THE NUTRITION AND GROWTH OF LUCERNE ON A SEDENTARY BLACK EARTH OVERLYING A PERCHED WATERTABLE ON THE EASTERN DARLING DOWNS, QUEENSLAND

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ABSTRACT

Following glasshouse screening, two nutrient experiments with Hunter River lucerne were carried out on a shallow, eroded, brown basaltic clay soil overlying a perched watertable, on the eastern Darling Downs. High levels of dry matter production were sustained during two growth seasons. Lucerne was found to make most growth in spring-summer-autumn, and winter growth rates were relatively low.

Dry matter responses were measured to both phosphorus and sulphur fertilizers, and sulphur increased the crude protein content of plant tissue. There was no difference in dry matter or crude protein response to two forms of sulphur (elemental sulphur and gypsum) applied in early spring.

The response to phosphorus, and evidence of a response to micronutrients (particularly zinc) were not typical of the majority of sedentary soils of the region. These were attributed to fixation due to calcium and magnesium ion saturation associated with a high soil pH on the site.

INTRODUCTION

The eastern Darling Downs, defined as uplands (1,500-2,000 ft in elevation), approximately 15 miles wide and 50 miles long, west of the Great Divide, is dominated edaphically by black earths (Thompson and Beckman, 1959). Sulphur deficiency occurs extensively, with widest distribution on the skeletal and shallow sedentary members (R. M. Jones, L. Loader — personal communications). The upland slopes on which the deficiency has been recognized vary in approximate magnitude from 3-15%. Soil erosion is common and has resulted in the truncation of natural soil profiles (Thompson and Beckman, 1959).

The perennial legume lucerne (*Medicago sativa* cv. Hunter River) is extensively used in this area for grazing and as a hay crop. It is easy to establish, and on eroded sites, is an excellent species for the rebuilding of soil fertility.

Perched water tables (*syn.* shallow aquifers) occur commonly in the catchments and flood plains of creeks on the eastern Darling Downs (R. M. Jones — personal communication). The nutrient requirements and production potential of Hunter River lucerne were studied on one catchment site. The plant had exhibited a lack of vigour and general, though not severe, chlorosis.

MATERIALS AND METHODS

The soil studied was a dark brown, shallow, eroded clay, overlying strongly weathered basalt to a depth of 12 in. - 15 in. Carbonate nodules occurred abundantly throughout the profile; the soil type was not typical of the majority of sedentary upland black earths (C. H. Thompson, R. M. Jones — personal communications) and appeared best categorized by *Miscellaneous Group 3* (Thompson and Beckman, 1959). The occurrence of carbonate nodules was localized and the movement of the water table over a period of time seems a likely explanation for their accretion.

The available soil phosphate level, measured by both the acid (Kerr and von Stieglitz, 1937), and the bicarbonate (Colwell, 1963) extraction techniques was low (less than 20 ppm P throughout the profile). Soil pH varied little with depth, in the range 7.8-8.2.

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Glasshouse Screening

Soil for initial glasshouse screening studies was taken from three sites to a depth of 6 in. adjacent to an area of established lucerne; it was considered representative (R. M. Jones — personal communication) of that involved in subsequent field experimentation.

The sample taken was passed through a $\frac{1}{4}$ in. sieve and the coarser fraction discarded.

Two experiments were carried out. In each, 1,200 g soil (12% moisture content) was added to $5\frac{3}{4}$ in. diameter plastic pots, closed with a plastic liner. Nutrients (in solution), and de-ionized water were added to a moisture content of 40% prior to planting with inoculated lucerne seed. Pots were watered to a constant weight daily. Plants were harvested at crown level and the samples dried at 80°C for 48 hours.

The first experiment was a factorial of four treatments — three macro-nutrients, viz. phosphorus (P), potassium (K) and sulphur (S), and a complete micro-nutrient addition. Five plants were grown per pot. Nutrients were applied in solution at the following rates/acre equivalent of pot surface:

P — Sodium dihydrogen phosphate	at	672 lb
S — Sodium sulphate	at	224 lb
K — Potassium chloride	at	112 lb
Zn — Zinc acetate	at	14 lb
Cu — Copper acetate	at	14 lb
Mn — Manganese chloride	at	14 lb
Mo — Sodium molybdate	at	3 lb
Co — Cobalt acetate	at	3 lb
Fe — Iron citrate	at	14 lb

The experiment was conducted during winter 1966, and a harvest made after 10 weeks.

