THE EFFECT OF FERTILIZERS ON THE PRODUCTIVITY AND PERSISTENCE OF LUCERNE (*MEDICAGO SATIVA*) AT NANANGO, SOUTH-EAST QUEENSLAND

R. M. JONES*

ABSTRACT

The effect of phosphorus, potassium, molybdenum, lime and lime pelleting on the productivity and persistence of lucerne (Medicago sativa *cv. Hunter River*) *was studied in three experiments on a podzolic soil at Nanango, south-east Queensland. Annual average rainfall is 750 mm and summer dominant.*

Lucerne yield increased with up to 48 kg phosphorus per ha as superphosphate, with no further response to higher rates. Either lime pelleting or lime application improved lucerne nodulation and in one experiment lime significantly increased lucerne yield. There was no response to sulphur, potassium or molybdenum. Lucerne density declined in all experiments. Fertilizer application is unlikely to be a major factor in improving lucerne persistence.

INTRODUCTION

A programme of soil nutrient and pasture species evaluation was started in 1965 at Nanango, south-east Queensland, on a podzolic soil derived from granodiorite. These soils support a woodland vegetation with species such as narrow leaf ironbark (*Eucalyptus crebra*) and occupy considerable areas in the South Burnett and West Moreton regions of Queensland. For the most part they provide only extensive cattle grazing with relatively little pasture improvement or development for cropping.

A preliminary pot trial on soil from the Nanango site showed a marked phosphate deficiency, using phasey bean (*Macroptilium lathyroides*) as a test species. There were also interactions between yields from calcium, sulphur and potassium treatments and an increase in plant nitrogen percentage with molybdenum (Roe, unpublished data). Field experiments were obviously required to define fertilizer requirements.

Pasture studies at this site have shown that lucerne is a productive legume, although it persists for only about five years (Jones and Rees, 1972). Cameron (1968) and Jones (1972) have also recorded a limited life span of lucerne elsewhere in subcoastal south-east Queensland. Grazing management, competition, diseases, soil moisture and soil characteristics are all factors that may affect lucerne persistence, but there is little data relating lucerne persistence to experimental variables within this region (Cameron, personal communication).

Consequently the fertilizer experiments at Nanango described in this paper examined the effect of phosphorus, potassium, sulphur, molybdenum, lime and lime pelleting of seed on both the productivity and persistence of lucerne.

MATERIALS AND METHODS

The site has an average rainfall of approximately 750 mm, two-thirds falling from October to March. The podzolic soil has a sandy loam topsoil of approximately 20 cm depth overlying a sandy clay subsoil. All trials were sown on land cleared and ploughed two years previously, and lucerne seed was inoculated with Rhizobium strains U45 + AH2 using cellophas sticker. The fertilizer treatments applied are listed in Table 1 and rainfall data over the experimental period in Table 2.

* Division of Tropical Agronomy, C.S.I.R.O., St. Lucia, Queensland, 4067.

TABLE 1
Experimental details

Experiment	Design	Variable Tested	Chemical Applied	Rates of variable (kg/ha)	Basal elements	Plot Size (m^2)
1	Randomised block 4 replicates	P	Superphosphate (9.6% P)	0, 12, 24, 48, 96, 144	Ca*, S*, K†, Mo‡	32.5
2	Factorial, split for pelleting, 3 replicates	Lime	Agricultural lime	0, 1250, 5000	S§, Ca§, P§	25
		Mo	Sodium molybdate	0, 0.045		
		Pelleting	Plaster's lime	—, +,	K†	
3	Factorial, randomised block	Lime	Agricultural lime	0, 1250, 5000	Mo‡	25
		P	Triple superphosphate (20.5% P)‖	24, 72		
	2 replicates	K	Potassium chloride	0, 65		
		S	Elemental sulphur	0, 36		

* Adjusted by lime and gypsum to that in highest rate superphosphate.
† KCl at 125 kg/ha.
‡ Sodium molybdate at 0.3 kg/ha.
§ As 750 kg 9.6% P superphosphate/ha.
‖ Includes 2 and 6 kg S/ha.

