Winchmore long-term fertiliser trial: 2017-2018 annual update

Chris Smith, Ray Moss

June 2018

Report for the Fertiliser Association of New Zealand

CLIENT REPORT NUMBER: RE450/2018/042

agresearch
āta mātai, mātai whetū

Contents

1. Executive Summary

The long-term fertiliser trial at Winchmore, mid-Canterbury, New Zealand was set up in 1952 and has yielded a wealth of biophysical data on the effect of phosphate fertiliser on pasture production while under border-dyke irrigation and sheep grazing. Currently however, the trial is in a transition stage as it is converted from border-dyke irrigation to overhead irrigation by means of a centre pivot. While the method of water application may be changing, the control (No P), 188 and 375 kg superphosphate (SSP) ha^{-1} treatments have been in place and measured for >65 years while the 250 kg SSP ha^{-1} and equivalent reactive phosphate rock (RPR) treatments have been in place for nearly 40 years. In the 2017 – 2018 season pasture production was assessed eight times, using the rate of growth technique with movable pasture cages. Annual pasture production on the fertilised plots for 2017 - 2018 averaged 12.3 t ha^{-1}, similar to the 10 year average of 12.5 t ha^{-1}. Production for the No P treatment was significantly less at 6.3 t DM ha^{-1}. Over the spring period the 250 and 375 kg SSP ha^{-1} treatments produced significantly (P=0.023) more than the 175 kg SSP ha^{-1} treatment. The clover content of the pasture was badly affected by the drier than normal spring and late scheduling of irrigation due to the transition of irrigation type. This year 99% of maximum pasture production was achieved at an Olsen P of 20 µg ml^{-1}. The soil S concentrations were initially above optimum for the fertiliser treatments only, but declined through the season to be below optimum levels by May 2018. The pH levels, with the exception of the No P plots, have been below 5.8 for most of the last 20 years, therefore the application of a small amount of lime with the intention of lifting pH to 5.9 - 6.0 could be considered.

2. Background

The Winchmore long-term fertiliser trial under border-dyke irrigation commenced in 1952. Treatments applied annually since then include 0, 188, 250 and 375 kg ha^{-1} of single superphosphate (SSP). Since 1980, there has also been a Sechura reactive rock phosphate (RPR)/elemental Sulphur (S) treatment applied annually at a phosphorus (P) rate equivalent to 250 kg SSP ha^{-1}. Fertiliser is applied in late winter or early spring each year. Currently, however, the trial area is in a transition stage as it is converted from border-dyke irrigation to overhead irrigation by means of a centre pivot.

This trial has been used extensively by many researchers over the years from a range of organisations for a wide variety of studies, including soil carbon (C), nitrogen (N), P, potassium (K) and sulphur (S) chemistry, nutrient cycling, organic matter, effects on earthworm populations as well as DDT, cadmium (Cd) and fluorine (F) residue research. It has resulted in numerous scientific publications and has been used in the development and validation of several models including OVERSEER® and Farmax. The trial was highlighted in a special Winchmore edition of the New Zealand Journal of Agricultural Research in 2012 (Smith et al. 2012).

This report details and summarises the results from the soil and pasture monitoring programme over the 2017 – 2018 growing season.

3. Methods

Large plots (0.09 ha), replicated four times, are grazed by separate mobs of sheep that rotate between the replicates during the September-May growing season. Stocking rates are set to ensure 80% pasture utilisation for each treatment (Rickard & Moss 2012).

Pasture production is measured by the rate of growth technique using movable pasture exclusion cages (Radcliffe 1974) with approximately 6 - 8 cuts per year. Soil samples are collected seasonally and after laboratory analysis are archived for future studies. Seasonal botanical composition of grass, clover and weeds is also tracked (Lynch 1966).

All treatments received their fertiliser treatments in August 2016. This was applied by drill with down tubes removed. To avoid the risk of applying too much fertiliser, the drill was calibrated to apply less than required and the deficiency applied by hand. The RPR/S treatment was all applied by hand with the S sieved through a 2 mm screen. The phosphate rock used for the 2017-2018 season is from a source supplied by Ravensdown

and contained 13% total P, 3.7% citric soluble P, 7.3% formic soluble P, 33.5% calcium and a maximum of 60 mg Cd kg^{-1} P. The product is referred to as direct application RPR (DAPR) and was applied at the same rate as in the past, which equates to an application rate of 22.9 kg P ha^{-1}. The plot area on which fertilizer was applied included the full length and width of the plot to within 400 mm of fences. Samples of the fertiliser applied (SSP and RPR/S) were retained.