Production was increased by P, S and micro-nutrients.

A second was thus designed as a 2^6 $\frac{1}{2}$ replicate factorial to establish which elements among zinc (Zn), copper (Cu), manganese (Mn), boron (B), molybdenum (Mo) and cobalt (Co) produced the micro-nutrient response. To limit the size of the experiment, Iron was eliminated since it seemed unlikely to be limiting on a black earth.

Nutrients, excepting Iron, but including a basal dressing of P, K and S were applied as above. Seven plants/pot were grown during autumn 1967, and a harvest made after 7 weeks.

Field Studies

Two factorial experiments were designed to test the glasshouse responses. These were conducted under dryland conditions in the second and third seasons after lucerne establishment (1966/1967 and 1967/1968) respectively. Each was replicated three times.

In the first, responses to two elements were studied:

(a) P — as sodium di-hydrogen phosphate at 120 lb sodium di-hydrogen phosphate/acre, and

(b) S — as 1. Flowers of S at 50 lb S/acre, and 2. Gypsum at 50 lb S/acre.

The second investigated the effects of the following micro-nutrients:

(a) Zn — as Zn chloride at 56 lb Zn chloride/acre,

(b) Mo — as Na molybdate at 3 lb Na molybdate/acre,

(c) Mn — as Mn sulphate at 56 lb Mn sulphate/acre.

A basal dressing of P (240 lb sodium di-hydrogen phosphate/acre) and S (100 lb S as gypsum/acre) was applied to all plots.

Nutrients were broadcast on the soil surface in early September, approximately 50 days prior to the first harvest. Harvests were made at 1/10 flowering using one (3 ft x 3 ft) quadrat per plot and samples were retained for Kjeldahl nitrogen analysis. Plot dimensions were 20 ft x 10 ft.

RESULTS AND DISCUSSION

Initial Screening

Individual nutrient treatment effects measured in the pot experiments are shown in Tables 1 and 2.

Dry matter production was increased by the addition of P, S, Zn, Mn and Mo. The responses were measured as single effects and as various interactions.

Field Studies

The combined P + S nutrient treatment interacted to increase the total D.M. production of lucerne in 1966/1967 by 77% over the control (Table 3). Responses were measured to both P and S singly. S also increased the crude protein (CP) content of lucerne at each harvest, though in each case the % increase over control was small, eg 19.7% to 20.6% at Harvest 2; 21.9% to 23.3% at Harvest 5. The response to S was in keeping with the findings of R. M. Jones and L. Loader (personal communications) in the region, and its magnitude was probably accentuated by erosion and a shallow soil profile. Sulphur responses have also been measured by Crofts and Blain (1967), Hilder (1954), McLachlan (1951), and McLachlan (1955) on soils of similar geological origin in other parts of Australia.

Responses to applied phosphate on sedentary basaltic soils have been generally uncommon. McLachlan (1955) first suggested that wide deviations in general response patterns do exist in Eastern Australian soils, and R. M. Jones (personal communication) considers there are potentially responsive sites in parts of the eastern Darling Downs. J. Hart (personal communication) has, from soil test data, shown that many potentially responsive sites exist in the area broadly defined by Jones, but their distribution is sporadic and the reasons for the low soil test values have not yet been explained.

On this site, however, high soil pH and a concentration of calcium and magnesium ions (as evidenced by nodular development throughout the profile) have resulted in phosphorus fixation (Hemwall, 1957). The total phosphorus content of the soil, measured by perchloric acid digestion (Jackson, 1962), was relatively high (3-6 in – 380 ppm P; 6-12 in – 330 ppm P); the nodules also contained 200 ppm P, less than 1/10 of which was available to plants, suggesting the occurrence of complex, insoluble calcium phosphates in the soil. This explains the responses to applied phosphate.

In phosphorus predictions studies being made at the Queensland Wheat Research Institute (M. J. Whitehouse — personal communication), a sedentary black earth, responding to the application of phosphate, and with similar composition, (pH – 8.2; available P – less than 10 ppm P in 0-4 in; total P – 200 ppm P; the presence of carbonate nodules), was sampled at Willowvale near Warwick.

