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Nitrogen and phosphorus fertilization of forage oats in the Maranoa region of southern Queensland

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Summary

Six rates of nitrogen (0, 10, 20, 40, 80 and 160 kg N ha^{-1}) and four rates of phosphorus (0, 7.5, 15 and 30 kg P ha^{-1}) were applied to oats at planting in a full factorial design on six sites during 1973 and 1974. Prior to planting, the nitrate–nitrogen concentrations in soil (0 to 20 cm) varied from 4 to 44 ppm and 'available' phosphorus (bicarbonate method, 0 to 10 cm) varied from 6 to 34.5 ppm; soils ranged in clay content from 17 to 58%.

Phosphorus application increased oat yields at the first harvest where available soil phosphorus was 30 ppm or less. Positive residual responses to fertilizer were obtained in oat regrowth when the original soil phosphorus was low. Regrowth was depressed at one site where the original soil phosphorus level was 30 ppm and when the application of phosphorus exceeded 35 kg ha^{-1}. Phosphorus application increased the phosphorus concentration in oats at all sites and harvests.

Applying nitrogen increased oat yields at the first harvest where soil NO_3–N was initially 13 ppm or less. Residual yield responses to fertilizer were obtained in regrowth when soil NO_3–N was initially 19 ppm or less. Nitrogen fertilizer increased the nitrogen concentration in oats in all harvests at sites where soil NO_3–N was initially 19 ppm or less. A significant interaction between nitrogen and phosphorus applications occurred only at the first harvest at one site.

Multiple regressions are presented which relate yield response to the availability of soil nitrogen and phosphorus at planting and the nitrogen and phosphorus fertilizer rates.

An economic assessment of fertilizer application to oats for fattening cattle showed that optimum application rates for phosphorus were between 7.5 and 15 kg P ha^{-1} up to available soil phosphorus levels of 30 ppm, prior to planting. Only one site gave an economic response to nitrogen.

1. Introduction

In the semi-arid region of southern Queensland, winter forage crops (mainly oats) are a significant factor in maintaining the condition of breeder cows, improving the growth of calves and weaners, and in fattening older animals at a time when alternative forages are of poor quality. Store cattle grazing forage oats may gain as much as 0.9 kg per day, while on native or introduced tropical grass pastures they gain very little or may lose weight (Howard 1961). In 1972–73, the Condamine–Maranoa basin of southern Queensland supported a cattle population of 0.6 m and 56 000 ha were sown to forage oats (Weston, Nason and Armstrong 1975).

In the sub-humid region of the Darling Downs, Cull and Muir (1969) recorded widespread yield responses in forage oats to nitrogen fertilizer but a lesser incidence of response to applied phosphorus. In trials in the Maranoa region, however, large responses to phosphorus but not nitrogen have been obtained in wheat (Best and Strong 1978). No comparable information is available for forage oats, especially for the lighter textured soils where wheat is not commonly grown.

Trials were therefore conducted on a range of soils in the Maranoa region to assess the response of forage oats to applied nitrogen and phosphorus, and to relate yield responses to fertilizer application and soil factors.

2. Materials and methods

Six rates of nitrogen (0, 10, 20, 40, 80 and 160 kg N ha^{-1}), as urea, and four rates of phosphorus (0, 7.5, 15 and 30 kg P ha^{-1}), as Superking*, were applied to oats in a complete factorial design with two randomized blocks, at six sites. Two experiments were established in 1973 (sites 3 and 4) and four in 1974. All sites had been cultivated for a number of years (7 to 40) and were fallowed for 4 to 5 months prior to planting oats. Soil samples taken at planting were air dried and analysed for chemical and physical properties (table 1).

Oats were sown at 25 kg ha^{-1}, cv. Algerian at site 1, and cv. Camellia at all other sites. Nitrogen was applied on the soil surface immediately before planting and incorporated at planting. The superphosphate was drilled with the seed.

