bulk of material. It is highly palatable and young stands should be protected from overgrazing. Once established. it should be able to withstand heavier grazing.

Vigna should be sown at 3 to 5 lb per acre into a moist seed bed at a depth of about 1 in.

Seed can be obtained from Australian seed firms.

Vigna oligosperma

This is a fine-leafed, prostrate legume with pale blue flowers. It has spread naturally in pastures at Aiyura and is also spreading in the Eastern Highlands.

In view of its persistence and its ability to spread in pastures, it has good potential for the highlands. Once established it spreads quite rapidly without further treatment. The problem with it is that seed is very difficult to collect.

Seed is not obtainable from Australia and only very limited suplies are available from Aiyura.

Vigna sp.

A recent Vigna introduction from Queensland (NG 6164, CQ 502) has performed well in introduction plots at Aiyura. Unlike most members of this genus, it appears to have a high degree of resistance to insect attack. It is a prostrate twining legume.

It has not been commercially released in Australia and seed is difficult to obtain. A very small quantity may be obtainable from Aiyura.

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COFFEE ERADICATION IN A PREVIOUSLY COFFEE RUST INFECTED AREA IN PAPUA

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ABSTRACT

The results of regular inspections of two areas in Papua from which coffee and coffee rust were eradicated in 1965 *are reported. Mature coffee bushes, seedlings and regrowth suckers located at some sites on some inspections were destroyed. No coffee rust was recorded during the surveys.*

INTRODUCTION

ONE probable and two confirmed outbreaks of coffee rust caused by *Hemileia vastatrix* occurred in Papua in 1892, 1903 and 1965, two being eradicated and one apparently eradicated as described in detail by Shaw (1968).

As all the outbreaks occurred within approximately 50 miles of Port Moresby, the main port of call of overseas ships and the international airport, it was decided after the successful eradication of the 1965 outbreak of coffee rust to maintain continual surveys of the previously infected areas. The surveys were to detect any coffee, either Arabica or Robusta, which may have been missed in the 1965 eradication campaign, or which had grown subsequently from fallen berries or had been sown despite prohibition on planting. The inspection teams would check any coffee found to see whether coffee rust was present, and then destroy the coffee in an endeavour to keep the whole area free so that if *Hemileia vastatrix* reached the Territory again through the main port or the international airport, there would be no host available for infection or build-up of the fungus.

Eradication of coffee from the area immediately surrounding Port Moresby would not, of course, be of use if the fungus broke out first in the main coffee-growing areas in New Guinea; these areas are in daily air contact with the airport at Port Moresby and by road and air transport with Lae, one of the largest ports in the Territory. Travellers from overseas sometimes merely change planes at Port Moresby Airport before proceeding to other Territory centres, so that there is the possibility that rust spores being passively carried on these passengers or on their effects could reach the main coffee-growing areas direct.

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THE SURVEYS

The two areas under continual inspection are the Sogeri Plateau about 25 miles directly east of Port Moresby and the Rigo Subdistrict hinterland about 30 to 50 miles south-east of the port. The positions of these two areas and the other coffee-growing areas in the Territory are shown in the *Figure*.

The last coffee rust pustule seen during the 1965 eradication campaign was on 1st November, 1965. The inspections of the areas from that date until October, 1967, were reported by Shaw (1968). During the present surveys, foot patrols were used in the more easily accessible areas; in the heavily forested mountain areas of the Rigo hinterland helicopter transport was used between villages and hamlets with foot patrols at each site. The inspecting teams comprised indigenous field staff while expatriate agricultural officers carried out general supervision with spot checks for efficiency of inspection.

The former coffee plantings on the Sogeri Plateau consisted of some plots, acres in extent, on plantations and some scattered sowings on private holdings and in village gardens. The former coffee plantings in the Rigo hinterland consisted entirely of small plots in village gardens. Wherever possible growers have been encouraged to plant rubber in the former coffee areas; a few areas have grazed cattle, some became village gardens and others reverted to secondary bush.

