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## SOIL FERTILITY AND HILL COUNTRY PRODUCTION

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### *Abstract*

Soil, pasture and animal responses to 2 levels of superphosphate were measured within a farmlet trial, at Ballantrae hill country research area, near Woodville, during 1975-80. Soil and pasture measurements were also made for 3 years before the trial started. Pastures, which were dominated by low-fertility-tolerant grasses (LFTG), moss and flatweeds, were **oversown** with 4 legumes before the trial started. Soil Olsen P level was 5 under untopdressed pasture in 1973, and 9 in 1975 after application of 500 kg/ha superphosphate. Superphosphate rates were 120 (on low fertiliser areas = LF) and 640 (on high fertiliser areas = HF) kg/ha/yr average during 1975/80.

Annual pasture production (adjusted for variable summer rainfall) was 7.1 t DM/ha from untopdressed pasture and 8.1 t following 500 kg superphosphate/ha in 1973-74. LF production rose to 8.5, and HF to 12.0, in 1980. Legume contribution rose from 5% in untopdressed pasture to 18% and 23% in LF and HF respectively in 1975/76. By 1979/80 legume contribution had steadily declined to 10% on both treatments, probably due to a measured increase in soil N availability and increased competitiveness of associated grasses. Ryegrass content rose at both fertiliser levels, while LFTG content fell; these trends were greatest under HF. Winter stocking rate was increased from 6 to 10.9 and 14.9 su/ha on LF and HF-respectively. Per animal performance did not decrease.

A range of techniques which could increase efficiency of superphosphate use in hill country is discussed. These techniques include: selective application to responsive pastures; spring application; grazing management to encourage legume growth.

### INTRODUCTION

Low soil N availability to pasture plants is often the primary nutritional limitation to pasture production in New Zealand hill country. Topsoils generally contain medium to high levels of total N, but its availability to plants is low because of wide C:N ratios in organic matter. Fertilisers other than N are commonly applied to relieve nutrient stress in legumes. Superphosphate, containing P and S, and sometimes K or Mo, increases legume growth and N fixation, leading to increased soil N availability for other pasture species.

Fertiliser purchase and application costs are a large and increasing proportion of hill farmers' expenditure, and hence have a major influence on farm profitability.

Work at Grasslands Division's Ballantrae research area, near Woodville, during 1972/80 has examined the influence of soil fertility on hill country production.

### BALLANTRAE GRAZING TRIAL

In a 100 ha grazing trial involving 10 self-contained farmlets (Grant *et al.*,

1978) influences of 2 fertiliser treatments on soil, pasture and animals have been investigated during 1975-80. Pasture and soil measurements were also made for 3 years before the trial started. Three grazing managements were used at each fertiliser level (Clark et al., 1982).

Fertiliser treatments were low (LF) and high (HF) application rates of superphosphate (Table 1) usually applied in late winter/ spring. Molybdenum was applied across both treatments, and lime was applied to the HF treatment — 1250 kg/ ha in 1975 and 2500 kg/ ha in 1979. Fertiliser had not previously been applied to the area.

TABLE 1: SUPERPHOSPHATE (9.5% P) APPLICATION RATE (kg/ha/yr) AND NOVEMBER-APRIL RAINFALL (mm)

	Superphosphate rate			Rainfall
	Low fertiliser	High fertiliser		
1972/73:		0		392
1973/74:		250		445
1974/75:		250		448
1975/76:	200		760	673
1976/77:	0		520	460
1977/78:	130		900	439
1978/79:	130		510	620
1979/80:	130		510	798

Olsen P level was 5 in 1973, and 9 in 1975. Olsen P remained near the latter level in LF areas, and averaged 14 in HF areas, during 1976-80. pH was about 5.3 and 5.4 in LF and HF areas respectively during 1975-1979, rising to 5.8 in HF in 1980.

White (*Trifolium repens* L.) and red (*T. pratense* L.) clovers and *Lotus pedunculatus* Cav. were oversown into pasture in 1974 and 1976, and subterranean clover (*T. subterraneum* L.) in 1974.