4. Results and Discussion

4.1 Pasture production

Unfortunately, with the transition from border strip to an over-head system of irrigation there was a delay in water application in late spring which was one of the driest springs on record. This, unsurprisingly, adversely affected dry-matter production and species composition, especially clover production. Despite this, annual pasture production for the 2017 - 2018 year was higher than the last three years reaching 12.7 t DM ha^{-1} for the 250 kg SSP ha^{-1} treatment (Figure 1; Table 1). The fertiliser treatments overall averaged 12.3 t DM ha^{-1}, which was similar to the 10 year average of 12.5 t DM ha^{-1} with applied fertiliser. The No P treatment produced 6.3 t DM ha^{-1} which is the same as the 10 year average for this treatment. The application of fertiliser significantly increased pasture production ($P<0.001$; Table 1). There was a significant fertiliser effect over the spring with the 250 and 375 kg SSP ha^{-1} treatments producing more than the 175 kg SSP ha^{-1} treatment ($P=0.023$; Table 1). There was however, no significant fertiliser effect in total annual production ($P=0.058$; Table 1). The spring fertiliser effect occurred in early spring (Figure 2) before production was affected by the dry season and delayed irrigation.

Table 1. Seasonal and annual pasture production from the irrigated Winchmore long-term fertiliser trial for 2017-2018 (t DM ha^{-1}). The least significant difference ($LSD_{0.05}$) at the $P<0.05$ level is given along with the *F*-statistic for comparison of treatment means (bold if significant).

Treatment	Winter	Spring	Summer	Autumn	Total
No P	0.62	1.91	2.09	1.65	6.27
188 kg SSP ha^{-1}	1.33	4.09	3.95	2.37	11.73
250 kg SSP ha^{-1}	1.46	4.53	4.19	2.51	12.69
175 kg RPR ha^{-1}	1.59	4.37	3.69	2.55	12.20
375 kg SSP ha^{-1}	1.45	4.51	4.00	2.61	12.58
All LSD $_{0.05}$	0.41	0.46	0.61	0.36	0.99
All F-Statistic	**0.002**	**<0.001**	**<0.001**	**<0.001**	**<0.001**
Ex. No P LSD $_{0.05}$	0.34	0.28	0.66	375	0.72
Ex. No P F-Statistic	0.411	**0.023**	0.444	0.539	0.058

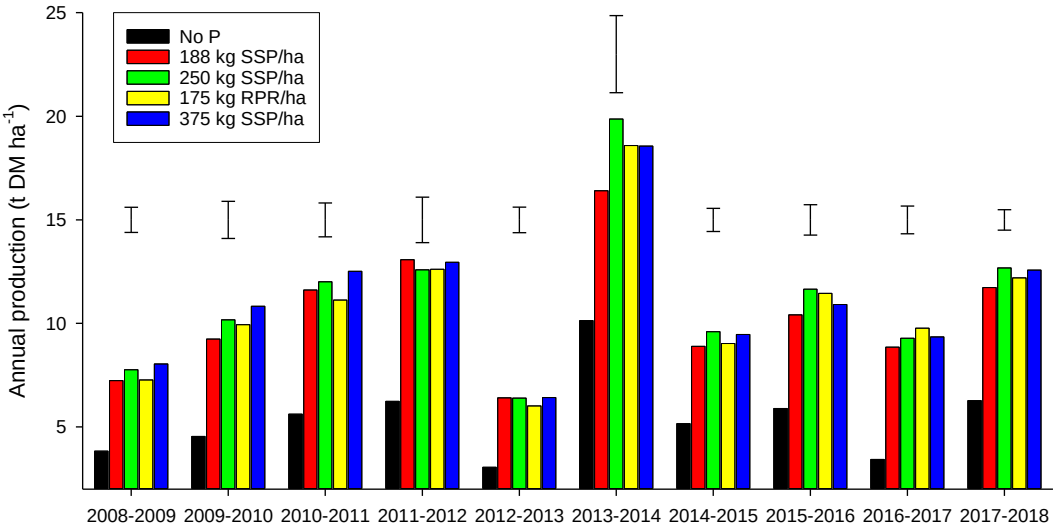

Figure 1. Annual pasture production over 10 years for the long-term irrigated fertiliser trial at Winchmore (t DM ha^{-1}). Bars indicate LSD (P<0.05)

