GROWTH AND PHOSPHORUS RESPONSE OF SOME PASTURE LEGUMES SOWN UNDER COCONUTS IN BALI

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ABSTRACT

Phosphorus (P) *was the main nutrient deficiency in the* 0–30 *cm horizon of a loamy, fine sand at Kuta, Bali. In a pot experiment* Centrosema pubescens *(centro) and* Stylosanthes guyanensis *(stylo) showed positive quadratic responses to P addition over the range* 10 *to* 80 $kg\ ha^{-1}$ *P;* Lotononis bainesii *was less responsive and exhibited greater P uptake per unit root weight. Growth of these legumes under coconuts at the Kuta field site was independent of P application, presumably because of increased soil P availability at depth. Stylo showed superior first season vigour in the field, and lotononis grew longer into the dry season, giving a similar nitrogen yield.*

Pasture growth, soil moisture, and light transmission were not affected by proximity to trees and coconut roots exploited the inter-tree areas. Noon light transmission was 77 *to* 80% *full sunlight through palms from* 30 *to* 50 *years old spaced* 10 *to* 12 *m apart.*

INTRODUCTION

Bali has an estimated 68,000 ha of coconuts (Djapa Winaya 1972). Some of this land is inter-cropped, but most of the coconut lands on sandy soils adjacent to the coast are lightly used by cattle grazing volunteer pasture and weeds. Cattle (*Bos banteng*), which number about 0.35 mill., are integrated with crop production and are a significant source of export income. More intensive use of coconut land is one strategy for increasing cattle production.

Pastures and coconuts do not compete for light in the classical sense, since the canopy of the palms is well above the pasture sward. However, pastures have reduced the availability of nutrients and moisture to palms in some situations, with consequent reduction in copra yield (Santhirasegaram 1966). The selection of well adapted pasture legumes and an understanding of the fertilizer needs of the pasture-coconut association are therefore of high priority. This paper reports a short term comparative study of the performance of *Centrosema pubescens* (centro), *Stylosanthes guyanensis* cv. Endeavour (stylo) and *Lotononis bainesii* cv. Miles (lotononis) and their response to phosphorus (P) on a sandy soil bearing coconuts at Kuta, Bali (lat. 8°S). The fertility of this soil was also assessed using *Macroptilium lathyroides* (phasey bean).

MATERIALS AND METHODS

Site description

The experimental site at Kuta is situated 2 km from the sea at 10 m elevation. The soil is a loamy fine sand (10 YR 3/2) overlying loamy coarse coralline sand (7.5 YR 4/4) at 80-90 cm, with pH stable at 6.5 in the 0-70 cm layers and increasing to 8.5 at 80 cm depth. Mature coconut palms about 30 years old were spaced 10 to 12 m apart on a rectilinear grid; these averaged 10.2 m high (range 6.5 to 12.6 m) and 1.01 m girth at 1.5 m height. The area had recently grown cassava,

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and had a history of many years cropping to sweet potato, peanut, and green bean without use of fertilizer or animal manure. The investigation was planned after a pot experiment in 1971 with soil collected at the Universitas Udayana Guest House. Kuta (2 km distant) showed acute P deficiency uncomplicated by other nutrient shortages (Djapa Winaya personal communication).

TABLE 1

*Mean monthly climatic data at Tuban Airport, Bali**

Month	Rainfall (mm)	Temperature (°C) Max.	Temperature (°C) Min.	Relative Humidity (%)
Jan.	345	30.8	25.5	79
Feb.	287	31.1	25.5	80
March	211	31.0	25.5	80
April	113	31.4	25.5	78
May	77	30.8	25.4	79
June	95	30.3	24.5	76
July	70	29.7	24.3	74
August	32	29.9	24.6	73
Sept.	34	30.4	24.6	75
Oct.	88	31.3	25.1	76
Nov.	181	32.1	26.3	74
Dec.	299	30.9	25.7	78
	1,832	30.7	25.2	77

*1956-1965

Kuta is one of the wetter districts in Bali growing coconuts, and Table 1 shows climatic data for Tuban Airport 8 km away. The annual rainfall of 1,832 mm has a pronounced seasonal occurrence from November to March, but sufficient falls in the dry season for the growth of perennial tropical legumes. The warm temperature (annual mean 27.8°C) of this tropical island climate shows little seasonal fluctuation.