## RESULTS

### PASTURE PRODUCTION

Pasture production was measured using grazing enclosures and a trim technique. In the first year of differential fertiliser application HF produced 9% more pasture than LF, thereafter 21-50% more on an annual basis (Table 2). Where variable summer rainfall effects were removed using a regression equation, adjusted pasture production values (in parentheses in Table 2) were obtained. November to April rainfall was variable (Table 1), causing year-to-year variation in pasture production of 23% about the mean value. LF was near maintenance superphosphate rate for an adjusted yield of 8.5 t DM/ ha/yr, but adjusted pasture production on HF had increased to 12 t by 1979/80 (Table 2). Fertiliser treatment did not affect seasonal pattern of pasture production.

Superphosphate applied in any particular year had a residual effect on

TABLE 2: MEASURED PASTURE PRODUCTION (t DM/ha/yr), AND ESTIMATED PASTURE PRODUCTION IN ABSENCE OF VARIABLE SUMMER RAINFALL (IN PARENTHESES).

	Low fertiliser		High fertiliser
1972/73:		5.5 (7.1)	
1973/74:		5.5 (7.8)	
1974/75:		7.8 (8.1)	
1975/76:	9.9 (8.2)		10.8 (9.7)
1976/77:	6.4 (7.9)		9.5 (9.9)
1977/78:	7.0 (8.2)		10.3 (11.6)
1978/79:	10.3 (8.4)		12.4 (11.5)
1979/80:	10.4 (8.5)		13.9 (12.0)

pasture production. Regression analysis involving current superphosphate application rate, superphosphate application history, summer rainfall, and annual pasture production, suggests that this residual effect lasted several years and was 40% as big as the effect of superphosphate applied in the current year (Lambert *et al.*, in prep.).

#### BOTANICAL COMPOSITION

Ryegrass (*Lolium perenne* L.) and legume (sown legumes plus suckling clover *T. dubium* Sibth.) content increased, and the contribution of low-fertility-tolerant grasses (mainly browntop *Agrostis* spp. sweet vernal *Anthoxanthum odoratum* L., crested dogstail *Cynosurus cristatus* L.) decreased during 1972-80 (Table 3). HF magnified these effects from 1975/76 on. Legume content rose to highest levels in the early years of differential application, and a marked contrast between HF and LF was observed. In later years legume content decreased, more rapidly in HF than LF (Table 3). Production of legume DM was initially much higher in HF and LF but this difference was less in later years. Grass production continued to rise throughout the trial (Fig. 1).

#### ANIMAL PRODUCTION

Winter stocking rate was increased in annual steps from 6 su/ha before 1975 to 10.9 and 14.6 on LF and HF areas respectively in 1980. Per animal performance was relatively high and did not decrease with increasing stocking rate (Clark *et al.*, 1982).

#### SOIL FERTILITY

N fixation rose from about 30 kg/ha/yr in 1974/75 (Grant & Lambert 1979) to about 70 and 120 in sheep-grazed LF and HF areas respectively in 1976/77. N fixation in cattle-grazed pasture was considerably higher than in sheep-grazed pasture -- 110 and 250 on LF and HF respectively.

TABLE 3: CONTRIBUTION (%) OF LEGUMES, RYEGRASS AND LOW-FERTILITY-TOLERANT GRASSES (LFTG) TO DRY MATTER PRODUCTION FOR LOW (LF) AND HIGH FERTILISER (HF) TREATMENTS. VALUES ARE CALCULATED ON A GREEN MATERIAL BASIS.

	Legumes		Ryegrass		LFTG	
	LF	HF	LF	HF	LF	HF
1972/73:		5		10		62
1973/74:		4		7		70
1974/75:		11		9		62
1975/76:	18	23	14	20	53	50
1976/77:	14	22	17		50	41
				32		41
1978/79:	13	13	29	32	49	38
1979/80:	10	10	26		43	31

