

# EFFECTS OF DIFFERENT PHOSPHATE FERTILISERS ON PASTURE NUTRITION AND SOIL PHOSPHORUS IN CANTERBURY, NEW ZEALAND

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## ABSTRACT

A field trial was conducted over 6 years to assess the relative performance of three phosphate (P) fertilisers of differing solubility (single superphosphate, 'longlife' superphosphate, 'reactive' phosphate rock) on a permanent pasture at Methven in Canterbury, New Zealand. Plant P uptake data showed that while the overall relative effectiveness of the fertilisers was closely related to their water-soluble P content (single superphosphate > 'longlife' superphosphate > 'reactive' phosphate rock), the agronomic efficiency of the sparingly soluble phosphate rock fertiliser improved markedly with time. Soil P analysis demonstrated that significant dissolution of phosphate rock had occurred in the soil, and the findings of this trial confirm that phosphate rock is an appropriate P fertiliser for use in pastoral agriculture in New Zealand.

## KEYWORDS

Phosphorus, fertilisers, soil, pasture, agronomic performance, New Zealand

## INTRODUCTION

The relative agronomic effectiveness of phosphate (P) fertilisers comprising water-soluble P (e.g. monocalcium phosphate [MCP:  $\text{Ca}(\text{H}_2\text{PO}_4)_2 \cdot \text{H}_2\text{O}$ ]) and/or sparingly soluble forms of P (e.g. phosphate rock [apatite P:  $\text{Ca}_5(\text{PO}_4)_3(\text{OH}, \text{F}, \text{Cl}, \text{CO}_3)$ ]) in pastoral agriculture is mainly influenced by the reactions and subsequent availability of fertiliser P in the soil environment (Sanyal and DeDatta, 1991). This, in turn, is affected by a combination of soil properties (e.g. fertility, acidity, P retention), fertiliser characteristics (e.g. phosphate rock composition), pasture composition and time after application (Stephen and Condrón, 1986; Bolan *et al.*, 1990a). The main objective of this study was to assess the relative agronomic performance of three P fertilisers of differing solubility on an established pasture in Canterbury, New Zealand over a 6 year period. In addition, the effects of continued P fertiliser addition on the forms and availability of soil P was also investigated.

## MATERIALS AND METHODS

The field trial site was located at Methven, 90km south-west of Christchurch, New Zealand (annual rainfall: 1100mm). The soil was a Gorge silt loam (Yellow Brown Earth [New Zealand]; Dystrachrept [US]) developed from greywacke alluvium and loess. At the beginning of the trial in 1990, major chemical characteristics the topsoil (0-7.5mm) were: pH (water) 5.9 [moderately acid]; Olsen P 10 ( $\mu\text{P g}^{-1}$ ) [low]; P retention 33% [medium]; base saturation 56% [medium] (Blakemore *et al.*, 1987). The trial was established on a predominantly ryegrass (*Lolium perenne*) - white clover (*Trifolium repens*) pasture which was originally sown in the early 1950s, and had received regular inputs of superphosphate (125-250  $\text{kg ha}^{-1} \text{ yr}^{-1}$ ) and lime (4 tonnes  $\text{ha}^{-1}$  every 4-5 years).

The three fertilisers used included single superphosphate (SSP: total P 8.75%, water-soluble P 8.23%, 2% citric acid soluble P 8.49%), 'longlife' superphosphate (LSP: total P 10.10%, water-soluble P 4.65%, 2% citric acid soluble P 6.67%), and unground (<2mm) North Carolina 'reactive' phosphate rock (NCPR: total P 12.00%, 2% citric acid soluble P 3.60%). The SSP was made from a blend of Nauru and North Carolina phosphate rock (PR), while the LSP was made by mixing unground (<2mm) NCPR with SSP made from a

blend of Nauru and North Carolina PRs (Bolan *et al.*, 1990b; Condrón *et al.*, 1994). The trial comprised 21 plots (4 x 5m), which included 3 replicates of a control and two rates (12.5 and 25  $\text{kgP ha}^{-1} \text{ yr}^{-1}$ ) of each fertiliser arranged in randomised blocks. The plots were harvested as required (3-5 times each season), and the dry matter yield (tonnes  $\text{ha}^{-1}$ ) and corresponding P uptake ( $\text{kgP ha}^{-1}$ ) were determined. Herbage was removed from the plots after each harvest, and consequently nutrients other than P and calcium (i.e. nitrogen, sulphur, potassium, magnesium, zinc, manganese) were applied regularly. The P fertilisers were applied in spring (October) each year and the trial was continued for 6 seasons (from 1990-91 to 1995-96).

Soil samples (0-7.5cm) were taken from the trial area prior to treatment application in 1990 (4 replicates), and from every plot in April each year from 1991 to 1996. The samples taken in 1990 and 1994 were selected for detailed analysis of soil inorganic P by sequential fractionation (0.5M  $\text{NaHCO}_3$  [pH 8.5]  $\uparrow$  0.1M NaOH  $\uparrow$  1M HCl  $\uparrow$  0.1M NaOH) according to Condrón *et al.* (1996).