Pot experiments

Experiment 1 studied the nutrient deficiencies of the Kuta soil. The design was a 2^4 factorial with two replications. Elements were either absent or applied in the following amounts (kg ha^{-1} element, surface area basis) and forms: phosphorus (40) as Na_2HPO_4, potassium (50) as KCl, sulphur (40) as Na_2SO_4, and the combined elements molybdenum (0.2) as $(NH_4)_2MoO_4$, boron (0.9) as $Na_2B_4O_7.10H_2O$, copper (6.3) as $CuCl_2.2H_2O$, magnesium (12.7) as $MgCl_26H_2O$, manganese (11.4) as $MnCl_2$, and zinc (6.2) as $ZnSO_4.7H_2O$. The pot experiments were conducted in a greenhouse with translucent plastic roof on the campus of Universitas Udayana at Denpasar. Phasey bean seedlings were transplaned on July 7, 1972 from vermiculite to pots (4 seedlings per pot), each containing 1.8 kg soil taken from the 0–30 cm layer of the Kuta experimental site, and were harvested in the vegetative stage 58 days later.

Experiment 2 compared the response to phosphorus of the three pasture legumes centro, stylo and lotononis grown on the 0–30 cm layer of the Kuta soil. The experiment was a factorial with 3 species × 5 levels of phosphorus: 0, 10, 20, 40 and 80 kg ha^{-1} P as triple superphosphate, replicated 4 times. All 60 pots were given a basal application of 117 kg ha^{-1} potassium sulphate. Seed was scarified, inoculated with *Rhizobium* (CB 1923 for centro, CB 756 for stylo, CB 376 for lotononis), and sown on March 1, 1972; there were 5 seedlings per pot.

Dry weight of stems, leaves, and roots plus nodules were determined 98 days after sowing. Roots were washed out over a No. 10 1.7 mm sieve.

Pots were watered to 60 per cent moisture holding capacity daily in experiment 1 and in experiment 2 until May 16, and twice daily from May 17 to June 6.

Field experiment

Experiment 3 was of similar design to experiment 2 but was conducted in the field at the Kuta site. Replication was increased to five, one of these being made up of plots which were close to the base of coconut palms. Plot size was 2 m × 2 m.

The area was twice ploughed to 15 cm and hand ridged into raised beds in November 1971. It was hand-hoed prior to sowing on January 6, 1972 with scarified, inoculated seed at 10 kg ha^{-1}. The sowings were repeated on February 18, 1972, owing to uneven establishment. Triple superphosphate was broadcast on January 4, and basal potassium sulphate and flowers of sulphur at rates of 53 kg ha^{-1} K and 40 kg ha^{-1} S respectively were broadcast on February 17. The pastures were rain grown, ungrazed, and hand weeded throughout the experimental period.

Different sites within each plot were harvested to 1 cm on May 22, July 11, and August 30, 1972, and dry weight was determined. Moisture availability characteristics of the Kuta soil were determined using the filter paper method of Fawcett and Collis-George (1967), and soil moisture content was determined at four depths and at six distances from the palms on August 17, 1972. Light transmission measurements were made under palms and in adjacent open areas using a cadmium sulphide cell.

After Kjeldahl digestion of plant samples from experiments 2 and 3, per cent P was measured on a spectrophotometer using a modified version of the vanado-molybdo-phosphoric yellow method described by Jackson (1958) whilst per cent nitrogen (N) was determined colorimetrically on a Technicon Autoanalyser using a modified method similar to that of Williams and Twine (1967). More detail is available in Steel (1974).

RESULTS

Pot experiments

In experiment 1 the growth of phasey bean shoots was highly significantly increased from 1.45 g in the nil P pots to 2.30 g per pot in the plus P pots, and similar increases in root growth, plant height and leaf number occurred. This response was uncomplicated by deficiencies of other nutrients, and there were no significant interactions.