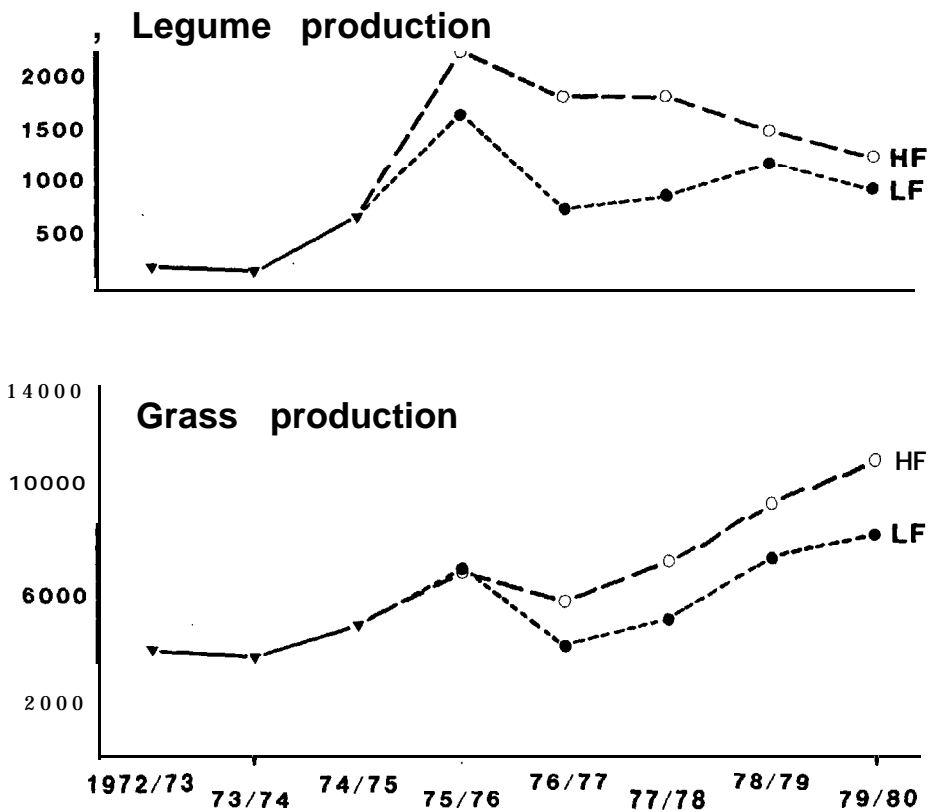


FIG. 1: Legume and grass production (kg DM/ha/yr) in Ballantrae grazing trial during 1972/73 — 1979/80. Low fertiliser (LF) and high fertiliser (HF) treatments commenced in 1975/76.

Differences between fertiliser treatments in 0-75 mm soil total N content and C:N ratio were difficult to detect against a background of about 2.6 t N/ha and 35 t C/ha. A modified stress labile N method (Luscombe & Johnson 1981) estimated the labile pool of N in winter 1980 at 53 and 64 kg N/ha for LF and HF treatments respectively. Measurements of N loss in runoff were made in small catchments. During 1975/76 and 1976/77 proportion of total N in runoff comprised of inorganic N was similar for LF and HF. In the subsequent 2 years a much higher proportion occurred in HF catchments — 58% cf 30% in LF catchments. In early spring 1979 earthworm populations were sampled using a formalin-extraction method (Springett 1981). Worm dry weight was 164 and 204 kg/ha for LF and HF treatments respectively.

## DISCUSSION

### PASTURE PERFORMANCE

Responses to fertiliser application were probably due mainly to Mo and superphosphate application, as plot work on the trial area showed Mo and lime to be substitutive in the short term (Lambert & Grant 1981). A relatively small amount of lime (1250 kg/ha) was applied in 1975, and the 2500 kg/ha lime applied in 1979 would have had little effect on the results presented here.

Superphosphate application, coupled with increased stocking rate and better utilisation of pasture, increased legume growth, N fixation, and the pool of readily available soil N. Increased production from the non-legume component was probably due to increased soil N, as was higher losses of mineral N in runoff. Earthworm activity was higher in HF blocks probably as a direct consequence of an increased supply of organic material. Increased pH and/or Ca supply, because of liming, may also have been implicated.

The absence of change in seasonality of pasture production with changing soil fertility level is contrary to conclusions of Grant et al., (1973) and Grant et al., (1981) at Ballantrae. They found that the proportion of annual production occurring in winter increased with fertility. Their range of fertiliser treatments was wider than ours, pastures were mown, and changes in botanical composition were much more pronounced.

Absence of a measured response by legumes during 1973/74, to superphosphate applied in 1973 (Table 3, Fig. 1) may have been partly due to the dry season. It may also have reflected the absence of a responsive legume population, resident legumes being suppressed by grasses, weeds and moss.

