PLANT NUTRIENT STATUS OF A PRAIRIE SOIL UNDER SCRUB AND FOREST VEGETATION IN SOUTH EASTERN QUEENSLAND

M. C. Rees*

ABSTRACT

A scrub soil and a forest soil, both derived from the same parent rock were studied. The large differences in productivity between these soils exhibited in the field were shown to exist in surface soil samples in glasshouse experiments.

The scrub soil contained more plant nutrients, had better structure and was more productive than the forest soil. It gave a lower yield response (80%) than the forest soil (170%) and remained more productive when all test nutrients were added. However, both soils gave significant increases in plant yield when molybdenum, sulphur or lime were added and marginal responses to phosphorus. They were similar also in profile and soil texture.

In field experiments on the forest soil, sulphur deficiency occurred in spring and early summer in all years after establishment. It was corrected by an initial application of 17 kg fertilizer sulphur per ha and maintenance applications of up to 11 kg fertilizer sulphur per ha per year. The main effect of lime was in making molybdenum more available to plants. Fertilizer phosphorus gave small responses in plant growth.

INTRODUCTION

Soils of the Boonah-Beaudesert area in south eastern Queensland were mapped by Paton (1971) according to the parent materials from which they were derived. The most extensive is a prairie soil classified as Churchbank subgroup developed from basic igneous rock. Despite the common parent rock this soil carries both scrub and eucalypt forest vegetations. The scrub soil which appears more fertile than the forest soil has been used for cropping and pasture improvement while the forest soil has largely remained under native vegetation. The aim of this study was to determine the nutrient status of these soils and their fertilizer requirements.

MATERIALS AND METHODS

Two sites were selected to represent the scrub and forest areas of the Churchbank subgroup. Site 1 was uncleared scrub vegetation five miles north of Boonah; it was the site used by Paton (1971) for his description of the scrub soil. Site 2 was forest vegetation (silverleaf ironbark—*Eucalyptus melanophloia*) nine miles north of Boonah. The trees had been ringbarked in 1960-61. Fertilizers had not been applied previously to these areas.

Soil texture increased from a grey brown loam at the surface to medium clay at 20 cm depth. Decomposed basic igneous rock underlay the soils at depths between 30 and 60 cm at both sites. Field pH using universal indicator (Raupach and Tucker 1959) showed an increase from 6.5 at the surface to 8.0-8.5 at 50-60 cm depth. The scrub soil was better structured with approximately twice the ped development of the forest soil. Analyses of soil samples of the 0-15 cm profiles from sites 1 and 2 are shown in table 1.

---

*Division of Tropical Pastures, C.S.I.R.O., Mill Road, Cunningham Laboratory, St. Lucia 4067.

TABLE 1

Analyses of 0-15 cm soil profiles of the Churchbank subgroup of prairie soils from site 1 originally under scrub vegetation and site 2 originally under forest vegetation

Soil	1 : 5 suspension pH	T.S.S. (%)	NaCl (%)	Avail P (ppm)	N	Total (%) P*	S*	K*	T.E.C.	Exchangeable cations to pH 8.4 Ca me%	Mg me%	K me%	Na me%	H me%	% satn	Moisture (%) Perm. wilting pt.	pF2	Water stable aggregates < 1 mm (%)
Site 1 (scrub)	5.6	0.02	0.013	980	0.304	0.217	0.045	1.49	35.7	19.9	6.0	1.0	0.3	8.4	76	16.6	38.8	90
Site 2 (forest)	5.5	0.05	0.014	470	0.112	0.177	0.020	1.45	20.8	9.3	4.9	0.4	0.4	5.8	72	11.3	23.3	53

*by X-ray fluorescence spectroscopy.
†soluble in 0.01 N H_2SO_4.

Mean rainfall at site 2 was 810 mm per year, approximately 250 mm falling in winter months April to September inclusive. Rainfall for the winters of 1967 to 1970 was 400, 330, 230, and 125 mm respectively and for the summers of 1967/68 to 1970/71 was 400, 250, 460, and 1070 mm.