Whilst these soils are not typical of the majority of sedentary black earths on the eastern Downs their occurrence and phosphorus nutrition should be noted.

There was no difference in the time and magnitude of responses between the forms of S applied (Table 4). This does not agree entirely with the findings of McLachlan and De Marco (1968) who demonstrated that superior plant responses were generally obtained to gypsum than to elemental S. However, when both forms were applied early, as in this experiment, the difference was lessened; here, the rates of application were high, and conditions following application must have favoured the mineralization of elemental S. This is emphasized by Hilder's finding (1954) on the New England Tableland, that the first response to applied gypsum was measured 59 days after application.

TABLE 1

Macro-nutrient and total micro-nutrient treatment effects on lucerne dry matter production in pots

Treatment	P +	P —	S +	S —	micro-nutrients +	micro-nutrients —	K +	K —
D.M. (g/5 plts)	1.331	0.666	1.257	0.740	1.637	0.833	1.003	0.994
L.S.D.	0.138 (5%); 0.185 (1%) for all treatments							

TABLE 2

Micro-nutrient treatment effects on lucerne dry matter production in pots

Treatment	Zn +	Zn —	Cu +	Cu —	Mn +	Mn —	B +	B —	Mo +	Mo —	Co +	Co —
D.M. (g/7 plts)	1.911	1.495	1.690	1.716	1.813	1.594	1.702	1.704	1.781	1.625	1.727	1.680
L.S.D.	0.137 (5%); 0.196 (1%) for all treatments											

TABLE 3

Total yields and individual nutrient treatment effects on total yield in 1966/67

Treatment	Total Lucerne D.M. Yield (lb/ac in 7 cuts)	P treatment	Total D.M. yield (lb/ac)	L.S.D. for P effect	S treatment	Total D.M. yield (lb/ac)	L.S.D. for S effect
PS_1	13654				$+ S_1$	11258	
PS_2	12663	+ P	11508	705 (5%)			864 (5%)
P	8539				$+ S_2$	10931	
S_1	9921			959 (1%)			1174 (1%)
S_2	9444	— P	8829		— S	8317	
Control	7414						