The daily pasture growth curve shows a steady increase in the spring followed by a sharp drop in early December before peaking again in January (Figure 2). This drop was predominantly a result of the change from border strip to an over-head system of irrigation delaying the scheduled irrigation application. Autumn daily growth was generally similar to previous years. The second harvest, which occurred in late September, saw the 118 kg SSP treatment producing significantly less (P<0.001) than the other rates and forms of P fertilisers.

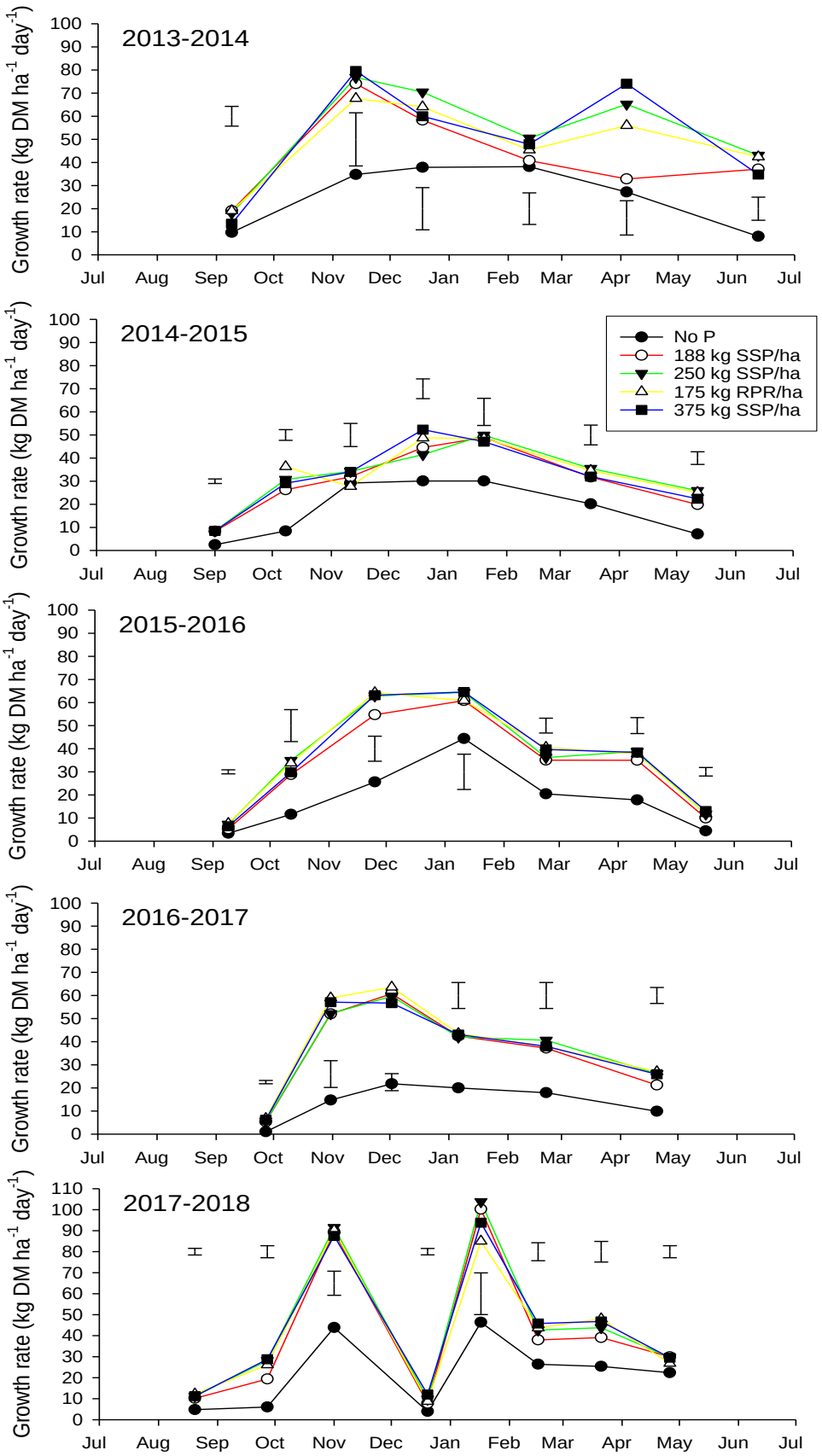

Figure 2. Daily pasture growth over 5 years for the long-term irrigated fertiliser trial at Winchmore (kg DM ha^{-1} day^{-1}) Bars indicate LSD ($P<0.05$). NB the growth rate shown is the daily growth rate from the previous measurement to the date shown in the graphs.

4.2 Species composition

Pastures were grass dominant over the summer-autumn period with significantly more grass where fertiliser had been applied (Table 2). The lack of clover over the summer and autumn months is a result of the dry spring, one of the driest on record, coupled with the delayed irrigation resulting from the change-over in irrigation systems.

Table 2: Seasonal and treatment effects of pasture species fractions from Winchmore long-term irrigated fertiliser trial for 2017-2018 (% species present). The least significant difference ($LSD_{0.05}$) at the $P<0.05$ level is given along with the *F*-statistic for comparison of treatment means (bold if significant). ND means data not able to be analysed statistically.

