RPR REVISITED (3):

A REVIEW OF RPR *vs* SUPERPHOSPHATE ON PUMICE SOILS

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Abstract

Results from the New Zealand 'National Series' of reactive phosphate rock (RPR) *vs* superphosphate trials were reassessed by Quin & Zaman (2012), using frequency distribution P response curves. Zaman & Quin (2012) developed revised farmer RPR recommendations based on this and on the results of a farmer survey. However, only one of the National Series trials was conducted on a pumice soil for only 3 years as a maintenance P comparison.

This paper summarises the results from 7 different RPR *vs* soluble P trials conducted on pasture on pumice soils over the period 1977-1996, and interprets them in the context of the approach taken by Quin & Zaman (2012).

The trials had been conducted on sites with a wide range of P retention (also called anion storage capacity or ASC), soil pH, rainfall and Olsen P levels ranging from very low to medium.

Assessment of the trials data, both individually and collectively (using frequency distribution P response curves), demonstrated that in this wide range of conditions on pumice soils, pasture production with RPR came to meet that with soluble P by the third year of its use, that is, after a maximum lag phase of two years, during which the median difference in production between RPR and soluble P is 7% (range 0-10%).

The performance of RPR on pumice soils is similar to that on the other low-medium P retention soils, except that because of the typically greater response to P of pumice soils, the size of the difference in production during the lag phase can be greater. This means that the use of appropriate RPR/soluble P blends initially is more likely to be the best approach in switching from soluble P to RPR on pumice soils.

Introduction

Data from the MAF's 'National Series' of RPR *vs* superphosphate trials has been reassessed by Quin & Zaman (2012). Because of staff locations at the time this trial series was conducted, only one of the 19 sites was on pumice soil, which ran for only 3 years as a maintenance comparison.

Given the proven reduction in P run-off where RPR is used instead of soluble P, and the serious decline in phosphorus water quality in most central North Island lakes, the catchments of many of which are largely pumice soils, it was considered important to review the results from all available trials conducted on pumice soils.

Site details for the 7 trials are presented in Table 1, in order of their date of commencement. Their results and discussion on each are presented in the same order. The trials were assessed individually, and rated a score of 1-5 for their value (5 being highest), based on trial duration, variability, statistical analysis and product, soil and other details. The combined data was assessed using P response frequency distribution curves, in the manner of Quin & Zaman (2012).

Results and discussion of individual trials

Table 1. Trial site data

Trial No.	*1*	*2*	*3*	*4*	*5*	*6*	*7*
Commenced	1967	1980	1980	1982	1987	1987	1990
Duration	4 yrs	2 yrs	2 yrs	3 yr	9 mths	9 mths	6yrs
Location	NA	Gisb	Rotorua	Waikite Valley	Gisb	Gisb	Motu
Stat. anal?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
WhichRPR?	Gafsa	Sechura	Sechura	Sechura	NC	NC	Sechura
Which soluble P?	MCP/ Gypsum	Comm. SSP	Comm. SSP	Comm. TSP	PAPR	PAPR	Comm. S-SSP
P Rate (kg/ha/yr)	42	30	60	50	7.5, 15 and 30	15	Above Maint.
Nil P control?	Yes	Yes	Yes	Yes	No	No	Yes
Soil pH	5.5	5.8?	6.0	5.1	5.6	5.6	5.8
Soil P retention	31	?	24	62	56	73	48
Rainfall (mm/yr)	1100-1500	?	?	1131	?	?	1750-2600
Soil Olsen P	13	?	24	24	7	9	8
Scientific Value*	3.5	2	2.5	3.5	1.5	1.5	5

N.C. = North Carolina RPR
Comm. SSP = New Zealand commercially manufactured single superphosphate
Comm.S-SSP = NZ commercially manufactured sulphur-fortified SSP
Comm. TSP = imported commercially manufactured triple superphosphate
PAPR = laboratory-made phosphoric partially acidulated RPR
? – data not recorded
* Assessed from trial duration, variability, statistical analysis and product, soil and other details

Trial 1 - Relative Efficiency of Phosphatic Fertilisers in Pasture Topdressing.V. On a Taupo Sandy Silt. Grigg, JL and Bimler, KH. Internal MAF Report 1982, 28pp.