Glasshouse experiments

Two glasshouse pot experiments were conducted on each soil; one was a half factorial (2^7) in which combinations of nine plant nutrients were added, and the other was a rate experiment using six levels of phosphate and a basal dressing of other nutrients.

Soil samples, excluding surface vegetation and litter, were taken to a depth of 15 cm from one location at each site in October 1966. Each soil was sieved through a 1.2 cm mesh screen, mixed thoroughly and 1600 g sub-samples of moist soil added to polythene lined plastic pots. The fertilizer treatments were added and the test species, phasey bean (*Phaseolus lathyroides*) planted in November 1966, with seed inoculated with *Rhizobium* strain CB756. The soils were watered daily to the respective pF2 values (table 1) with deionized water. Seedlings were thinned to five per pot and the pots randomised at weekly intervals. Plants were harvested in January 1967, six weeks after sowing, dried at 70°C, weighed, replications bulked to form treatment samples and ground for chemical analysis. Nitrogen, phosphorus, potassium and sodium content of the plant material were determined by automatic analysis (Williams and Twine 1967), calcium and magnesium by atomic absorption spectroscopy (David 1958), and chloride by automatic analysis using the mercuric thiocyanate method (Technicon Autoanalyser Methodology File No. N5A).

The nutrient treatments for the half factorial 2^7 experiments were:—lime at 0 and 1250 kg per ha; potassium as KCl at 0 and 125 kg per ha; sulphur as $Na_2\ SO_4$ at 0 or 250 kg per ha; copper as $CuCl_2$ at 0 and 8 kg per ha; zinc as $ZnCl_2$ at 0 and 8 kg per ha; molybdenum as $(NH_4)_6\ Mo_7\ O_{24}$ at 0 and 600 g per ha; and magnesium, manganese and boron at 0 and combined in one treatment as $MgCl_2$ at 63 kg per ha, $MnCl_2$ at 8 kg per ha and H_3BO_3 at 8 kg per ha.

Calcium carbonate was mixed through the soil, but other chemicals including a basal dressing of calcium phosphate, $CaH_4\ (PO_4)_2$, equivalent to 500 kg superphosphate per ha were added in solution to the soil surface.

The phosphorus experiment contained three replicates of calcium phosphate, applied at rates equivalent to 0, 125, 250, 500, 750 and 1250 kg superphosphate per ha. Lime, potassium, sulphur, copper, zinc, molybdenum, magnesium, manganese and boron were applied as basal dressings at the rates used in the factorial experiments.

Field experiments

Three field experiments were conducted on the forest soil to test glasshouse findings. They were a rate of sulphur experiment (Field experiment 1), a factorial nutrient experiment (Field experiment 2) and a rate of phosphorus experiment (Field experiment 3).

All experiments were planted at the same time on the same site and received similar management. Prior to establishment of experiments, the whole area was ploughed, disced and a mixture of Japanese millet (*Echinochloa crusgalli* var. *frumentacea*) and *Dolichos lab lab* sown in December 1966. This was grazed and the stubble ploughed in. Appropriate nutrients were applied by hand and mixed into the top 7 cm of soil by a tyne cultivator. Seed of Hunter River lucerne, inoculated with *Rhizobium* strains U45 and AH2, was sown at 9 kg per ha over all experiments in August 1967.

The responses in dry matter yield to fertilizer treatments were measured after each growth flush. Two samples each 0.9 m² in area were cut 5 cm above ground level from each plot, dried at 70°C and weighed. Samples for chemical analysis consisted of six lucerne shoots per plot, bulked according to treatment and dried at 70°C. After sampling, plots were mown to sampling height.

Field experiment 1 consisted of four replicates of six levels of sulphur as gypsum ($CaSO_4$) applied between August and October of three years, 1967 to 1969. Each year, treatments were applied to different areas of lucerne sown in 1967. The six levels applied in 1967 were sulphur at nil, 6, 11, 17, 22, and 34 kg sulphur per ha. The levels applied in 1968 and 1969 were based on the results obtained in 1967 and were nil, 11, 22, 34, 45 and 56 kg sulphur per ha. Gypsum applied in the first year was mixed with basal fertilizers of 700 g sodium molybdate, 125 kg muriate of potash, 250 kg monocalcium phosphate and 625 kg calcium carbonate per ha. Gypsum was applied to the surface of plots in the second and third years. Plots measured 4.0 m by 5.2 m.