Between 1974/75 and 1977/78 a large response by legumes to HF was observed (Fig. 1, Table 3) probably reflecting the presence of a strong legume population, after superphosphate application, oversowing, and better pasture utilisation.

In 1978/79 and 1979/80 legume production from HF decreased (Fig. 1), lowering the efficiency of use of applied P by legumes. If comparison of LF and HF is made, estimates of efficiency of use of applied P by legumes can be obtained. Efficiency values are 11, 22, 13, 8 and 9 kg extra legume DM/kg

extra P applied to HF, for the 5 years 1975/76 to 1979/80. A 5-year grazing trial at Te Awa (Suckling 1959) showed a similar trend. The decrease in legume performance was probably due to increased grass competition as a result of higher soil N availability. Luscombe and Fletcher (1982) found that late-winter application of fertiliser N to short-grazed pasture at Ballantrae resulted in increased grass competitiveness, and reduced legume yields and N fixation in the subsequent summer and autumn.

Use of white clover types better adapted to hill environments (Williams *et al.*, 1982) may increase the height of the legume curves in Fig. 1. However, use of a single genotype is unlikely to markedly affect the shape of the curves.

#### SUPERPHOSPHATE USE

##### TIMING OF SUPERPHOSPHATE APPLICATION

During (1972) considers that on semi-improved hill country late-winter/early spring or early autumn is the most suitable time for superphosphate application, and that on unimproved hill country time of application is unimportant. Access to airfields, weather, and cash flow problems influence time of application. In North Island hill country much superphosphate is applied in autumn, and fertiliser sales peak in both spring and autumn (N.Z. Fertiliser Statistics).

Barrow and Shaw (1974) show that effectiveness of applied superphosphate decreases exponentially with time. Extrapolation from their data indicates that at Ballantrae autumn-applied superphosphate would be much less effective in November than spring-applied superphosphate. Legume growth at Ballantrae is highest in November-January. Grant *et al.*, (1981) found that initial response in legume growth following superphosphate application was highest in spring and summer. Reworking their data for grass/clover pastures gives values of 0.56, 1.04, 0.23 and 0.06 kg legume DM/ day per kg P applied at start of season, for spring, summer, autumn and winter respectively. Lowered responses in autumn and winter are presumably a function of environmental limitations to legume growth at these times of the years.

It is probable that practical increases in efficiency of superphosphate use can be achieved by application just before season of main legume growth. As well as enhancing responses to applied P, changes of S deficiency will be decreased.

##### SELECTIVE APPLICATION

Saunders and Auld (1969) and subsequent workers, suggest differential topdressing within paddocks to increase efficiency of fertiliser use.

Our work suggests that increased efficiency of superphosphate use may also be obtained by applying higher rates to more responsive pastures and lower rates to less responsive pastures within a farm, as distinct from within a paddock. More responsive pastures would include those which have a strong legume base, a recent history of low to medium superphosphate application,

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and which have been well-utilised by grazing animals to minimise shading of legumes by other species. Less responsive pastures would fall into 2 main categories (i) under-utilised, with a history of low fertiliser application, and with low legume content, (ii) highly improved, grass-dominant pastures with a recent history of high fertiliser (including N) application.

### **PASTURE MANAGEMENT**

Responsive areas which have had, or are to have, higher rates of superphosphate application, should be well-utilised before peak legume growth. Grazing with cattle can improve summer legume content (Grant *et al.*, 1978) in some situations. Near time of peak legume growth grazing pressure can be eased or removed, allowing legumes to elevate leaves above associated species (Harris 1974) and to respond strongly to applied superphosphate.

Some evidence exists for luxury uptake of P by white clover, and relocation within the plant from older to younger tissue (Hart & Jessop 1981, Hoshino 1974). Once P has been taken up by legumes it may be used and reused for production of new tissue. Therefore, under conditions of vigorous legume growth less frequent and laxer grazings may encourage more efficient utilisation of superphosphate. High grazing pressures will encourage grazing of actively growing legume, which has high P concentrations (Hart & Jessop 1981), and deposition of P in a relatively unavailable form in dung.

An alternative, to feeding-off legume-dominant pastures in summer/autumn, is to allow legumes to achieve maximum growth through this period, and to aim for maximum entry of fixed N to the organic cycle i.e. a "composting" technique. This approach is described by Mauger (1978), for a Wairarapa hill country farm. Its merits would depend on the extra animal production from earlier feeding-off, losses in N-fixation incurred by earlier feeding-off, and the difficulty of cleaning-up pastures spelled for long periods.