This plot trial (Trial 1, Table 1) compared several different P fertilisers on Taupo sandy silt (pumice) soil. The pasture was ‘old and run-out’, and had received no fertiliser in the previous 3 years. Basal S was supplied as gypsum. The trial ran for 4 years from January 1967 to December 1970. The fertilisers were applied annually at 42 kg P/ha, which was assessed as sufficient to improve soil fertility over time. An additional treatment comprising a single application of 126 kg P/ha was also included (not reported on here).

The site was very responsive to P. Note that the treatment described as ‘superphosphate’ was actually a mix of pure water-soluble mono-calcium phosphate (MCP) and gypsum.

Summary of Pasture Dry Matter Results – Trial 1

	Period 1 *1/67-10/67*	*Period 2* *10/67-10/68*	*Period 3* *10/68-11/69*	*Period 4* *11/69-12/70*
Control (Gypsum)	3654 (100)	2828 (100)	5400 (100)	3766 (100)
Superphosphate (MCP/Gypsum)	4236 (116)	4560 (166)	8638 (160)	5923 (157)
Gafsa RPR + Gypsum	3950 (108)	3919 (139)	8647 (160)	5685 (151)
LSD 5%	412 (11)	456 (16)	697 (13)	638 (17)

Despite statistically significant differences between ‘SSP’ and RPR occurring at the 5% level in year 2 (‘Period 2) only, it seems reasonable to conclude from the data that there was a 2-year lag-phase (Periods 1 and 2 combined) with RPR. This is shorter than may have been expected; given the poor initial pasture quality (not resown).

Other data (not reported here) showed that Olsen P increased from 13 to 21 with ‘SSP’ over the trial, but to only 16 with RPR. Soil analysis confirmed that there was still considerable un-dissolved RPR (measured as Ca-P, which is not measured by the alkaline Olsen test) present at the conclusion of the trial.

Trials 2 and 3 - Alternative Phosphatic Fertilisers for Hill Country. Percival, NS, O’Connor, MB, Every, JP and Rajan, SSS 1984. Proceedings of the New Zealand Grassland Association 45: 107-115.

This publication reported on the results from a series of 5 plot trials conducted in the central North Island for 2 years from late 1980 until late 1982. Three of these trials were on pumice soil – one in the Gisborne area and 2 in the Rotorua area, but the authors reported on only one of these two, as ‘results were similar’.

The trials were designed primarily to establish whether a granulated 'biosuper' (finely ground RPR and elemental S granulated together as water-dispersible granules, laboratory-made by Dr Rajan) had a shorter lag-phase than 'as is' RPR. Therefore a trial duration of 2 years was considered adequate. The commercial superphosphate used contained 9.4% total P, but a mediocre 7.4% citric P and 6.0% water-soluble P. Basal applications of S, other nutrients and trace elements 'as appropriate' were made.

These two sites were considerably less responsive to P than Trial 1, probably as a result of higher initial fertility.

Summary of Pasture Dry Matter Results – Trials 2 and 3

	Trial 2 - Gisborne		*Trial 3 - Rotorua*	
Months Measured	0-5	Total 24	0-5	Total 24
Control (Nil P)	100	100	100	100
SSP	121	105	108	112
RPR/S Granules	114	105	104	107
RPR (as is)	110	107	101	110
SED*	2	4	2	5

* Standard error of the difference

Although PDMs for the first 5 months showed that (a) SSP was superior to both forms of RPR in the first 5 months, and (b) the RPR/S granules did reduce the size of the short-term lag-phase at both sites, over the full 2 years there were no differences between fertilisers, strongly suggesting a one-rear lag-phase only for 'as is' RPR (year 2 data was not reported individually).

While the performance of the RPR treatments relative to SSP is likely to have been helped by the rather mediocre quality of the SSP used, the results nevertheless strongly indicate that on these higher- P fertility sites, the lag-phase with RPR is unlikely to reach a full 2 years, even at a soil pH of 6.0 as in Trial 3.