Field experiment 2. The nutrient treatments used in the 2^6 factorial experiment were lime, potassium, copper, zinc, molybdenum and a combination of magnesium, manganese and boron at the same rates of application used in the glasshouse experiments. A basal dressing of 34 kg sulphur per ha as sodium sulphate and 36 kg phosphorus per ha as monocalciumphosphate was applied to all plots. When calcium carbonate was applied, it was mixed with the basal fertilizer. Other elements were applied after lucerne was sown to avoid transfer of micronutrients between plots. Plots were 4.0 m square.

Field experiment 3 was a randomised block design of three replicates of six rates of monocalcium phosphate ($Ca(H_2PO_4)_2H_2O$) equivalent to 0, 250, 500, 750, 1250 and 2000 kg superphosphate per ha. A basal fertilizer dressing of sodium tively was applied to the 5.2 m square plots.

RESULTS

In the glasshouse experiments which were run for the same length of time under the same conditions, phasey bean yielded significantly more on the scrub than on the forest soil with all test nutrients applied (7.9 v.s. 5.4 g per pot, $P < 0.001$). These plants had similar nitrogen contents averaging 3.2 and 3.3 per cent nitrogen respectively. Mean yields of plants without test nutrients were 4.4 and 2.0 g per pot respectively.

Sulphur and lime increased the yield of phasey bean plants on both soils ($P < 0.001$). Molybdenum also gave significant responses in yield; $P < 0.05$ for scrub soil and $P < 0.001$ for forest soil. There was an interaction between lime and molybdenum on both soils, but the yield response to addition of lime was greater than that by molybdenum. On the scrub soil, this additional affect of lime ($P < 0.10$) was independent of sulphur treatments while on the forest soil it was greater in the absence of fertilizer sulphur ($P < 0.001$) than when sulphur was applied ($P < 0.10$).

The effect of these nutrients on the nitrogen content of phasey bean plants was parallel to their effect on yield and is shown in table 2. Potassium chloride increased the level of potassium in these plants from a mean of 1.62 to 1.77 percent on the scrub soil and 1.27 to 1.67 on the forest soil. It also increased the chloride levels in plants from 0.34 to 0.91 per cent on the scrub soil and 0.48 to 1.03 per cent on the forest soil and reduced plant yields on both soils ($P < 0.001$). The response to phosphorus was only significant at the 10 per cent level.

TABLE 2

The effect of sulphur, molybdenum, lime and potassium on the nitrogen content of phasey bean plants grown on scrub and forest soils

Treatment	Nitrogen in herbage (%) Scrub soil	Forest soil
$S_0\,Mo_0\,Ca_0\,K_0$	1.99	2.27
$S_0\,Mo_0\,Ca_1\,K_0$	2.06	2.31
$S_0\,Mo_1\,Ca_0\,K_0$	2.14	2.23
$S_0\,Mo_1\,Ca_1\,K_0$	2.10	2.36
$S_1\,Mo_0\,Ca_0\,K_0$	2.05	2.29
$S_1\,Mo_0\,Ca_1\,K_0$	3.00	3.14
$S_1\,Mo_1\,Ca_0\,K_0$	3.00	3.13
$S_1\,Mo_1\,Ca_1\,K_0$	3.45	3.40
$S_1\,Mo_1\,Ca_0\,K_1$	3.03	3.25
$S_1\,Mo_1\,Ca_1\,K_1$	3.13	3.69

Field Experiment 1—Sulphur experiment

This experiment was sampled eight times over three years. Figure 1 shows the yields and spring responses to sulphur at six of these harvests. The response to sulphur in the first year indicated that the original range of treatments was not large enough (Figure 1a) so a wider range was used in subsequent years.