Plots were 9 m long and had nine rows 18 cm apart. Forage yield was determined from duplicate samples 1 m long by two rows wide, taken from the inner five rows. Samples were dried at 80°C for 48 hours and nitrogen and phosphorus concentration was determined colorimetrically on an auto-analyser.

Following sampling, the crop was mown to 2 cm above ground level and material removed (sites 1 and 2) or grazed (sites 3, 4 and 5) for periods of 2 days and then mown as for sites 1 and 2. The crop was allowed to regrow for further sampling. Urine and dung patches were avoided in sampling the regrowth. A second regrowth occurred only at site 3.

Details of rainfall, harvest dates and growth duration are given in table 1.

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* Registered trade name for a double superphosphate containing 19.2% P and 1.6% S.

Table 1. Soil analyses, rainfall and growth periods for trial sites

	Depth (cm)	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6
Soil analyses							
pH†	0–10	8.45	7.35	7.10	5.95	8.50	7.25
	10–20	8.75	8.20	6.60	5.95	8.50	7.15
Available P‡	0–10	6.0	14.0	25.0	23.5	46.0	40.0
(ppm, acid)	10–20	5.0	3.5	14.0	7.5	8.0	17.5
Available P§	0–10	6.0	12.5	18.0	21.5	30.0	34.5
(ppm. bicarbonate)	10–20	5.5	6.0	10.0	8.5	8.5	13.0
Total N%	0–10	0.060	0.070	0.070	0.065	0.150	0.080
Nitrate-nitrogen¶	0–10	13.0	41.4			39.0	14.0
(ppm)	10–20	13.0	46.0			40.0	18.0
	0–30			19.0	4.0		
	30–60			23.0	2.5		
	60–90			17.0	1.5		
Clay%	0–10	58	31	18	17	36	57
Northcote classification		Ug 5.3	Db 1.1	Db 4.4	Db 1.1	Db 3.1	Ug 5.1
Rainfall (mm)							
Harvest 0–1		88	54	15	198	191	84
Harvest 1–2		90	58	159	202	60	
Harvest 2–3				169			
Planting date		May 14 1974	May 12 1974	Apr. 4 1973	Mar. 3 1973	May 13 1974	May 12 1974
Growth period (days)							
Harvest 0–1		82	75	72	156	93	127
Harvest 1–2		58	62	54	81	58	
Harvest 2–3				70			

† 1 : 5 soil in water
‡ Kerr and von Stieglitz (1938)
§ Colwell (1963)
¶ 2N KCl extraction

3. Results

Simple correlation analysis between yield and fertilizer application and site variables showed that yield at the first harvest was most closely related to rainfall and growth duration (table 2). The most important nutritional factors were phosphorus fertilizer and the availability of phosphorus in the surface soil, with the bicarbonate extractable phosphorus test a better indicator of yield than the acid extractable phosphorus test. For regrowth, however, the most important nutritional factors at planting were nitrogen fertilizer and the availability of soil phosphorus at depth.

Table 2. Correlation coefficients (r) between yield of oats and N and P fertilizer and site variables

Attributes	Initial growth (n=288)	Regrowth (n=240)
N fertilizer (kg ha^{-1})	0.113 n.s.	0.173 **
P fertilizer (kg ha^{-1})	0.300 **	−0.008 n.s.
Rainfall (mm)	0.660 **	0.193 **
Growth duration (days)	0.644 **	−0.026 n.s.
Available soil N (NO_3—N, 0–20 cm)	−0.246 **	−0.103 n.s.
Available soil P (acid P, 0–10 cm)	0.317 **	−0.111 n.s.
Available soil P (acid P, 10–20 cm)	0.023 n.s.	0.436 **
Available soil P (bicarb. P, 0–10 cm)	0.403 **	−0.193 **
Available soil P (bicarb. P, 10–20 cm)	0.170 **	0.236 **
Clay % (0–10 cm)	0.220 **	−0.092 n.s.