In experiment 2 (Table 2) P increased shoot growth particularly in centro which gave much higher yields than the other two species. Centro and stylo showed a significant quadratic response in the growth of shoots, but this was not evident for lotononis. Increasing P supply increased leaf number but not main shoot branch number or main shoot length at harvest, although centro height at earlier stages was positively related to P rate (Steel 1974). P additions increased root weight only in centro. The roots of all three species bore numerous red-centred nodules. Individual nodules were larger in centro.

N concentration of lotononis shoots (Table 3) averaged 2.32%, compared with 1.87 and 1.79% for centro and stylo respectively. In centro, N concentration showed a positive quadratic response to P supply, increasing from 1.64 to 2.10% at the P_{80} level. This reinforced the growth response, and N yield at P_{80} was 91% more than the control N yield. The concentrations of N and P were significantly and positively correlated in centro, but not in lotononis and stylo. P concentration in lotononis shoots averaged 0.275%, relative to 0.182 and 0.147% for stylo and

TABLE 2

Dry matter yield of three legumes at various levels of phosphorus supply—Experiment 2

Species	Phosphorus level (kg ha^{-1}) 0	10	20	40	80
	Yield of shoots (g pot^{-1})				
Centro	28.7a*	35.0b	37.2bc	39.8cd	44.0d
Stylo	11.0a	12.7ab	12.1ab	15.4c	14.2bc
Lotononis	6.3a	7.3ab	8.1ab	6.7a	8.9b
	Yield of roots (g pot^{-1})				
Centro	6.0a	7.3b	7.3b	7.5b	7.3b
Stylo	2.1	2.4	2.2	3.1	2.5
Lotononis	0.6	0.8	0.8	0.8	0.8
	Shoot yield response (g additional yield g^{-1} P applied)				
Centro		360	243	144	109
Stylo		103	32	63	24
Lotononis		57	52	6	19

*Values in the same horizontal line not followed by the same letter differ at P = 0.05 by Duncan's new multiple range test.

TABLE 3

Effect of increasing phosphorus supply on nitrogen and phosphorus content of three legumes—Experiment 2

Species	Phosphorus level (kg ha^{-1}) 0	10	20	40	80
	N concentration of shoots (%)				
Centro	1.64a	1.75a	1.90b	1.97b	2.10c
Stylo	1.74	1.75	1.79	1.84	1.82
Lotononis	2.30	2.41	2.48	2.29	2.12
	P concentration of shoots (%)				
Centro	0.116a	0.130a	0.149b	0.157b	0.181c
Stylo	0.126a	0.142a	0.187b	0.186b	0.272c
Lotononis	0.223a	0.241ab	0.273bc	0.291c	0.345d
	P uptake per unit root dry weight (mg P g^{-1} root)				
Centro	5.6	6.2	7.6	8.3	10.9
Stylo	6.5	7.5	10.2	9.3	15.6
Lotononis	21.9	21.1	26.7	23.5	38.3
	Apparent P recovery (%)				
Centro		69	62	41	33
Stylo		22	18	21	17
Lotononis		21	18	8	12

centro respectively. In shoots P concentration was quadratically related to level of P addition in centro, and linearly related in stylo and lotononis. P uptake per unit of root weight was positively related to P supply, and was substantially greater in lotononis than in stylo and centro (Table 3). Per cent apparent recovery of applied P was negatively related to P supply, and was greater in the higher yielding centro.

Field experiment

Heavy rain (276 mm) fell in the week before sowing on January 6, and 91 mm was recorded in the next 8 days. This was succeeded by an abnormal dry period (8 mm in 33 days) which was unfavourable for establishment. Wet conditions then occurred until the end of March, 562 mm falling on 28 wet days. Dry conditions prevailed for the rest of the experimental period.