Trial 4 - 'National Series' Site No. 8 (Waikite Valley). O'Connor, MB and Longhurst, R. 1988. MAF Internal Report (more detailed data reported in Smith et al. 1990).

Like all 'National Series' trials, this contained full response curves covering 0, 0.5, 0.75, 1.0 and 2.0 times the assessed maintenance P requirement for each site for both Sechura RPR and good-quality TSP (commercial imported triple superphosphate). Unlike most of the other National Series' trials however, it ran as a 'maintenance' trial for the first 3 years, after which only the TSP treatments were reapplied, unfortunately.

Note that because (a) the duration of the trial was only 3 years, (b) it was the only site on a pumice soil in the Series, and (c) the site had a higher soil P retention (62%) than most pumice soils, Quin & Zaman (2012) included the 3 years data into the 'Central North Island and Taranaki higher P retention' group.

Summary of Pasture Dry Matter Results – Trial 4
Note – Fertiliser PDMs averaged over all rates of P

	Year 1 (82/83)	*Year 2 (83/84)*	*Year 3 (84/85)*
Control	7465 (100)	10935 (100)	8963 (100)
TSP	8266 (111)	12173 (110)	9693 (108)
RPR	7764 (103)	11773 (108)	9667 (108)
SED*	522 (7)	372 (3)	226 (2)

* Standard error of the difference

Again, the results show a maximum lag-phase of 2 years. The difference even in Year 2 is not statistically significant – RPR may have been helped by the low initial pH (5.1) and higher Olsen P (still only 24) at this site. The results are noteworthy given the relatively high P retention for a pumice soil (62).

Trials 5 and 6 - Reactive Rock Phosphate on Gisborne Hill Country. Korte, CJ., MAF Advisory Division. A Report Compiled for Northern Phosphate Company, March 1988.

Two separate short-term (9 months duration) trials were conducted from March-September 1987 to compare SSP with North Carolina RPR and a phosphoric PAPR. Basal S as gypsum and other nutrients were applied. The fertiliser treatments were applied twice; once 6 months before the trial measurements began, and again 6 weeks before its conclusion. The technique of moving cages (after each cut) on grazed pasture was used, allowing animal excreta and treading effects to be incorporated, at the cost of some increase in variability in pasture growth. Trial 5 included a range of P rates, but only a single nil-P control plot; Trial 6 had replicated single-rate plots of P (15 kg P/ha), and a single nil-P control plot.

The trial sites had P retentions of 56 and a high (for pumice) 73 respectively, and very low Olsen P levels of 7 and 9. The pastures not surprisingly were of low-quality, dominated by Yorkshire fog, browntop and sweet vernal, although Trial 6 had a surprising amount of clover present.

Because of pasture variability and the nil-P control not being replicated, control yields were not reported. The commercial SSP used was described as being of poor quality, but the chemical analysis was not reported.

Summary of PDM results – Trials 5 and 6

	*Trial 5**	*Trial 6*
SSP	4028 (100)	4508 (100)
Commercial PAPR	3975 (99)	5986 (133)
RPR	4200 (104)	5767 (128)
SED**	262 (6)	640 (14)

* average of 7.5, 15 and 30 kg P/ha treatments; ** Standard error of the difference

There were no significant differences between the forms of P in Trial 5. The control yield was not reported, but was less than the 3686 kg PDM achieved with 7.5 kg P/ha. In the much more P-responsive Trial 6, both RPR and PAPR considerably outperformed commercial SSP. The report's author stated that the actual relative PDM with RPR in both trials (taking PAPR as the yardstick in Trial 6 because of the poor performance of SSP), was 8-10% higher than predicted by the Perrott & Metherell (1997) predictive model.

The short duration of these trials did not interfere with the conclusion that, under moving plot grazed pasture conditions, there was no lag-phase with RPR.

Trial 7 - Results from Forms of Phosphate Trial, Motu, 1990-1996 (conducted by AgResearch Ltd). A farmer field-day handout produced by Ravensdown Fertiliser Co-operative Limited in 1998 (3pp).