## RESULTS AND DISCUSSION

In general, P uptake is a more reliable indicator of relative agronomic performance than dry matter yield in this type of trial which included basal dressings of major nutrients (Condrón *et al.*, 1995). In the first two years of the trial (1990-92), relative P uptake for the three fertilisers at equivalent application rates was closely related to water-soluble P content (i.e. SSP > LSP > NCPR (control) (Table 1). However, the agronomic performance of NCPR compared with the control and LSP/SSP fertilisers improved over the 1992-96 period (Table 1). Cumulative P uptake data (Table 1) showed that although the overall relative effectiveness of the P fertilisers was related to their respective water-soluble P content (SSP > LSP (NCPR), NCPR performed very favourably compared with LSP and SSP, especially at the lower rate of application (12.5  $\text{kgP ha}^{-1} \text{ yr}^{-1}$ ). Furthermore, cumulative P uptake was greater for LSP/25 compared with SSP/12.5 (similar amounts of water-soluble P applied) (Table 1), which indicates that the PR component of the LSP contributed to plant P requirements (Condrón *et al.*, 1995).

Soil analysis (Table 2) showed that as expected the continued application of fertiliser P increased amounts of inorganic P in the soil, while data from control soil sampled in 1990 and 1994 indicated that plants obtained P mainly from the 'labile' BPi and N1Pi pools. The presence of higher amounts of acid soluble P (HPi) in the NCPR and LSP treated soils (Table 2) can be attributed to the accumulation of residual PR, although the fact that levels of BPi (and N1Pi) were similar in the NCPR treatments compared with SSP reflects significant PR dissolution (Di *et al.*, 1994). This in turn accounts for the improved agronomic performance of NCPR with time in this trial (Table 1).

In conclusion, the results of this study clearly demonstrate that 'reactive' PR such as NCPR (applied alone or as a partially acidulated product) can contribute significantly to the long-term P requirements of pastures in New Zealand.

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**Table 1**

Mean data for annual pasture P uptake (kgP ha<sup>-1</sup>) for seasons 1990-91 through 1995-96, and cumulative dry matter production (DM - tonnes ha<sup>-1</sup>) and P uptake (PU - kgP ha<sup>-1</sup>) for 1991-96

<i>treatment</i>	<b>1990-91</b>	<b>1991-92</b>	<b>1992-93</b>	<b>1993-94</b>	<b>1994-95</b>	<b>1995-96</b>	<b>DM 1990-96</b>	<b>PU 1990-96</b>
control	26.25	17.77	22.65	19.10	18.33	19.15	50.47	123.25
NCPR/12.5*	26.58	19.06	33.02	26.06	21.81	25.00	56.47	151.54 (123)**
NCPR/25	26.91	20.09	35.25	30.05	20.86	24.17	55.46	157.32 (128)
LSP/12.5	29.79	21.45	28.85	25.36	22.38	25.56	55.24	153.40 (125)
LSP/25	28.13	24.98	33.95	30.85	22.68	27.69	56.11	168.27 (136)
SSP/12.5	32.66	22.73	33.58	24.62	25.18	25.73	57.14	164.50 (133)
SSP/25	32.79	27.91	43.30	28.73	31.04	33.28	60.49	197.06 (160)
SEM***	1.316 (7.9)	1.001 (6.3)	2.123 (9.9)	NS (11.9)	NS (17.0)	1.297 (6.9)	NS (4.4)	5.692 (6.1)

\* fertiliser / rate (kgP ha<sup>-1</sup>)

\*\* relative agronomic effectiveness [RAE] (control = 100)

\*\*\*standard error of means (coefficient of variation - cv%); NS = not significant (P>0.05)

**Table 2**

Mean data for inorganic P fractionation (µgP g<sup>-1</sup>) for soil (0-7.5cm) taken from the trial area in 1990 and from the different treatments in 1994

	<b>BPi*</b>	<b>N1Pi*</b>	<b>HPi*</b>	<b>N2Pi*</b>	<b>YiPi fractions*</b>
1990 (trial area)24		156	107	31	318
1994:					
<i>control</i>	15	131	93	28	267
<i>NCPR/12.5**</i>	20	147	113	30	310
<i>NCPR/25</i>	25	153	144	34	356
<i>LSP/12.5</i>	17	142	108	30	297
<i>LSP/25</i>	18	141	114	31	304
<i>SSP/12.5</i>	19	147	94	29	289
<i>SSP/25</i>	25	161	99	30	315
<b>SEM***</b>	<b>1.6 (13.9)</b>	<b>5.5 (6.5)</b>	<b>4.7 (7.5)</b>	<b>0.5 (2.9)</b>	<b>10.0 (5.7)</b>

\* BPi (0.5M NaHCO<sub>3</sub> [pH 8.5]); N1Pi (0.1M NaOH); HPi (1M HCl); N2Pi (0.1M NaOH);

YiPi fractions (BPi + N1Pi + HPi + N2Pi)

\*\* fertiliser / rate (kgP ha<sup>-1</sup>)

\*\*\* standard error of means (coefficient of variation - cv%); NS = not significant (P>0.05)