TABLE 4

Yield and nitrogen content of three legumes at Kuta—Experiment 3

Species	Harvest date 22.v.72	11.vii.72	30.viii.72
	Dry matter yield (kg ha^{-1})		
Centro	635a*	1,430a	1,240a
Stylo	3,720c	5,790c	5,640c
Lotononis	1,270b	3,110b	3,740b
	N concentration of shoots (%)		
Centro	2.33b	1.77b	1.23b
Stylo	1.67a	1.33a	0.97a
Lotononis	2.22b	1.80b	1.77c
	N yield of shoots (kg ha^{-1})		
Centro	14a	26a	15a
Stylo	61c	76c	54b
Lotononis	28b	56b	66c

*Values in the same column not followed by the same letter differ at P = 0.05 by Duncan's new multiple range test.

Density of seedlings from both sowings was 17, 74 and 150 plants m^{-2} on March 21, for centro, stylo, and lotononis respectively; density was independent of P rate. Seedling survival and early growth of stylo was superior, and plant cover on April 21 averaged 22, 72 and 57 per cent for centro, stylo and lotononis respectively. Satisfactory nodulation occurred in all species. Flowering was observed in lotononis on April 21 and in stylo and centro on May 1. Endeavour stylo reached peak yield of 5,790 kg ha^{-1} at the second harvest on July 11 (Table 4) when centro yielded 1,430 kg ha^{-1}; lotononis continued to grow into the dry season and yielded 3,740 kg ha^{-1} on August 30. N concentration of centro and lotononis shoots exceeded that of stylo; the net effect was that N yield attained the same levels in stylo and lotononis towards the end of the experimental period, which were superior to centro.

Plant yield was independent of P application rate. P concentration in the flowering shoots on May 22 was 0.171, 0.155 and 0.219% for centro, stylo and lotononis respectively, and was unaffected by level of P addition. Soil samples taken from the experimental site indicated 9.4, 14.5 and 25.4 ppm available P (Olsen's bicarbonate method in Jackson 1958) in the 0-20, 40-50 and 80-90 cm layers respectively.

Some other measurements were made to characterise the coconut-pasture environment. A trench dug from 0.7 to 3 m from a tree showed that palm roots were still very dense 3 m from the trunk. Roots of both stylo and lotononis were followed to 95 cm depth, and occupied the same region as the palm roots. No lateral gradient of root distribution of palms was evident, which is consistent with

TABLE 5

Soil moisture content (%) in relation to tree position

Sample depth (cm)	Distance from tree (m) 1.5	3	5	6	7.5	10	Mean
0-10	4.8	5.1	3.8	4.4	4.6	6.3	4.8
30-40	10.9	16.7	11.4	12.0	13.7	11.2	12.7
60-70	12.1	11.6	12.5	16.6	14.1	14.4	13.6
90-100	9.0	10.1	12.7	11.7	14.3	15.1	12.2

TABLE 6

Light transmission of coconut palms (%)

Time	Kuta site		Sangiang‡
	Experimental area*	Adjacent area†	
0900	77	72	
1000	88	82	
1200	80	77	79
1400	66	66	73
1500	61	63	

*Based on 175 measurements over 2 days
†Based on 198 measurements over 2 days
‡Based on 85 measurements on 1 day.

the finding that no pasture yield differences occurred between the block of plots located contiguous to trees and the blocks located farther from the trees. Soil moisture observations (Table 5) made late in the dry season on August 17, 1972 showed no discernible gradient along a diagonal line 1.5 to 10 m from a tree, at least in the 0-70 cm layer. Wilting points (pF 4.2) were 7.2, 11.5 and 7.0% in the 0-30, 30-70, and 70-100 cm horizons; on this basis surface soil was below wilting point and little moisture was available to plants at depth on this sampling occasion.

Light measurements on clear or sparsely cloudy days made at and adjacent to the experimental site (Table 6) indicated 77 to 80% noon transmission of full sunlight to the top of the pasture canopy. Measurements made at the site of a grazing experiment conducted by Universitas Udayana at Sangiang in west Bali showed 79% noon transmission; the trees at this site were about 50 years old and were taller than at the Kuta site. The data in Table 6 suggest reduced per cent transmission during the early morning and afternoon when sun angle is low. No consistent pattern of variation in transmission according to proximity to trees was evident within the plantations. Shaded patches often received only 10% transmission, but shading of any point was intermittent according to wind movement of the palm canopy and to changes of sun angle.