Significant responses in lucerne yield to fertilizer sulphur were recorded at four sampling times, 20/ix/68, 8/i/69, 12/xi/69 and 13/xi/70 (see Figs 1a, 1b, 1c and 1e), when the levels of fertilizer sulphur needed to maximise yields were 11, 17, 11 and 11 kg sulphur per ha respectively ($P < 0.05$). Pale colouration, indicative of sulphur deficiency was seen on lucerne plants in control plots in September 1968, November 1969 and November 1970.

Fertilizer sulphur significantly increased the nitrogen level of lucerne plants in June 1968 from 3.9 to 4.2 per cent ($r = 0.88$, $P < 0.05$).

The residual effect of fertilizer sulphur was measured by the differences in yield of treatments of different years. Data were used from the harvests which showed sulphur responses. Plots that received 11 kg fertilizer sulphur per ha in the first year (1967), produced significantly less dry matter than plots that received 11 kg fertilizer sulphur in the second ($P < 0.001$) and third years ($P < 0.05$). Plots that received 11 kg sulphur per ha in the second year yielded less than plots that received 11 kg sulphur per ha in the third year although this difference was not significant. The yield of lucerne on plots that received an initial 22 kg sulphur per ha did not decline significantly with time.

Field Experiment 2—Factorial nutrient experiment

This experiment was sampled to determine yield of lucerne on 5/12/67, 20/9/68 and 16/7/69. Molybdenum increased the yield on the second ($P < 0.05$) and third harvests ($P < 0.05$). Lime significantly increased the yield of lucerne at all harvests ($P < 0.05$, <0.001, and < 0.05), but lime had no significant effect when used in combination with molybdenum.

Field Experiment 3—Rate of phosphorus experiment

Phosphate addition increased the total yield of lucerne over four harvests but the differences between treatments were small. Mean yield of control plots per harvest was 972 kg dry matter per ha compared with a mean yield of 1204 kg dry matter per ha for plots that had received phosphorus equivalent to 2000 kg superphosphate per ha ($P < 0.05$). The mean percentage of phosphorus in lucerne shoots