This trial, one of a 'Mini-Series' conducted to cover the East Coast of the North Island, compared the performance of SSP (year 1), then S-SSP (year 2 onwards) with an RPR elemental S mix over 6 years..

Please note that (a) the rainfall range is stated in the handout to have been in the range 2000-2200 mm/yr over the trial, whereas the graphed rainfall data supplied indicated a range of 1750-2600mm, (b) the PDM yield for RPR/S is given as 40735 kg PDM/ha, whereas the individual years add to a slightly lower 40560 kg PDM/ha, (c) the site had a very low initial Olsen P of 7, which increased to 21 with SSP and 17 with RPR/S at the end of the trial, (d) the citric solubility of the SSP and S-SSP used in the trial is not reported, but would have been high at this time.

The PDM data supplied is repeated in the following table. The trial suffered from high variability to start with, probably because of the poor pasture and very high P-responsiveness (P responses were statistically significant in all except Year 1).

Summary of PDM results – Trial 7

	1990/91	*1991/92*	*1992/93*	*1993/94*	*1994/95*	*1995/96*	*Total*
Control	4875b (100)	2305c (100)	3460c (100)	4365b (100)	5710b (100)	6665b (100)	27380b (100)
SSP/S-SSP	5790a (119)	5520a (239)	6760b (195)	6300a (144)	7230a (127)	8395a (126)	39995a (146)
RPR/S	5565ab (114)	4520b (196)	7395a (214)	6710a (154)	7460a (131)	8910a (134)	40560a (148)
LSD 5%	885 (18)	675 (29)	650 (19)	505 (12)	530 (9)	585 (9)	2075 (8)

The report reasonably suggests, although without any supporting herbage S data, that the straight SSP used in the high-rainfall Year 1 might have limited PDM as a result of leaching of the sulphate-S in this year, and the presence of a browntop mat. 'Maxi sulphur super' (SSP fortified with elemental S) was used in subsequent years. Regardless, the report correctly concludes that 'From the third year, RPR/elemental S mixes performed *at least as well* as super/elemental sulphur mixes'. In other words, a maximum 2-year lag phase.

P response frequency distribution curves

The combined data from the trials, excluding Trials 5 and 6 for which the nil-P control data was not reported, was used to prepare P response frequency distribution curves, as reported for all trials of the RPR *vs* SSP 'National Series' of trials by Quin & Zaman (2012). The results for RPR and SSP are presented for Years 1 and 2 (Fig 1a) and Years 3 onwards (Fig 1b). The graphs demonstrate a substantial median P response difference of 7% between SSP and RPR in the first 2 years, and a (non-significant) median higher yield of 2% for RPR in years 3 onwards. The greater difference between SSP and RPR in the first two years compared to other low-medium P retention soils (Quin & Zaman 2012) reflects the typically higher P responsiveness of pumice soils, especially at low soil Olsen P levels.