** $P < 0.01$

Table 3. The effect of nitrogen and phosphorus fertilizer rates on oat dry matter production (kg ha^{-1})

Fertilizer rates	Site 1		Site 2		Site 3			Site 4		Site 5		Site 6
	Initial growth	Re-growth	Initial growth	Re-growth	Initial growth	First re-growth	Second re-growth	Initial growth	Re-growth	Initial growth	Re-growth	Initial growth
Nitrogen (kg ha^{-1})												
Nil	1240	2570	1020	1050	590	2040	3240	1450	750	1680	1660	1670
10	1110	2180	960	2140	490	2030	2990	1760	790	1740	1840	1680
20	1150	2370	970	2000	610	2130	3700	1910	790	1560	1890	1770
40	1390	2540	1100	2030	550	2460	3740	2130	870	1860	1920	1690
80	1460	2490	830	1910	670	2380	4690	2240	870	1670	1910	1950
160	1660	2670	1020	2030	510	2500	4920	2210	1040	1600	1970	1940
LSD ($P=0.05$)	226	360	n.s.	n.s.	161	307	836	263	128	n.s.	n.s.	n.s.
LSD ($P=0.01$)	306	n.s.	n.s.	n.s.	n.s.	415	1131	356	173	n.s.	n.s.	n.s.
Phosphorus (kg ha^{-1})												
Nil	660	2090	590	1760	520	2110	4590	1650	870	1380	1940	1790
7.5	1360	2690	890	1810	530	2170	3830	2090	840	1610	1840	1760
15	1620	2630	1090	2240	620	2280	2790	1990	930	1740	2010	1860
30	1710	2470	1360	2300	710	2470	3320	2160	780	2010	1670	1700
LSD ($P=0.05$)	185	294	264	219	131	250	682	215	105	262	287	n.s.
LSD ($P=0.01$)	250	398	357	297	178	339	923	290	142	254	n.s.	n.s.
Interaction Nitrogen x Phosphorus	*	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.

*Significance of Interaction: $P<0.05$

Significant yield responses to phosphorus fertilizer were obtained at five of the six sites, but nitrogen increased yield significantly only at three sites (table 3). The largest responses to phosphorus application, both in the first growth period and in regrowth, were obtained at sites which had the lowest available soil phosphorus. At site 3 phosphorus application caused a significant reduction in the second regrowth following significant yield increases during the first two growth periods. The largest yield response to nitrogen in the first growth period was obtained at site 4, which had the lowest level of soil NO_3–N. Significant residual responses to nitrogen were also obtained at this site as well as site 3 where the climate favoured high oat yields in the two regrowth periods. The only instance of a significant interaction between nitrogen and phosphorus fertilizer rates was for the first harvest at site 1 where significant responses in yield to nitrogen fertilizer were obtained only at the two highest phosphorus fertilizer rates. There was no significant interaction for total oat yield at any site.

If site variation in rainfall and growth duration are minimized by expressing the yield for each fertilizer rate as a percentage of the control yield for each site it is evident that the availability of nutrients in the soil at planting provides an index of yield response to fertilizer application both for the initial growth and regrowth (figure 1). These relationships show that yield response was more closely related to available phosphorus than to available nitrogen, the response was greater for the initial growth than for regrowth, and there is an indication that high phosphorus application at a high level of available soil phosphorus caused a depression in oat regrowth.

The significance of the availability of soil nutrients and their interaction with fertilizer application to total (initial growth plus regrowth) yield response were examined by step-wise regression analysis for nitrogen and phosphorus fertilizer applications (table 4). For phosphorus no significant improvement was found beyond the inclusion of the interaction term between phosphorus application and available soil phosphorus whereas for nitrogen the prediction of yield response was significantly improved by including further variables, particularly the ratio of availability of nitrogen to phosphorus in the soil. This has a negative regression coefficient which indicates that yield response to applied nitrogen is also dependent on a high availability of soil phosphorus relative to soil nitrogen.