	28 August 2017			1 November 2017		
	Grass	Clover	Weeds	Grass	Clover	Weeds
No P	100	0.0	0.0	77	6	16
188 kg SSP ha^{-1}	100	0.0	0.4	94	4	2
250 kg SSP ha^{-1}	100	0.0	0.0	91	6	3
175 kg RPR ha^{-1}	99	0.1	0.5	94	4	2
375 kg SSP ha^{-1}	99	0.0	0.6	96	3	2
$LSD_{0.05}$	0.7	0.2	0.7	8	6	6
F-Statistic	0.229	0.445	0.297	**0.002**	0.709	**0.001**

	16 February 2018			28 April 2018		
	Grass	Clover	Weeds	Grass	Clover	Weeds
No P	87	1.3	12	99	0.1	0.6
188 kg SSP ha^{-1}	95	0.3	5	100	0.0	0.1
250 kg SSP ha^{-1}	89	0.3	10	100	0.0	0.1
175 kg RPR ha^{-1}	99	0.0	1	100	0.0	0.1
375 kg SSP ha^{-1}	95	0.0	5	100	0.0	0.1
$LSD_{0.05}$	9	0.9	9	0.2	0.2	ND
F-Statistic	0.068	0.062	0.108	**<0.001**	0.445	ND

4.3 Soil Analysis

Results of the soil sampling completed prior to fertiliser application (July 2017) and in November 2017, January and May 2018 are presented in Table 3. Plots receiving P fertiliser application had lower pH, higher calcium (Ca), Olsen P and sulphate sulphur (SO_4-S), than the No P plots in July 2017. These trends for Olsen P and SO_4-S were also apparent in November, January and May, though the high variability in the SO_4-S resulted in a lack of significant differences in November and January. There was a fertiliser rate effect with Olsen P with 375 SSP > 250 SSP = 175 RPR = 188 SSP. The Olsen P concentration for the 375 kg SSP ha^{-1} treatment in July 2017 was lower than that measured in winter 2015, but similar to that measured in 2006-2007 (Figure 3).