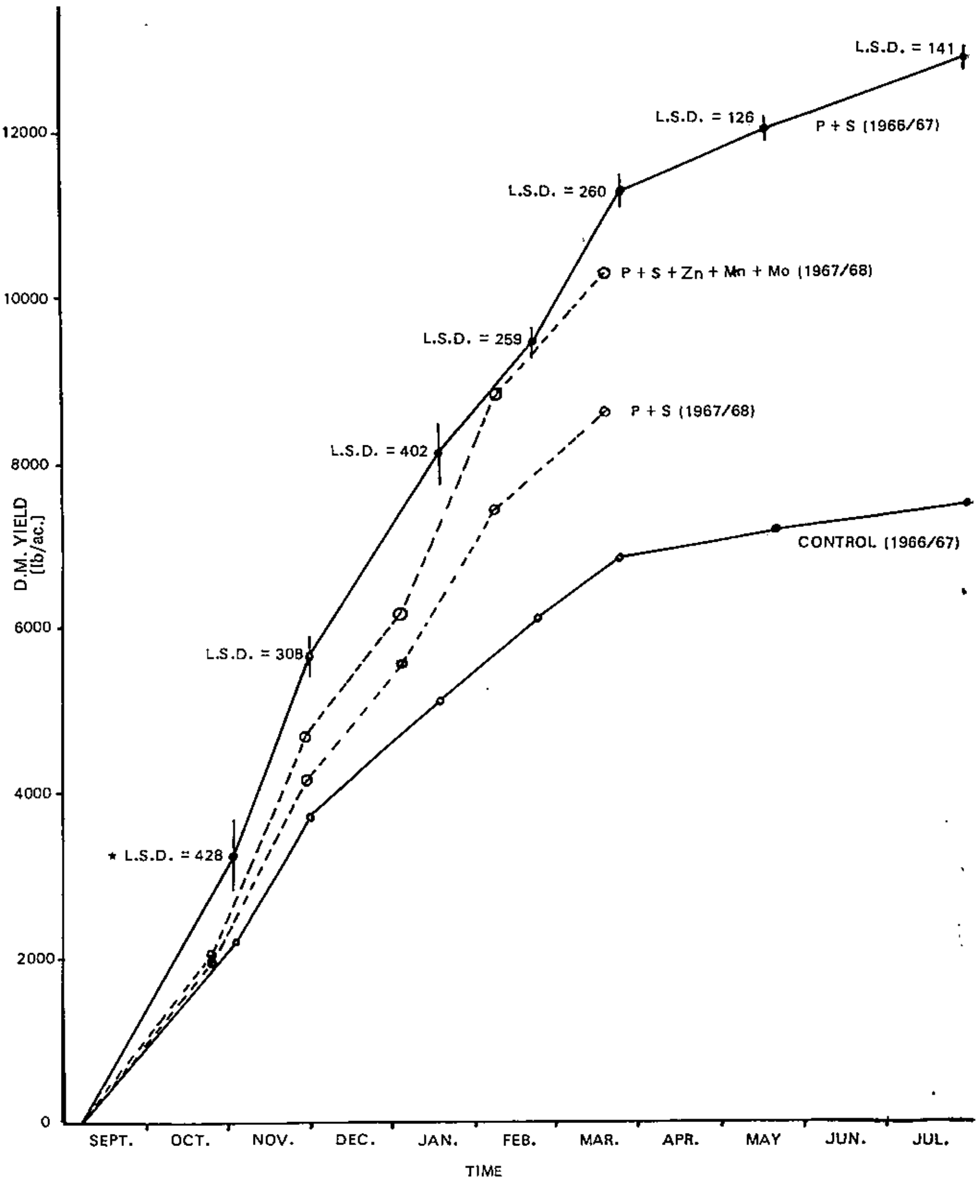

FIGURE 1
Cumulative Lucerne Dry Matter Production According to Nutrient Treatment in 1966/67 and 1967/68
*L.S.D. — P = 0.05

High lucerne yields (Table 3, Figure 1) obtained in both seasons have been associated with the presence of a perched water table on the trial site. It seems expedient to determine in more detail the extent of such moisture reserves in the region, and to encourage their exploitation by deep rooting plants.

Total production (P + S treatment) in 1966/1967 exceeded that in 1967/1968 to the same time, and this could have been due to a difference in incident rainfall (Figure 2), and its effect on the quantity of water in the perched water table.