The total yield response for each fertilizer combination relative to the yield of the unfertilized control was also examined by step-wise regression analysis across sites. Nitrogen and phosphorus fertilizer rate, available soil nitrogen and phosphorus and their first powers, the ratio of available soil nitrogen to phosphorus and the interaction of nitrogen fertilizer with available soil nitrogen and phosphorus fertilizer with available soil phosphorus were all included as significant variables. This regression explained 64% ($P<0.001$) of the variation in yield response, which is not high enough for its use as a general predictor of yield response in the Maranoa.

The phosphorus concentration of the oats was always increased by phosphorus application and the nitrogen concentration was usually increased by nitrogen application (figure 2). The latter occurred in first growth at sites 1, 2, 4 and 6 and in regrowth at sites 1, 2, 3 and 4. The nitrogen concentration decreased substantially in successive growth periods whereas the phosphorus concentration was more constant and in some instances increased.

Table 4. Stepwise regression analysis of percentage response in total yield of oats to (a) nitrogen (n=36) or (b) phosphorus (n=24) fertilizer application rate (kg ha^{-1}) and available nitrogen and phosphorus in the soil

Variable added to equation	Regression Coefficients x10^2							
	Constant	b_1	b_2	b_3	b_4	b_5	R^2	Residual S.D.
(a) N fertilizer	9.9	0.121	..	..	..	..	0.08	23.36
Soil N*	12.1	0.100	–0.422	..	..	..	0.38	10.78
N fertilizer x soil N	5.4	0.228	–0.128	–0.0057	..	..	0.50	9.86
(Soil N)^2	19.7	0.228	–1.811	–0.0057	0.0332	..	0.63	8.59
Soil N/Soil P**	23.7	0.228	–1.740	–0.0057	0.0387	–6.57	0.79	6.55
(b) P fertilizer	5.7	0.837	..	..	..	..	0.23	17.52
Soil P	31.9	0.837	–1.283	..	..	..	0.66	11.98
P fertilizer x soil P	15.0	2.124	–0.456	–0.063	..	..	0.78	9.76

* Soil N is the NO_3–N (ppm) in 0–20 cm depth.