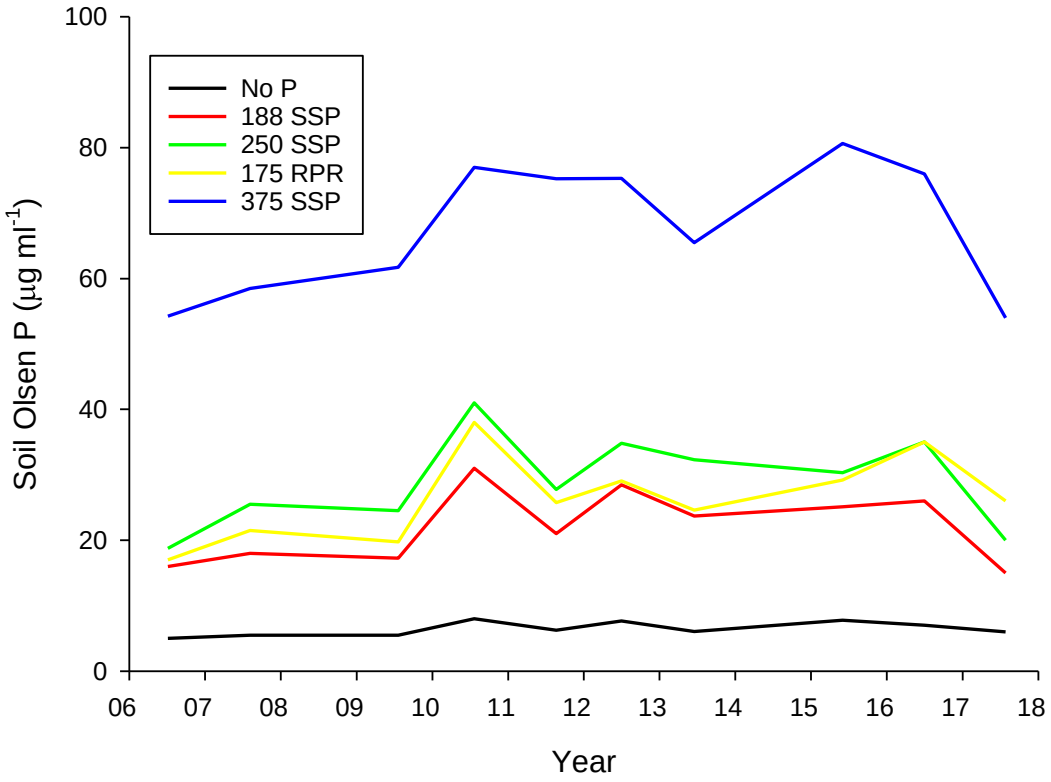

Figure 3. Soil Olsen P (0-75mm depth) measured in winter each year from the long-term irrigated fertiliser trial at Winchmore

The soil S concentrations for all fertiliser treatments were above optimum (10-12 ppm; Morton & Roberts 2009) in November 2017 and in January 2018 for all except the 188 kg SSP treatment, but consistently below optimum for the No P treatment. Concentrations had dropped considerably by May 2018 to be below optimum for all SSP treatments.

Table 3. Soil test results from the Winchmore long-term irrigated fertiliser trial for the 2017-2018 year. The least significant difference (LSD_{05}) at the *P*<0.05 level is given along with the *F*-statistic for comparison of treatment means (bold if significant).

Treatment	pH	Ca	P	K	Mg	Na	SO_4-S
July 2017							
No P	5.97	7	6	14	20	3	5
188 kg SSP ha^{-1}	5.70	8	15	11	17	4	6
250 kg SSP ha^{-1}	5.66	9	20	9	16	4	7
175 kg RPR ha^{-1}	5.66	10	26	10	20	4	11
375 kg SSP ha^{-1}	5.74	10	54	9	17	4	7
$LSD_{0.05}$	0.16	1	5	5	2	1	2
F-Statistic	**0.005**	**<0.001**	**<0.001**	0.142	**0.016**	0.234	**0.001**
November 2017							
No P			7				4
188 kg SSP ha^{-1}			23				29
250 kg SSP ha^{-1}			32				34
175 kg RPR ha^{-1}			27				12
375 kg SSP ha^{-1}			69				36
$LSD_{0.05}$			9				27
F-Statistic			**<0.001**				0.085
January 2018							
No P			8				4
188 kg SSP ha^{-1}			27				7
250 kg SSP ha^{-1}			35				12
175 kg RPR ha^{-1}			29				87
375 kg SSP ha^{-1}			70				14
$LSD_{0.05}$			10				10
F-Statistic			**<0.001**				0.255
May 2018							
No P			8				5
188 kg SSP ha^{-1}			25				7
250 kg SSP ha^{-1}			35				6
175 kg RPR ha^{-1}			32				11
375 kg SSP ha^{-1}			69				7
$LSD_{0.05}$			6				1
F-Statistic			**<0.001**				**<0.001**