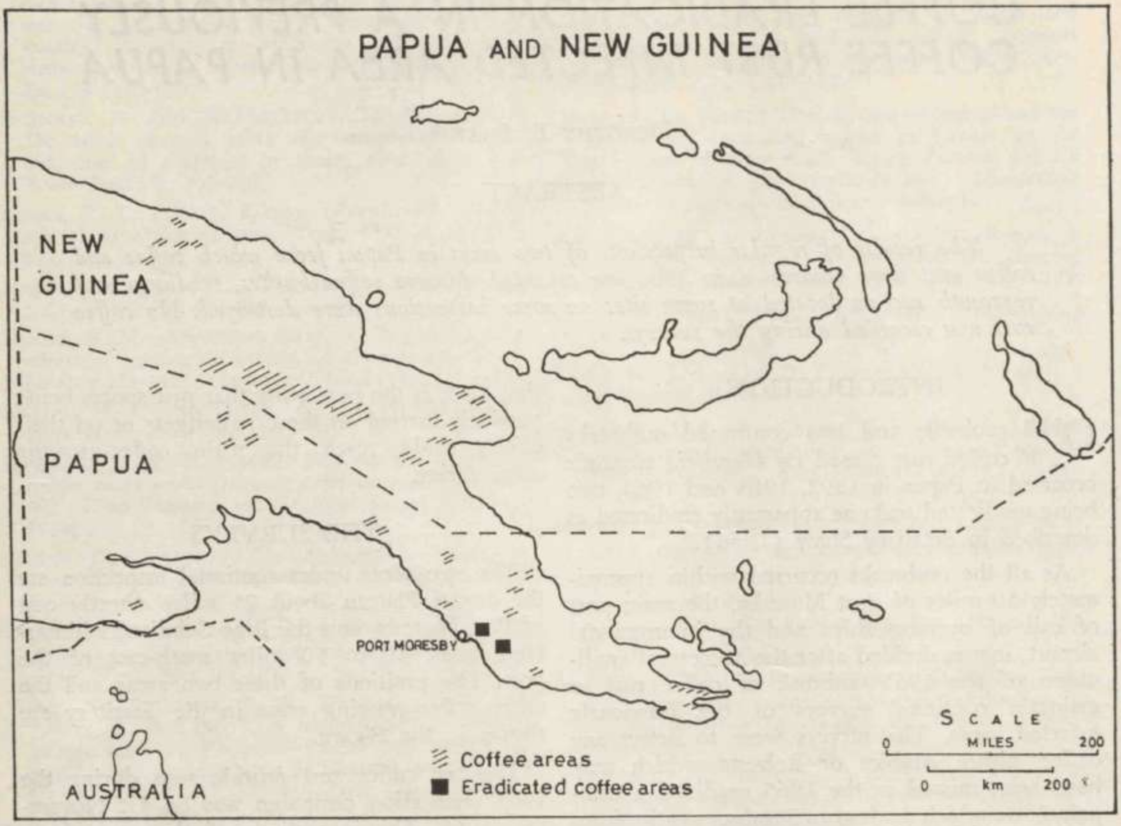

Figure.—Location of coffee areas and eradicated coffee areas in Papua and New Guinea.

The amount of coffee found during the inspections was recorded, also the locality and whether seedling or sucker regrowth, this latter being an indication of inefficient removal during a previous survey. Later it was found desirable for the teams to record approximate height of coffee found, this being an indication of its age, which in turn was an indication as to whether it had been missed during previous surveys. If seedlings were found a search had to be made to try and locate the source of the seed. Any coffee found during the survey was checked for coffee rust and then removed and burnt or forwarded to the Port Moresby laboratory for a second check for rust and size, and then burnt.

The main results of the surveys from October, 1967, until October, 1970, are summarized in the *Table*.

The variation in the number of sites inspected as listed in the *Table* arose because of limitation in the amount of helicopter time available during some patrols, of curtailment of some surveys due to weather conditions, and of the fact that some teams located new sowings or could not locate old sites.

From the results it will be seen that—

(1) no rust was recorded on any coffee found in either area, indicating the efficiency of the eradication campaign carried out in 1965;* and

* The eradication of the fungus was greatly assisted by a severe drought during which any rust spores which may have remained in the air or on other substrates after the destruction of infected coffee bushes apparently became inviable before shed coffee seed germinated at the onset of the next wet period.

Table.—Results of inspections for coffee and coffee rust in two areas in Papua from October, 1967 to October, 1970

Area	Date of Inspection	Number of sites					
		Inspected	Recorded free from coffee	Recorded with coffee			
				Seedlings and/or regrowth			With coffee rust
				1-99 plants	100-999 plants	More than 1000 plants	
Sogeri Plateau	June 1968	23	12	10*	1*	0	0
	Sept. 1968	25	13	9	3	0	0
	Feb. 1969	26	12	8*	6*	0	0
	Sept. 1969	16	4	6*	2*	4	0
	Aug. 1970	25	10	8	5	2	0
Rigo hinterland	Feb. 1968	87	77	6	4	0	0
	June 1968	86	76	10	0	0	0
	Nov. 1968	86	79	7	0	0	0
	Oct. 1969	89	72	16*	1	0	0
	April 1970	61	55	5	1	0	0
	Nov. 1970	44	40	4	0	0	0

* Including some estimations.

(2) mature coffee bushes, seedlings and regrowth continued to be found in both areas, despite continual surveys and eradication.

As will be realized, it only needs one or two coffee plants to be missed during a few patrols and for these to flower and set seed to give rise to hundreds and in a few cases several thousands of young seedlings. If even a few berries are carried into gardens, secondary bush or forest by water run-off, birds or man, and if the resultant seedlings in turn escape notice during a few subsequent patrols and then start bearing and shedding a new crop of berries, the cycle will continue *ad infinitum*, the amount of coffee increasing or decreasing depending on the frequency and efficiency of subsequent surveys.

It was obvious that some sites were kept free from coffee by the villagers, whereas at other sites little control appears to have been carried out at all. On a few occasions new sowings were located which the owners claimed were made in ignorance of the prohibition. The most difficult site was on a plantation where coffee had previously become established in secondary bush over a wide area.

It was evident that more patrols each year would have been desirable, especially if accompanied by more trained field staff who could have been retained in the eradication work even though they also continue to carry out normal extension duties. The teams would have been able to become more *au fait* with sites and villagers, so that the work of each patrol would have been directly continued in the succeeding survey.

However, as mentioned in part previously, changes in personnel, limitations on the number of trained and responsible field staff and supervisory officers, finance for helicopter transport and availability of helicopters limited the number of inspections possible and the efficiency of the operations.

Nevertheless, it is considered that by keeping the region around the main port and international air terminal relatively free from coffee the risk of any viable coffee rust spores introduced by accidental importation finding the host in the locality has been greatly reduced.

ACKNOWLEDGEMENT

The work of the inspection teams and the agricultural officers on both the Sogeri Plateau and in the Rigo hinterland is gratefully acknowledged—on them fell the main burden of the eradication patrols. The figure was drawn by Mrs C. Crofts.

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