** Soil P is the bicarbonate extractable P (ppm) in 0–10 cm depth.

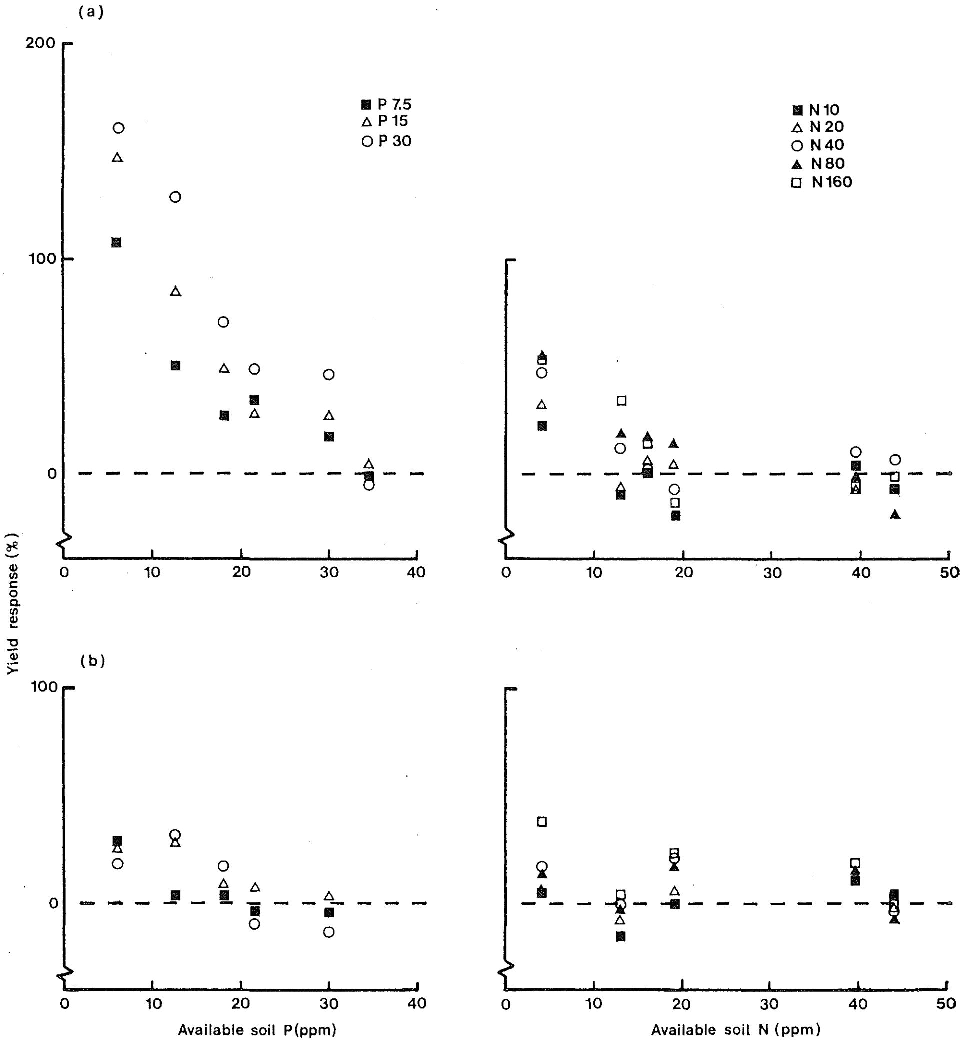

Figure 1. Relationships between mean percentage yield response of oats for (a) initial growth and (b) regrowth and phosphorus and nitrogen fertilizer rate (kg ha^{-1}) and available soil phosphorus (bicarbonate P, 0–10 cm) and nitrogen (NO_3–N, 0–20 cm) respectively, at planting.