TABLE 2
Seasonal Rainfall at Nanango from 1965–1971 *(mm)*

(a) Winter (April–September)

Average	1966	1967	1968	1969	1970	1971
254	326	305	191	214	132	648

(b) Summer (October–March)

Average	1965/66	1966/67	1967/68	1968/69	1969/70	1970/71
508	585	674	506	303	598	930

Experiment 1—Rates of phosphorus

Six phosphorus rates were applied at sowing to a pasture of lucerne (*Medicago sativa* cv. Hunter River), siratro (*Macroptilium atropurpureum*) and scrobic (*Paspalum commersonii*) sown in January 1966. The experiment was grazed as a separate unit over four days approximately six times a year for five years. Yields were measured once a year during a period between successive grazings, usually in spring, when there was good lucerne growth and little growth of other species. At the same time twenty-five lucerne stems per plot were plucked for chemical analysis. Available soil phosphorus was measured three years after sowing on the 0–7.5 cm depth by the technique of Kerr and von Stieglitz (1938). Annual maintenance dressings of all fertilizers were one-quarter the initial rate, except that no further molybdenum was applied.

Experiment 2—Lime, molybdenum and lime pelleting

Lime was broadcast and incorporated into the topsoil by rotary hoeing five weeks before the experiment was sown to Hunter River lucerne in July 1968. Twenty lucerne seedlings were taken from each plot two months after emergence and scored for presence of pink nodules. Lucerne yield was measured as in experiment 1, at 4, 12 and 26 months after emergence and shoots were plucked for chemical analysis at the last two samplings. Lucerne plants were counted at 1, 12 and 36 months after emergence. Five soil cores per plot, taken from the 0–7.5 cm depth four weeks after sowing, were bulked, subsampled and analysed for pH using a 1:5 soil/water suspension. The experiment was fenced with experiment 3 and grazed over four days approximately five times a year. Annual maintenance dressings of variable and basal fertilizers were half the initial rate, except that no further molybdenum was applied.

Experiment 3—Lime, phosphorus, sulphur and potassium

The two phosphorus rates were above and below that required to maximise yield in experiment one. Lime application, sowing date of lucerne, maintenance fertilizers and measurements taken were as for experiment two.

RESULTS

Rainfall conditions were about average from 1966 to 1969 except for the dry 1968/69 summer. The 1970 winter rainfall was low but the 1970/71 summer rain was well above average (Table 2).

Experiment 1—Rates of Phosphorus

There was an increase in lucerne yield with increasing phosphorus rate ($P < 0.001$) in all years (Figure 1). Lucerne comprised over 90% of total yield