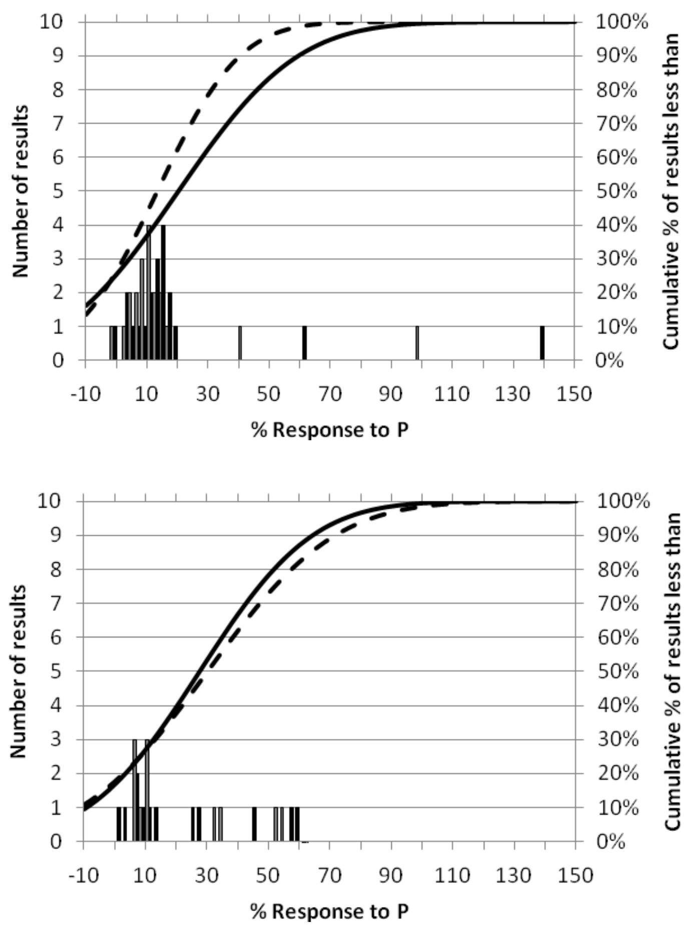

Figure 1 (a, b). Frequency distribution (2% group classes) of % response to P from soluble P fertiliser (black columns) and RPR (gray columns) trials on pumice soils, with normal cumulative distribution curves (based on population mean and standard deviations), solid line = Sol P and dashed line = RPR; (a) Years 1 and 2, (b) Years 3 onwards.

Conclusions

The results of the 7 individual trials, and the frequency distribution of the combined data from the 5 of these trials which included multiple nil P control plots, clearly demonstrate that on pumice soils with a wide range of P retention, rainfall and initial pH, very low to maintenance initial Olsen P levels, and very poor to good initial pasture, RPR mixed with adequate elemental S equals the performance of high-quality soluble P by the third year of its use.

The greater size of the difference in P response between SSP and RPR in the first 2 years compared to that typically seen on other soils reflects the typically high P responsiveness of pumice soils, especially at low soil fertility. This in turn suggests that the initial use of appropriate RPR/soluble P sources is more likely to be the most cost-effective strategy for farmers wishing to realize the benefits of the much lower P run-off losses that result from switching from superphosphate to RPR as their P input.

Acknowledgement

The authors thank Dr Peter Bishop of Bishop Research Ltd for his preparation of the P response frequency distribution curves.

References

Grigg, J.L. and Bimler, K.H. (1982). Relative efficiency of phosphatic fertilisers in pasture topdressing. V. On a Taupo sandy silt. *Internal Report, MAF Agricultural Research Division,* 28pp.

Korte, C.J. (1988). Reactive rock phosphate on Gisborne hill country. *MAF Advisory Division; a Report compiled for Northern Phosphate Company,* March 1988, 8pp.

Percival, N.S. O'Connor, M.B. Every, J.P. and Rajan, S.S.S. (1984). Alternative phosphatic fertilisers for hill country. *Proceedings of the New Zealand Grassland Association 45*: 107-115.

Perrott, K.W. and Metherell, A.K. (1997). Incorporation of reactive phosphate rock into a phosphorus fertiliser decision support model for grazed pasture. *Proceedings Dahlia Greidlinger International Symposium on Fertilization and the Environment,* 133-146.

Quin, B.F. and Zaman, M. (2012). RPR revisited (1): Research, recommendations, promotion and use in New Zealand. *Proceedings of the New Zealand Grassland Association 74*: 255-268.

Ravensdown Fertiliser Co-operative Ltd (1998). Results from forms of phosphate trial, Motu, 1990-1996, conducted by AgReasearch Ltd. *A field-day handout produced by Ravensdown Fertiliser Co-operative Ltd, 3pp.*

Smith, L.C. Johnstone, P.D. Sinclair, A.G. Shannon, P.W. O'Connor, M.B. Percival, N. Roberts, A.H. Smith, R.G. Mansell, G. Morton, J.D. Nguyen, L. Dyson, C.B. Risk, W.H. (1990). Final report on the MAF 'National Series' forms of phosphate fertiliser trials. Part1: Description of the trials and annual herbage dry matter production. *MAF, Wellington, New Zealand.* December 1990, 87pp.

Zaman, M. and Quin, B.F. (2012). RPR revisited (2): Long-term farmer experience helps define the role of RPR in grazed pastures. *Proceedings of the New Zealand Grassland Association* 45:269-275.