Despite no lime application since 1975 the soil pH has remained, with the exception of 2007, 2010 and 2016, between 5.7 and 5.9 for the last 25 years (Figure 4). Whereas fertiliser application resulted in a significant drop in pH in July 2016, to levels previously noted in 2007 and 2010, it lifted again in the 2017 sampling. The reasons for the drops in pH in 2007, 2010 and now 2016, are unknown as normally changes in soil pH are small and predictable. As the pH levels, with the exception of the No P plots, have been

consistently below 5.8 for the last 20 years the application of a small amount of lime with the intention of lifting pH to 5.9 - 6.0 could be considered.

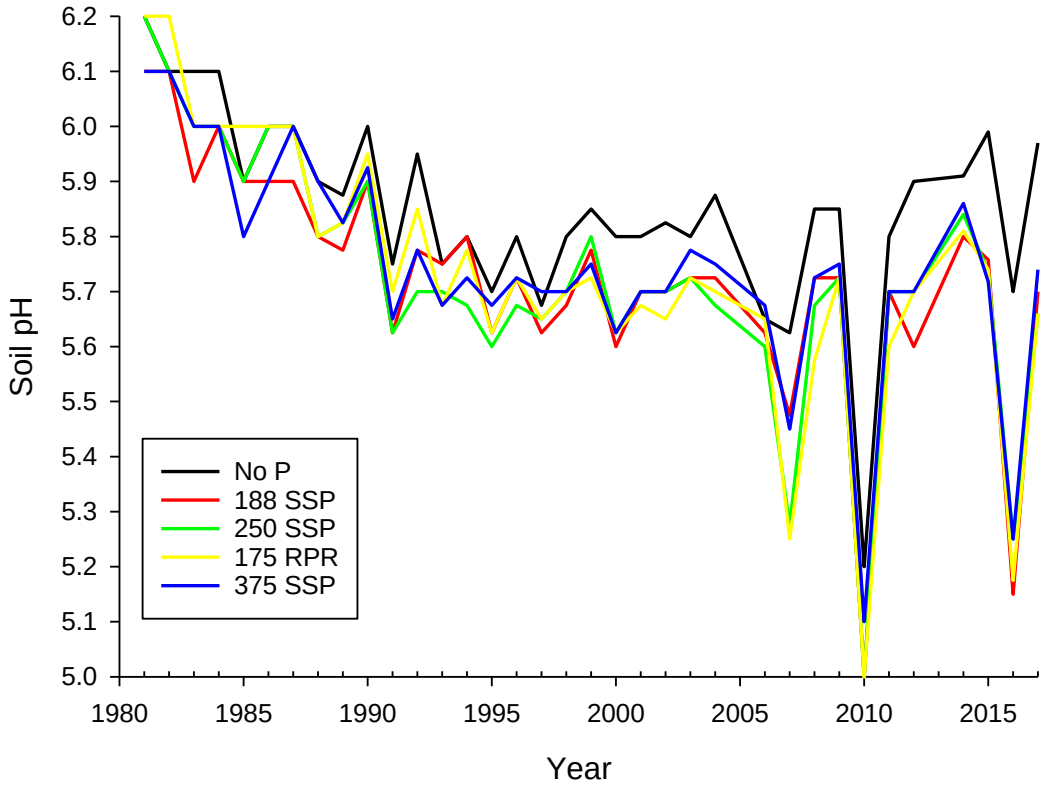

Figure 4. Soil pH (0-75mm depth) measured in winter each year from the long-term irrigated fertiliser trial at Winchmore

5. Response curves

Using the methodology of Sinclair et al. (1997), it was possible to use data from 24 of the 37 years over the 1981 to 2018 period to obtain a long term response curve between Olsen P and relative pasture yields. The relative yields from this year's production are on or above this long term response curve (Figure 5) for all the SSP treatments. The 97% relative production from the long term response curve is obtained at an Olsen P concentration of 20 µg ml^{-1}, whereas the measured response this year at an Olsen P of 20 µg ml^{-1} was 99%.