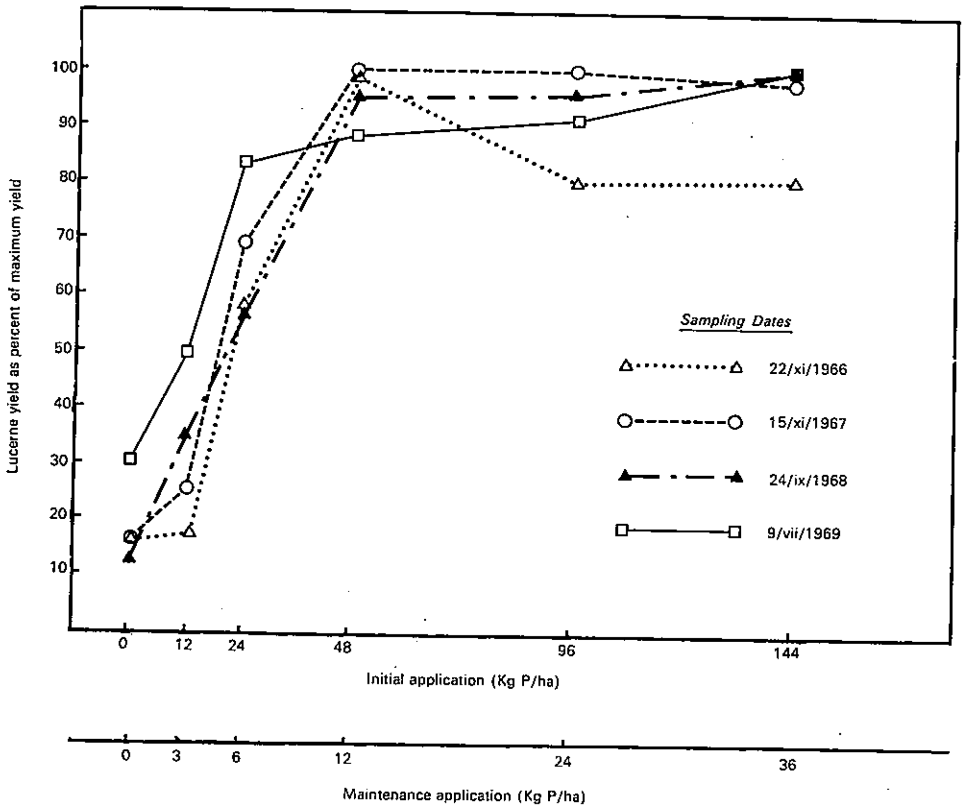

FIGURE 1
Yield response of lucerne to varying phosphorus rates at four sampling dates.

during the sampling periods which were in winter and spring. There was usually a marked yield increase up to 48 kg P/ha initial application with 12 kg maintenance, but negligible increase thereafter. Regular grazing and dry spells in summer prevented sufficient siratro build up to give a reliable siratro or scrobic response curve. Siratro only dominated after late 1970 when grazing was less frequent and summer rainfall good. Scrobic did not persist after three years.

Application of phosphorus increased both lucerne phosphorus percentage and soil available phosphorus (Table 3).

TABLE 3
The effect of fertilizer phosphorus on lucerne phosphorus percentage and topsoil available phosphorus.

Phosphorus level		*Phosphorus rate kg/ha/annum*					
	Initial:	0	12	24	48	96	144
	Maintenance:	0	3	6	12	24	36
Lucerne phosphorus % 22-11-66)*		0.18	0.18	0.18	0.21	0.22	0.24
,, ,, ,, (24- 9-68)		0.17	0.20	0.20	0.20	0.24	0.26
,, ,, ,, (9- 7-69)		0.18	0.20	0.21	0.21	0.23	0.26
Soil available phosphorus (ppm)†		8	12	7	23	64	80

* L.S.D. at $P < 0.05 = 0.02$, other samplings bulked over replicates.
† 10 ppm is a typical available phosphorus level for this soil type—unpublished data.

Phosphorus rate had no significant effect on the densities of lucerne and siratro which were 9.1 and 3.6 plants/m^2 five years after sowing (1970). After a further two years lucerne density had decreased to 1.5 plants/m^2 and siratro density increased to 14.0 plants/m^2.

Experiment 2—Lime, molybdenum and pelleting

Nodulation was significantly improved either by application of lime to the soil or by lime pelleting of seed, both of these treatments giving near complete nodulation (Table 4). Both lime rates significantly increased topsoil pH (Table 4).

TABLE 4
The effect of lime and lime pelleting on lucerne nodulation and topsoil pH.

Lime rate	% plants nodulated		L.S.D. ($P < 0.01$)	Topsoil pH
	pelleted	not pelleted		
0	93	79	9	5.5
1250 kg/ha	100	97		6.2
5000 kg/ha	100	99		6.8
L.S.D. ($P < 0.01$)		10		0.5

Lime, which increased lucerne yield at all three harvests (Table 5), was the only treatment to significantly affect yield. The low yields from the first sampling five months after sowing were due to poor rainfall.

Aluminium and manganese levels in lucerne shoots never exceeded 200 ppm and 120 ppm respectively, were not affected by lime and were below threshold toxicity levels (Jones, 1967; Andrew and Hegarty, 1969). Calcium levels on nil lime plots never fell below 1.55%.

Mean lucerne density decreased from 50 plants/sq. m in 1969 to 9 plants/sq. m in 1971 when density was significantly increased by lime application (Table 5). The main decline in lucerne density occurred during the wet 1970/71 summer.

TABLE 5
The effect of lime on dry matter yields and density of lucerne—experiment 2.