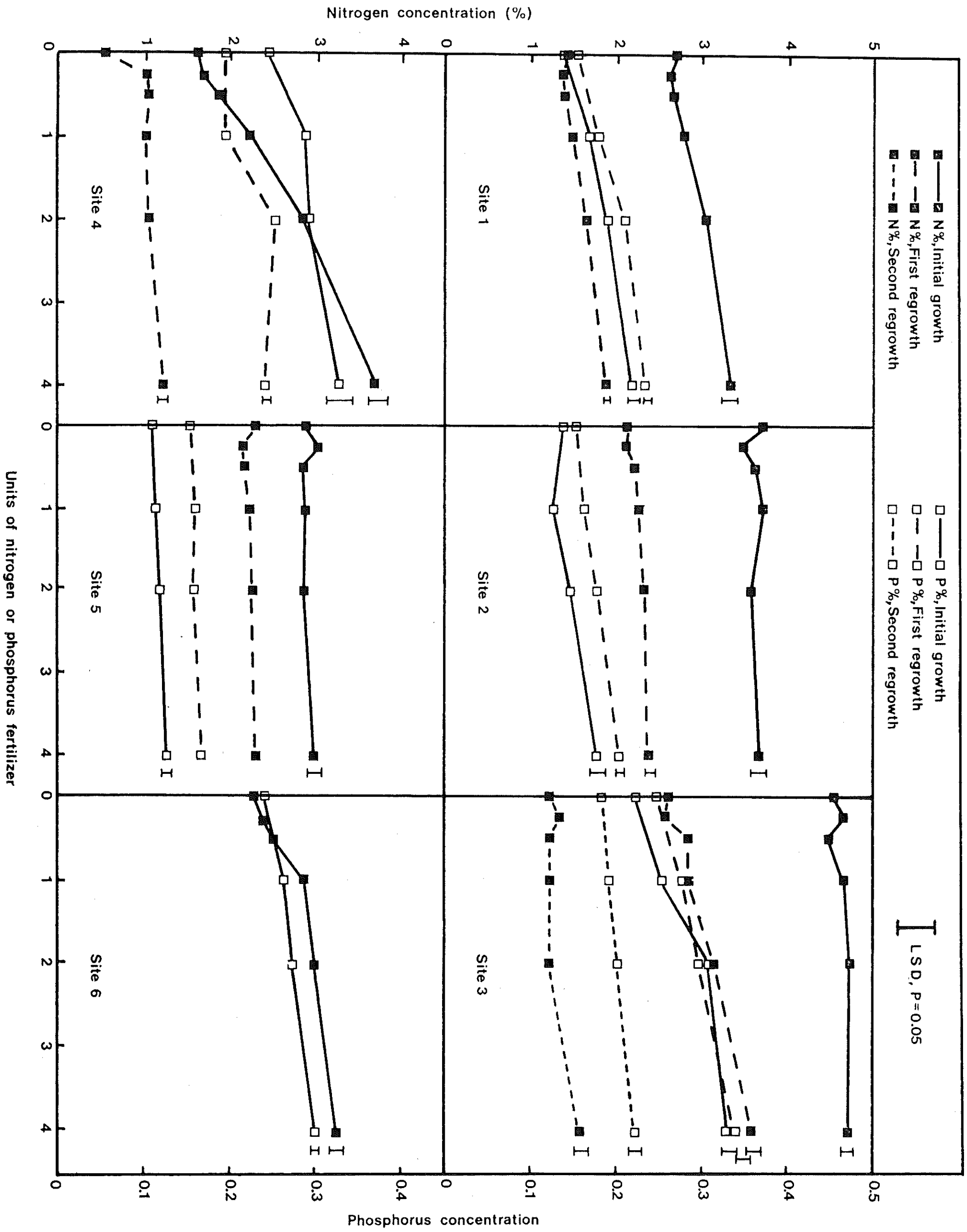

Figure 2. The mean effect of rate of nitrogen and phosphorus fertilizers on nitrogen and phosphorus concentration in oats following initial growth and regrowth periods. One unit of nitrogen and phosphorus applied is equal to 40 and 7.5 kg ha^{-1}, respectively.

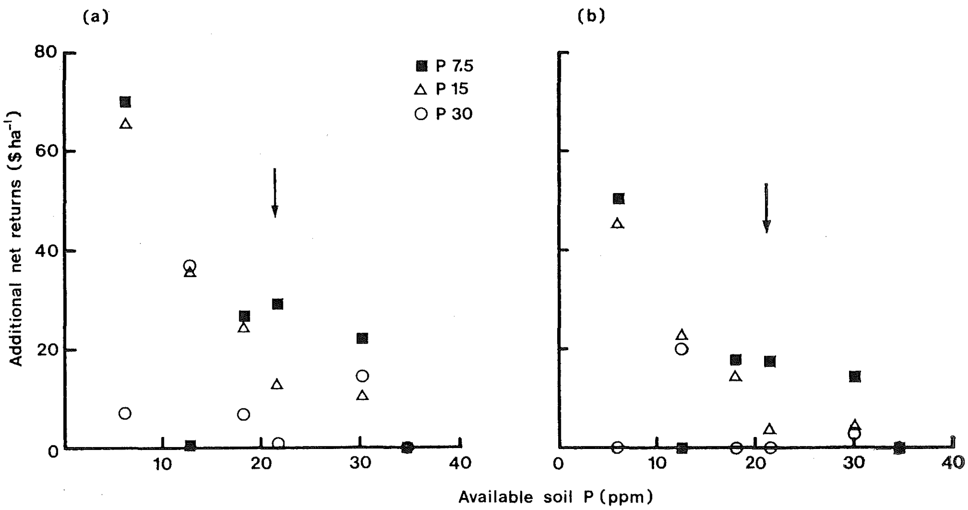

Figure 3. Estimated additional net returns from phosphorus application rates of 7.5, 15 and 30 kg P ha^{-1} at selling prices for cattle of (a) 100 and (b) 75 cents per kg live weight. At site 4 (↓) net returns were calculated for the 20 kg ha^{-1} nitrogen application rate compared with no nitrogen at the other sites.