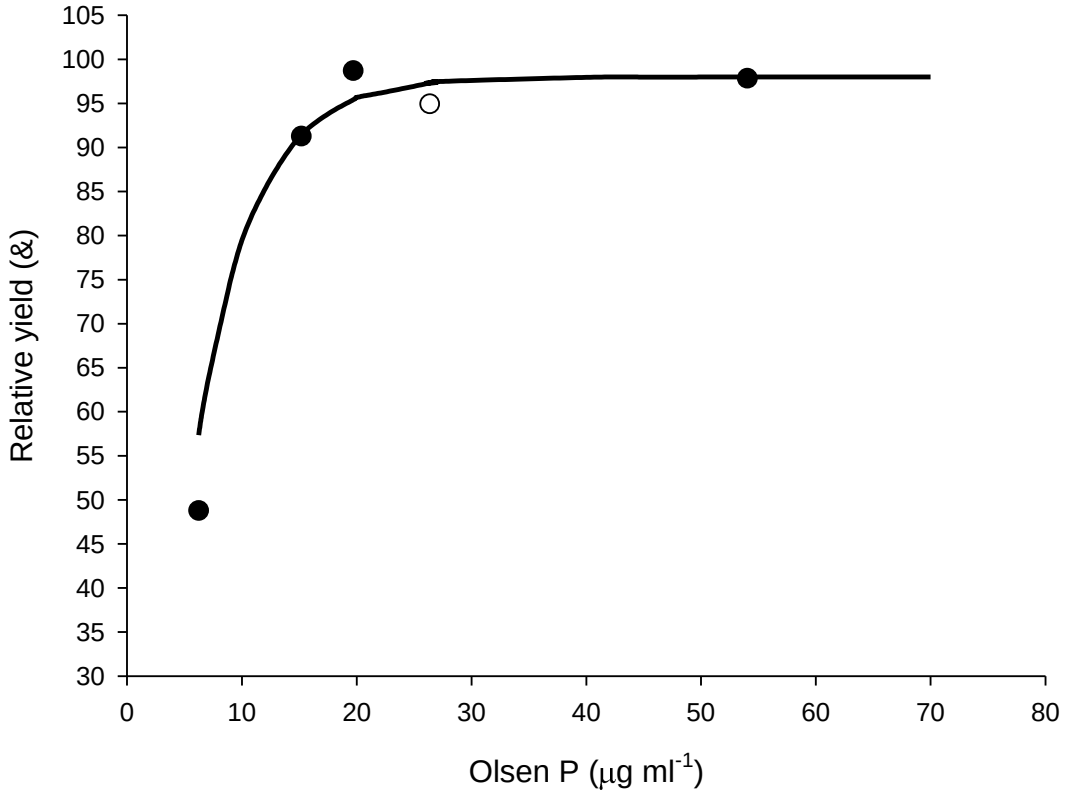

Figure 5. Relative yields for 2016-2017 production plotted with long term (1980-2015) response curve (solid line). ● Indicates relative yields for No P and SSP treatments; ○ indicates RPR relative yield.

6. Acknowledgements

We would like to acknowledge Lincoln Lloyd (farm manager) for his assistance with the day to day running of the trial, and the fertiliser industry for their continued funding of this trial.

7. References

Lynch PB, 1966. Conduct of field experiments. New Zealand Department of Agriculture Bulletin 339. 154pp.

Morton JD, Roberts AHC, 2009. Fertiliser use on New Zealand sheep and beef farms. Auckland, New Zealand, New Zealand Fertiliser Manufacturer's Research Association. 40p.

Radcliffe J E. 1974. Seasonal distribution of pasture production in New Zealand I. Methods of measurement. New Zealand Journal of Experimental Agriculture 2: 337-340.

Rickard DS, Moss RA. 2012. Winchmore and the long-term trials: the early history. New Zealand Journal of Agricultural Research 55; 93-104.

Sinclair AG, Johnstone PD, Smith LC, Roberts AHC, O'Connor MB, Morton JD, 1997. Relationship between pasture dry matter yield and soil Olsen P from a series of long-term field trials. New Zealand Journal of Agricultural Research; 40: 559-567.

Smith LC, Moss RA, Morton JD, Metherell A, Fraser T, 2012. Pasture production from a long-term fertiliser trial under irrigation. New Zealand Journal of Agricultural Research 55; 105-118.