Lime rate (kg/ha)	Lucerne Yield (kg/ha)			Density (plts/sq.m)	
	18.12.68	14.7.69	22.10.70	4.9.69	9.9.71
0	247	602	452	46	5.3
1250	344	848	576	51	7.8
5000	365	898	635	48	12.5
L.S.D. ($P < 0.05$)	73	123	125	n.s.	3.5
($P < 0.01$)	100	167	170	n.s.	4.7

Experiment 3—Lime, sulphur, potassium and phosphorus on lucerne

Lucerne yield was increased at the higher phosphorus rate by 45% in the first sampling ($P < 0.01$), 50% in the second ($P < 0.001$) and 25% in the third ($P < 0.01$). There was never a significant increase in lucerne yield with lime application and there was only one slight lime/phosphorus interaction ($P < 0.05$). There was no yield response to potassium or sulphur.

Lucerne density declined from 78 (± 1.6) plants/sq. m in 1969 to 24 (± 1.2) in 1971, but the density of surviving plants in 1970 varied both within and between plots with extreme plot densities of 46 and 5 plants/sq. m. Use of numerical analysis techniques could not relate lucerne survival to microtopography, treatments or to number of topsoil and subsoil properties.

DISCUSSION

Yield response to fertilizers

Phosphorus application gave an approximate four fold increase in lucerne yield, with 500 kg basal superphosphate/ha (48 kg P/ha) and 125 kg annual maintenance/ha giving maximum yields. Results of Brockman, Shaw and Wolton (1970) suggest that this result would not be appreciably affected by the grazing technique used.

The current recommendation for establishing pastures on this soil type (Anon, 1970), 250 kg superphosphate/ha (24 kg P/ha), only gave about two-thirds of the maximum yield. The desirability of applying a higher rate would largely depend on the individual farm situation.

Lucerne phosphorus contents of below 0.19% were associated with a yield response to phosphorus, contents of 0.19–0.21% indicated a critical range and contents of 0.22% or above were associated with maximum yield (Table 3, Figure 1). This critical range is slightly below a suggested critical level of 0.23% phosphorus in lucerne, based on pot experiments (Andrew and Robins, 1969a). At maximum lucerne yield, under these experimental conditions, there was a topsoil available phosphorus content of 23 ppm or above.

Lucerne yield did not respond to sulphur, molybdenum or potassium application. Lucerne sulphur levels were always high (0.30–0.40%) and were not changed by sulphur application. It is therefore unlikely that common grazing could have masked a sulphur deficiency. A severe molybdenum deficiency would presumably have shown up under common grazing but a marginal deficiency could possibly have been masked. Potassium levels in lucerne tops at times equalled the critical level of 1.2% (Andrew and Robins, 1969b). Consequently this element may become limiting with time, especially as this soil has poor ability to supply potassium once initial reserves are exhausted (Fergus, personal communication).

Lime increased lucerne yield in experiment 2 but not in experiment 3. This could be partly a result of a topsoil pH of 6.0 in experiment 3 compared with 5.5 in experiment 2.

Nodulation

As rain fell immediately after sowing experiment 2, soil moisture conditions were favourable for rhizobium survival on the inoculated seed. Consequently although 90–100% of plants nodulated with either lime pelleting or lime application, there was still 80% nodulation in the unpelleted nil lime treatment. Under less favourable rainfall conditions the effect of lime pelleting could well be greater as found in a similar soil by Mannetje (1967).

The slightly lower nodulation level in the unpelleted nil lime treatments was not sufficient to lower lucerne yields, which were the same in both pelleting treatments even in the absence of lime. Consequently the yield increase with lime measured in experiment 2 cannot be attributed to improved nodulation.

Lucerne Survival

Phosphate application did not affect the decline in lucerne density in experiments 1 and 3. Lime reduced the decline in lucerne density in experiment 2 but not in experiment 3. In a preliminary trial at Nanango 5,000 kg lime/ha reduced the decline in lucerne density but only increased effective lucerne sward life from five to seven years (Jones and Rees, 1972).