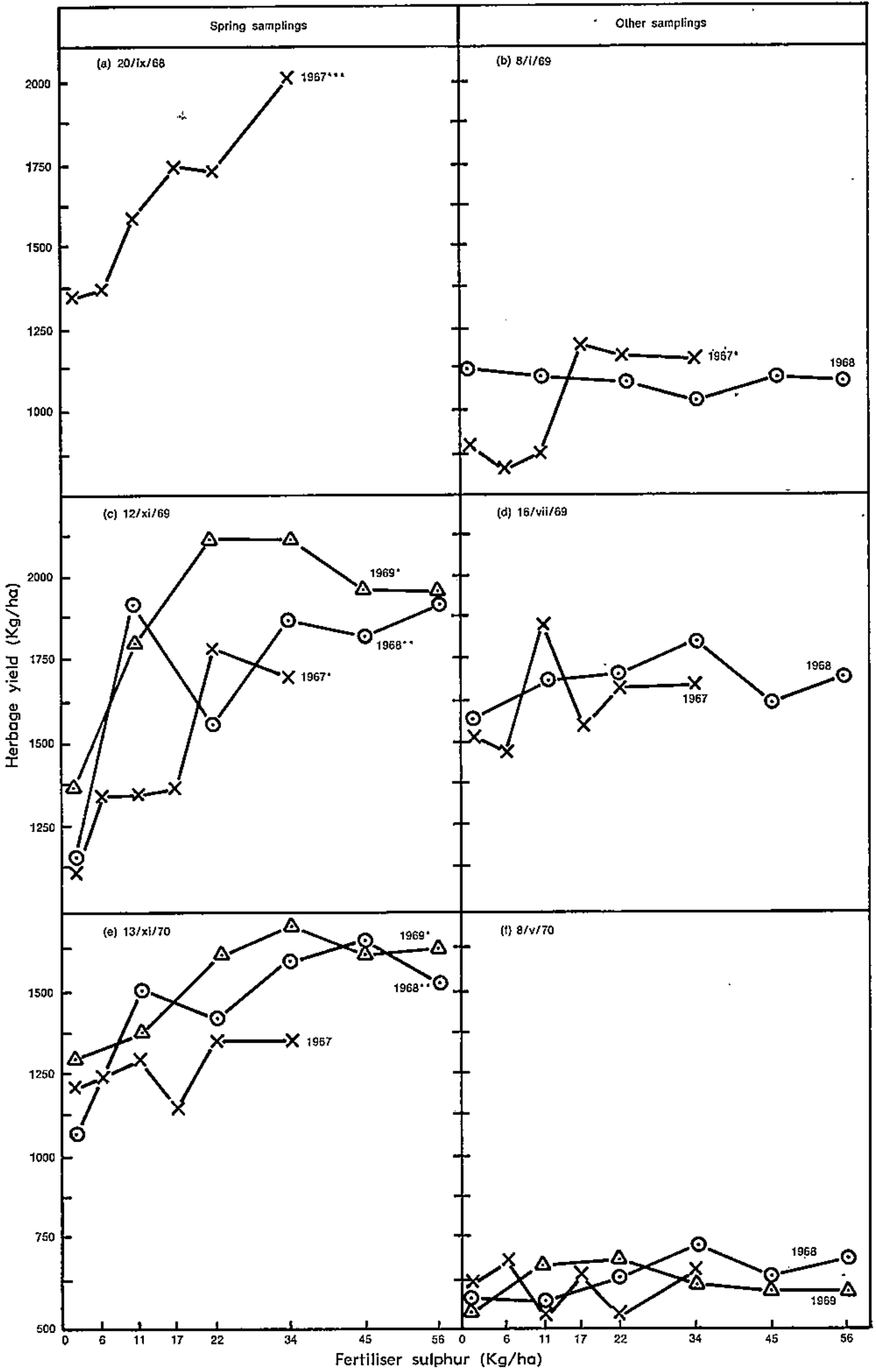

FIGURE 1

The effect of fertilizer sulphur applied in 1967, 1968 and 1969 on the dry matter yield of Hunter River lucerne at six harvest dates.

* = $P < 0.05$, ** = $P < 0.01$, *** = $P < 0.001$.

harvested in September 1968 and January 1969 was 0.27 percent when no phosphate was applied compared with 0.30 percent when the equivalent of 2000 kg superphosphate was applied.

DISCUSSION

In glasshouse experiments, the scrub soil produced 80 percent more herbage than the forest soil when all nutrients were applied for legume growth. It also showed a lower percentage yield increase (80%) to addition of these nutrients than the forest soil (170%). Table 1 shows that the scrub soil contained approximately twice as much exchangeable calcium and potassium, total sulphur and available phosphorus and about three times as much total nitrogen as the forest soil. This higher level of total nitrogen in the scrub soil would indicate a higher level of organic matter, which on mineralization, should release greater amounts of these elements. As large differences in growth were obvious in these experiments only 23 days from sowing, it is suggested that differences between the soils in release of nitrogen are of prime importance.

The differences in productivity of the soils in glasshouse experiments were measured when soil water was not limiting growth. Wider differences are expected in the field under natural rainfall since the scrub soil held more available soil water than the forests soil and had better structure (Table 1).

Paton (1971) showed a relationship between the level of available soil phosphorus and the type of parent rock in the Boonah-Beaudesert area. These experiments have shown that a relationship probably exists between the parent rock and level of other plant nutrients also. The two soils derived from the same parent material were deficient in the same elements, i.e. molybdenum and sulphur, and gave similar responses to other nutrients particularly lime and phosphorus. The parent rock probably contained insufficient molybdenum and sulphur, and set a ceiling to these in the resultant soil.

Potassium chloride equivalent to 125 kg per ha depressed the yield of phasey bean plants grown in pots but not lucerne grown in the field. The most likely reason for this negative response is the level of chloride in the phasey bean which rose from an average 0.4 to 1.0 percent of dry weight. High chloride ion concentration has caused similar yield depressions in Townsville stylo (*Stylosanthes humilis*) and Siratro (*Phaseolus atropurpureus*) (Hall 1971), and probably in *Desmodium intortum* and *Desmodium uncinatum* (Andrew and Robins 1969).