DISCUSSION

P requirement and P response are, in the simplest case, positively related to the genetic potential for growth. Legumes which grow well require higher levels of P uptake to maintain adequate P concentrations in their tissues. In experiment 2, the larger seeded centro climbed up the supporting rods in each pot, grew more than stylo and lotononis at all P levels and showed greater absolute yield response, P requirement for maximum yield (Table 2), and apparent P recovery (Table 3). Stylo behaved similarly with respect to the more diminutive lotononis. These results generally conform with the species behaviour reported by Roe and Jones (1966), Andrew and Robins (1969), Blunt and Humphreys (1970) and Wendt (1970).

There are, however, some interesting variations from the above generalization. The relative yield response was higher in centro. The utilization of P in growth, which is indicated by the reciprocal of P concentration (Table 3), was most efficient in centro, and least efficient in lotononis. For instance, the P utilization quotients were 1.23, 0.77 and 0.43 g dry matter/mg P uptake at the 15 mg P yield pot^{-1} level for centro, stylo and lotononis respectively. The relative capacity to extract P from the soil, as judged by P uptake per unit root weight, was substantially higher in lotononis, which agrees with the study by Andrew and Vandenberg (1973). The use of P in improving N yield, presumably through increased N fixation, was more efficient in centro, and this characteristic is of great significance both in soil fertility and in the improvement of animal diet.

The lack of legume response to P at the Kuta site (experiment 3) is an encouraging result, since pasture development under coconuts can be accomplished more cheaply. It is also a cautionary tale of the dangers of using surface soil (0-30 cm) for nutritional diagnosis when superior P status occurs at depth. It is just possible that the absence of P response may have been due to other constraints, e.g. preferential absorption of added P by coconut roots, but P concentration in the shoots at advanced flowering was above or equal to the critical P values suggested by Andrew and Robins (1969) for centro, the related Townsville stylo, and lotononis.

Satisfactory stylo performance occurred at Kuta, despite abnormally dry conditions in January-February, and an early closure to the wet season at the end of March, and this agrees with stylo's reputation as a pioneer legume. The continued growth of lotononis during the dry season and its high content of N and P were noteworthy. Centro showed poorer first year establishment and growth in the field than might be expected from the results of pot experiment 2, but has since shown better adaptation in the second and third years after sowing. *Macroptilium atropurpureum* cv. Siratro has been the best adapted legume in companion experiments at this site (K. Mendra personal communication).

Estimates of light transmission vary from 50% for mature palms at 8 m spacing in Sri Lanka (FAO 1967) to 90% for tall mature palms at 8.5 m spacing in Fiji (Ranacou 1972), but we have not sighted reports in the literature of any actual measurements. Our light measurements (77 to 80% noon transmission), confirm that the environment under mature coconuts is favourable for pasture development. Other studies in Bali are concerned with grass adaptation, stocking rate, cattle growth, and the effect of pastures on copra production.

ACKNOWLEDGEMENTS

We are indebted to the Australian Asian Universities Cooperation Scheme and the Australian Freedom from Hunger Campaign for support, and to Professor dr. I. G. Ng. G. Ngoerah, Rektor of Universitas Udayana, and Drh. M. Supardjata, then Dean, Fakultas Kedokteran Hewan Peternakan for provision of facilities. We are grateful to many Indonesian friends, including Drs. Djiwa Darmadja, Ir. Pt. Djapa Winaya, Drs. Kt Dajuh Nurbudhi, Ir. Kt Rika, Ir. Kt Mendra, I. Nj Merit and I. Wj Leo Andel. We appreciate the advice of Dr. C. J. Asher and Dr. P. C. Whiteman, and the active help given by Mrs. S. Steel in all phases of the project.

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(Accepted for publication August 1, 1974)