At other sites where lucerne fertilizer trials have been laid out in south-east Queensland, lucerne yield increased with application of sulphur on a black earth (site 1—Jones, 1970) and with lime, molybdenum and sulphur on a prairie soil (Rees 1972). However, on both sites lucerne has subsequently died regardless of fertilizer treatment. Even where there has been a marked initial effect of lime on lucerne persistence (Roe and Jones 1966, Douglas 1962), limed lucerne still had an effective life span of some four years (Roe, Douglas, personal communications). Presumably factors other than nutrition, i.e. summer waterlogging, pathogens, limiting subsoil moisture and competition from other species, are usually more important in limiting lucerne persistence in south-east Queensland even under rotational grazing.

ACKNOWLEDGEMENTS

Thanks are due to Mr. R. Roe, Mr. A. Johnson and Dr. W. T. Williams, C.S.I.R.O., Division of Tropical Agronomy for advice, chemical analyses and numerical analyses respectively, to Mrs. C. Kirkman, C.S.I.R.O. Division of Mathematical Statistics, for assistance in statistical analyses and to Mr. R. W. Burcher and Mr. G. A. Bunch for technical assistance. Appreciation is also given to Mr. A. P. Beatty for provision of land and to the Australian Dairy Produce Board for financial support.

REFERENCES

ANDREW, C. S., and HEGARTY, M. P. (1969)—Comparative responses to manganese excess of eight tropical and four temperate pasture legume species. *Australian Journal of Agricultural Research.* **20**: 687-96.

ANDREW, C. S., and ROBINS, M. F. (1969a)—The effect of phosphorus on the growth and chemical composition of some tropical pasture legumes. I. Growth and critical percentages of phosphorus. *Australian Journal of Agricultural Research.* **20**: 665-74.

ANDREW, C. S., and ROBINS, M. F. (1969b)—The effect of potassium on the growth and chemical composition of some tropical and temperate pasture legumes. I. Growth and critical percentages of potassium. *Australian Journal of Agricultural Research.* **20**: 999-1007.

ANON. (1970)—Crop and pasture planting guide. Division of Plant Industry, Queensland Department of Primary Industries Advisory Leaflet No. 1058.

BROCKMAN, J. S., SHAW, P. G., and WOLTON, K. M. (1970)—The effect of phosphate and potash fertilizers on cut and grazed grassland. *Journal of Agricultural Science, Cambridge.* **74**: 397-407.

CAMERON, D. G. (1968)—Lucerne as a pasture legume. *Queensland Agricultural Journal.* **94**: 534-43.

DOUGLAS, N. J. (1962)—Fertilisers promote legume growth at Cooran. *Queensland Agricultural Journal.* **88**: 133-5.

KERR, H. W., and VON STIEGLITZ, C. R. (1938)—Technical communication No. 9, Bureau of Sugar Experiment Stations, Brisbane.

JONES, J. BENTON (1967)—Interpretation of plant analysis for several agronomic crops. Soil Science Society of America. Special Publication Series No. 2, Part 2. 49-58.

JONES, R. M. (1970)—Sulphur deficiency of dryland lucerne in the Eastern Darling Downs of Queensland. *Australian Journal of Experimental Agriculture and Animal Husbandry.* **10**: 749-54.

JONES, R. M. (1972)—Methods of oversowing lucerne and medic into native pasture on non-arable soils in the Eastern Darling Downs of Queensland. *Tropical Grasslands.* **6**: 85-90.

JONES, R. M., and REES, M. C. (1972)—Persistence and productivity of pasture species at three localities in subcoastal south-east Queensland. *Tropical Grasslands.* **6**: 119-34.

MANNETJE, L. 't (1967)—Pasture improvement in the Eskdale district of south-eastern Queensland. *Tropical Grasslands.* **1**: 9-20.

REES, M. C. (1972)—Plant nutrient status of a prairie soil under scrub and forest vegetation in south-eastern Queensland. *Tropical Grasslands.* **6**: 205-12.

ROE, R., and JONES, R. J. (1966)—Soil fertility and pasture species investigations on soils derived from phyllites in the North Deep Creek and Kin Kin areas, Gympie, Queensland. *Tropical Grassland Society of Australia Proceedings,* No. 6.

[Accepted for publication July 12, 1973]