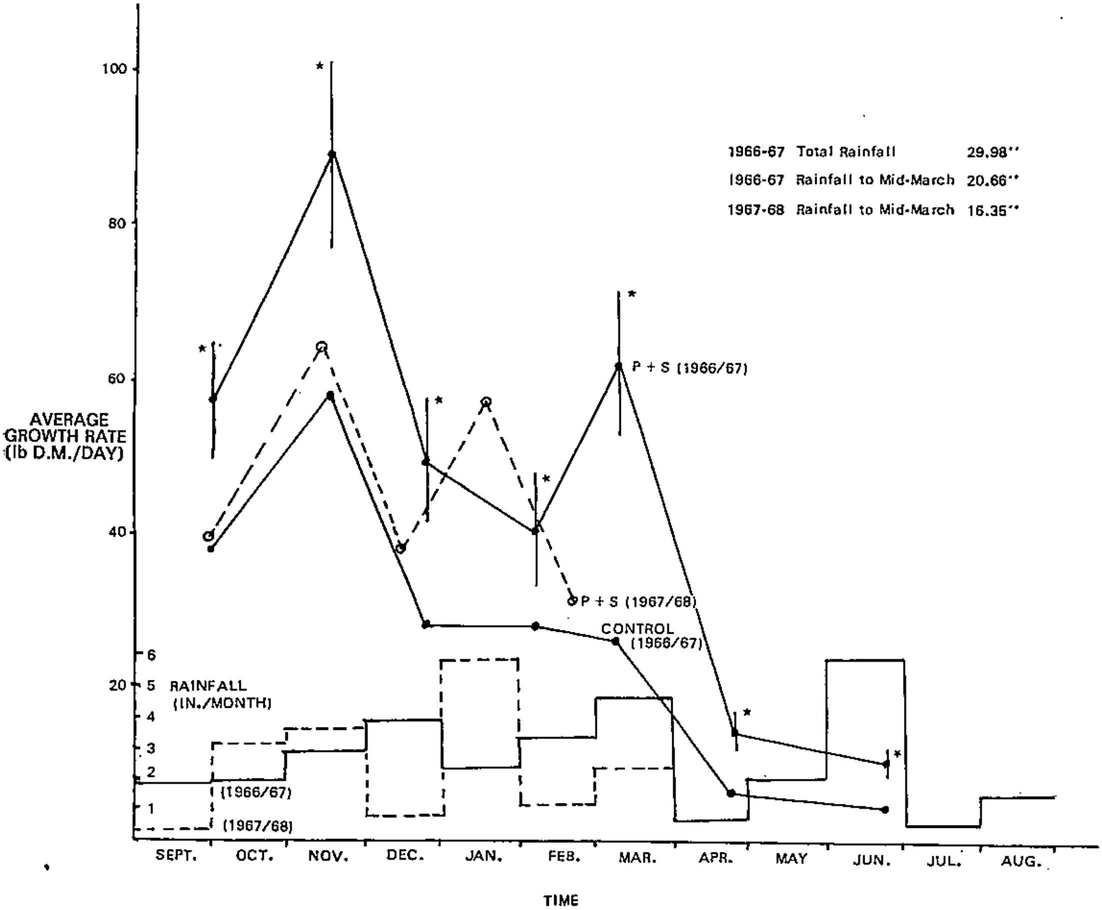

FIGURE 2

Growth Rhythm of Lucerne in 1966/67 and 1967/68 According to Nutrient Treatment

*L.S.D. — (P = 0.05) Values calculated as per day averages of Total L.S.D. values at each harvest

The growth rhythm of Hunter River lucerne (Figure 2) has been dominated by growth rate extremes measured where moisture has been rarely limiting. The data emphasizes three significant points:

(i) Hunter River lucerne makes greatest growth in the spring-summer-autumn months,

(ii) A peak growth rate is attained in November, and

(iii) The growth rate in winter is relatively low.

TABLE 4

Effect of form of sulphur applied in time, on D.M. production by lucerne

Sulphur treatment	Harvest date/D.M. production (lb/ac)							Total D.M. Prodn. (lb/ac)
	3/11/66	29/11/66	18/1/67	21/2/67	22/3/67	19/5/67	2/8/67	
Flrs of S	2990	2041	2189	1172	1561	681	624	11258
Gypsum	2934	2070	2054	1235	1375	686	579	10933
L.S.D. (P = 0.05)	303	218	284	183	190	89	100	864

TABLE 5

Micro-nutrient treatment total yields (lb lucerne D.M./ac in 5 cuts) in 1967/68

Treatment	Zn + Mo + Mn	Zn + Mo	Zn + Mn	Mo + Mn	Zn	Mo	Mn	Control
Total D.M. yield lb/ac	10373	9222	9431	8279	9434	8899	9208	8607

"F" value non-significant L.S.D. (P = 0.05 : 1405)

In the second field experiment (1967/1968), a response trend (not statistically significant) was measured, to the addition of micro-nutrients Zinc, Manganese and Molybdenum (Table 5, Figure 1). It appeared largely due to zinc. True zinc deficiency on black earths is uncommon though availability is often low on such high pH soils containing high contents of soluble or total phosphates (Thorne, 1957).

CONCLUSIONS

(i) High yields were obtained from Hunter River lucerne on a site underlain by a perched water table. It was suggested that similar sites in the district could be exploited using deep rooting plants. The data emphasized that this lucerne cultivar grows most rapidly in spring, summer and autumn, and that winter growth rates are relatively low.

(ii) Plant growth responses to both sulphur and phosphorus were measured, and there was some evidence of a response to zinc. The sulphur response was in keeping with other findings on shallow skeletal and sedentary soils in the area. The other responses were not common for these soils but were explained by the fixation of phosphorus and perhaps zinc in complex compounds with calcium and magnesium, associated with high soil pH.

(iii) No difference in response pattern was measured to two forms of sulphur applied in early spring.

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