Field experiments were carried out on the forest soil only to study more closely the results of glasshouse experiments and to determine practical fertilizer requirements. As the same deficiencies were found on the scrub soil, the fertilizer requirements of the two soils should vary only in quantity. The results for the forest soil are expected to overestimate the fertilizer requirements of the scrub soil.

All growth during August to December inclusive responded to sulphur except in the first year of the field trial. Growth at other times did not respond to fertilizer sulphur. Similar seasonal trends have been reported by Jones (1970) for the Darling Downs of Queensland and by Barrow (1966) and Williams (1968) for temperate areas. The loss of sulphur by leaching in wet winters which is an important factor in southern Australia would be of negligible importance in most winters in the 760 mm rainfall area of south eastern Queensland. In winter the low temperature of soil, which restricts both chemical and microbial mineralization of organic sulphur (Williams 1967) is the most likely reason for the spring responses reported here. The lack of a response in plant yield in the field to sulphur addition in the first spring (1967) immediately after sowing is probably due to a build up in mineralized sulphur during fallowing. Initial application of sulphur at 10-20 kg per ha was required to maintain plant yields over the three year period. Heavy initial applications did not appear to lose efficiency with time.

Both glasshouse and field experiments have shown that phosphorus does not seriously limit growth on this soil. Heavy applications of phosphate gave only small increases in herbage yields and had little effect on phosphorus levels in plant tissue.

An initial application of molybdenised single superphosphate at 250 kg per ha would correct the sulphur, molybdenum and marginal phosphorus deficiencies recorded on both soils. Additional fertilizer sulphur may be needed after two or three years. Lime should not be required since its main effect was in the release of molybdenum.

ACKNOWLEDGEMENTS

I wish to thank MacFarlane Bros. for use of land and equipment, Mr. R. Roe of the Division of Tropical Pastures, C.S.I.R.O., for helpful advice in planning the experiments, Mr. C. Thompson, Mr. G. Stirk and Mr. R. Reeve, Division of Soils, C.S.I.R.O., for description and analysis of soils, Mr. J. Kerr, Division of Mathematical Statistics, C.S.I.R.O. for statistical analysis of data, Mr. M. Graydon for technical assistance and members of the Plant Chemistry section of the Division of Tropical Pastures, C.S.I.R.O., for analysis of plant material. Finally I thank the Dairy Produce Board for financing the project.

REFERENCES

Andrew, C. S., and Robins, M. F. (1969)—The effect of potassium on the growth and chemical composition of some tropical and temperate pasture legumes. II. Potassium, calcium, magnesium, sodium, nitrogen, phosphorus and chloride. *Australian Journal of Agricultural Research.* **20**: 1009-21.

Barrow, N. J. (1966)—The residual value of the phosphorus and sulphur components of superphosphate on some Western Australian Soils. *Australian Journal of Experimental Agricultural and Animal Husbandry.* **6**: 9-16.

David, D. J. (1958)—Determination of zinc and other elements in plants by atomic absorption spectroscopy. *The Analyst.* **83**: 655-61.

Hall, R. L. (1971)—Some implications of the use of potassium chloride in nutrient studies. *Journal of the Australian Institute of Agricultural Science.* **37**: 249-52.

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.

Paton, T. R. (1971)—A reconnaissance survey of soils in the Boonah-Beaudesert district, Queensland. Soils and Land Use Series No. 52. Division of Soils, Commonwealth Scientific and Industrial Research Organization, Australia.

Raupach, M., and Tucker, B. M. (1959)—The field determination of soil reaction. *Journal of the Australian Institute of Agricultural Science.* **25**: 129-33.

Williams, C. H. (1967)—Some factors affecting the mineralization of organic sulphur in soils. *Plant and Soil.* **26**: 205-23.

Williams, C. H., and Twine, J. R. (1967)—Determination of nitrogen, sulphur, phosphorus, potassium, sodium, calcium and magnesium in plant material by automatic analysis. Division of Plant Industry Technical Paper No. 24. Commonwealth Scientific and Industrial Research Organization, Australia.

Williams, C. H. (1968)—Seasonal fluctuations in sulphur under subterranean clover pasture in southern New South Wales. *Australian Journal of Soil Research.* **6**: 131-9.