### **IS SUPERPHOSPHATE USE PROFITABLE?**

The answer to this question depends on many factors, including those discussed here. At Ballantrae we calculate that an extra 100 kg/ha/yr superphosphate (9.5% P) would be required in order to stimulate enough extra pasture in our LF treatment to feed 1 extra su/ha. This assumes no increase in level of utilisation of pastures. Under present prices this would be a profitable course of action.

If the response to superphosphate were much lower than at Ballantrae this would not be the case. Lower responses could be due to a lower level of pasture utilisation; or a less responsive soil fertility complex, due either to inherent soil characteristics or a different history of fertiliser application and management. Responses greater than those achieved at Ballantrae could occur where features of the environment e.g. favourable soil moisture and physical characteristics, encourage strong legume growth (During 1972). Often increases in level of pasture utilisation, achieved primarily by increasing stocking rate, accompany increases in superphosphate application.

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Accordingly, the apparent response to applied superphosphate is enhanced. Legume seed is sometimes OVERSOWN during pasture improvement programmes and greater legume content may eventuate, increasing response to superphosphate. Increased quality of pasture often results from fertiliser application, and hence gains in animal production above those from greater pasture growth *per se* may occur,

Our work suggests that production from grazed low-fertility hill country is very responsive to superphosphate application, when coupled with high utilisation of pastures. Profitability of superphosphate application may be manipulated by the farmer by strategic application and pasture management to increase efficiency of use. However, control of costs associated with application, and income earned from resultant produce, remains largely outside farmers' direct control. Severe imbalance in these factors could restrict opportunities for increased hill country production.

#### ACKNOWLEDGEMENTS

D. A. Costall, B. P. Devantier, N. Dymock, P. J. Budding for technical assistance. Staff of Herbage and Soil Laboratories, Grasslands Division, for analytical services.

#### REFERENCES

- Barrow, N. J.; Shaw, T. C., 1974. *Comm. Soil Sci. Plant Analy.*, 5 (5): 355-364.  
Clark, D. A.; Lambert, M. G.; Chapman, D.A., 1982. *Proc. N.Z. Grassld Ass.*, 43: 205-214.  
During, C., 1972. *Fertilisers and Soils in New Zealand Farming*. Govt. Printer, Wellington.  
Grant, D. A.; Lambert, M. G., 1979. *N.Z. Jl exp. Agric.* 7: 19-22.  
Grant, D. A.; Lambert, M. G.; Guy, M. C., 1978. *Proc. N.Z. Soc. him. Prod.*, 38: 110-115.  
Grant, D. A.; Luscombe, P. C.; Thomas, V. J., 1981. *N.Z. Jl agric. Res.*: in press.  
Grant, D. A.; Rumball, P. J.; Suckling, F. E. T., 1973. *Proc. N.Z. Grass/d Ass.*, 34 (2): 185-194.  
Harris, W., 1974. *Ibid.* 35 (1): 101-109.  
Hart, A. L.; Jessop, D., 1981. *N.Z. Jl agric. Res.*: in press.  
Hoshino, M., 1974. *Bull. Natl. Grassld Res. Inst.*, 5: 35-84.  
Lambert, M. G.; Grant, D. A., 1981. *N.Z. Jl exp. Agric.*, 223-229.  
Luscombe, P. C.; Fletcher, R. H., 1982. *Proc. N.Z. Grass/d Ass.* 43: 171-181.  
Luscombe, P. C.; Johnson, D. M., 1981. *N.Z. Jl. agric., Res.*: in press.  
Mauger, J. H., 1978. *N.Z. Fert. Jl.*, 51: 4-6.  
Saunders, W. M. H., Auld, M. W., 1969. *Ruakura Frmr's Conf.*: 16-25.  
Springett, J., 1981. *Pedobiologia*, 21: 213-218.  
Suckling, F. E. T., 1959. *N.Z. Jl. agric. Res.* 2: 488-543.  
Williams, W. M.; Lambert, M. G.; Caradus, J. R., 1982. *Proc. N.Z. Grassld Ass.* 43: 1X9-195.