4. Discussion

Phosphorus deficiency appears to be widespread in the Maranoa. These experiments demonstrated responses to phosphorus fertilizer by forage oats at 5 out of the 6 sites while Best and Strong (1978) found profitable increases in grain yields by wheat at 20 out of 35 sites in the Maranoa. The available soil phosphorus (bicarbonate extractable P, 0 to 10 cm) levels at which 80% of sites responded to phosphorus fertilizer was higher for dry matter production in oats (30 ppm) than for grain yield in wheat (15 ppm) (Best and Strong 1978).

Rainfall was a dominant factor limiting growth in the Maranoa. Our work demonstrated that even in a semi-arid environment the limited supply of water was used more efficiently for crop growth when fertilizer was applied. Most soils in the Maranoa have sufficient nitrogen for crop growth. Only 3 out of 6 sites gave significant increases in the yield of forage oats to nitrogen fertilizer while Best and Strong (1978) found no economic responses in grain yield in wheat. This is in contrast to the Darling Downs where Cull and Muir (1969) found widespread yield responses in forage oats to nitrogen but not phosphorus fertilizer. Although nitrogen was not a major deficiency limiting oat growth in the Maranoa, where the available soil nitrogen is 10 ppm or less, significant responses would be expected from nitrogen application following grazing. Because nitrogen responses are small in this region an alternative strategy to nitrogen application which should be investigated is the sowing of medics with oats in order to assess their value to animal production and the nitrogen economy of the system.

Although there was no significant interaction between the effects of nitrogen and phosphorus fertilizers on the total yield of oats, the ratio of available soil nitrogen to phosphorus was a significant component of the multiple regressions for predicting yield response to nitrogen alone and to nitrogen and phosphorus together. Thus in using soil tests to assess the expected response to fertilizer application it is important to consider the availability of nitrogen and phosphorus both in terms of their individual concentrations and their relative availabilities. These experiments also confirmed the finding of Whitehouse (1970) that the bicarbonate extractable phosphorus test gave a better index of available soil phosphorus than the acid extractable phosphorus test. It is also apparent that yield response in the initial growth of oats was related to available phosphorus in the surface soil whereas regrowth was related to available phosphorus in the subsurface soil.

The economics of fertilizer application to oats for fattening cattle have been assessed from the experimental yields by assuming that the cost of nitrogen and phosphorus is 50 and 100 cents per kg respectively, that 9 kg of dry matter intake by cattle produces 1 kg of live-weight gain and that 50% of the extra dry matter produced from fertilizer application is consumed. This analysis showed that the additional net returns were significantly affected by nitrogen application only at site 4 (which had the lowest available soil nitrogen). The additional net returns from phosphorus application alone, except for site 4 where the 20 kg N ha^{-1} rate was used, are given in figure 3 for cattle selling prices of 75 and 100 cents per kg live-weight. It is apparent that the additional net returns are maximized at application rates between 7.5 and 15 kg P ha^{-1} and that the additional net return is considerable at low soil phosphorus availability.

An additional benefit from fertilization is the change in nitrogen and phosphorus concentration in the plant in relation to the nutritional requirements of the animal. The critical level of nitrogen required in pasture before intake is reduced by nitrogen deficiency has been estimated at between 0.96 and 1.36% (Minson 1971). In these experiments, the nitrogen concentration seemed inadequate in only two situations, namely, following the first defoliation at site 4 and the second defoliation at site 3. Hemingway (1977) has suggested that growing cattle require a dietary concentration of about 0.25 to 0.3% phosphorus for maximum growth. In many instances the phosphorus concentration was below these values and therefore the significant increases in phosphorus concentration from phosphorus fertilizer application may produce significant effects on live-weight gain.

5. Acknowledgements

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