Winchmore long-term fertiliser trial: 2018-2019 annual update

Chris Smith, Ray Moss

June 2019

Report for the Fertiliser Association of New Zealand

CLIENT REPORT NUMBER: RE450/2019/035

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 application on pasture production while under border-dyke irrigation and sheep grazing. The trial area has recently been converted from border-dyke irrigation to overhead irrigation by means of a centre pivot. While the method of water application may have changed, 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. Pasture production over the season to April 2019 was assessed eight times, using the rate of growth technique with movable pasture cages. Production on the fertilised plots averaged 11.6 t DM ha^{-1} for this period, which was slightly below the long-term annual average of 12.0 t DM ha^{-1}. Production for the No P treatment was significantly less at 7.3 t DM ha^{-1}. The re-fencing needed for the centre-pivot irrigation prevented normal grazing management; plots were left un-grazed from late March 2018 until September 2018. This resulted in a visible increase in cocksfoot growth and decrease in clover growth. Soil pH, with the exception of the No P plots, has been below 5.8 for most of the last 20 years and was 5.6 this year. The application of a small amount of lime with the intention of lifting pH to 5.9 - 6.0 should 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. Recently the trial area has been 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 2018 – 2019 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 September 2018. The fertiliser was applied relatively late that year to ensure plots were appropriately hard-grazed prior to fertiliser application. The was warranted due to the re-fencing for the centre-pivot irrigation preventing normal grazing management such that plots were un-grazed from late March 2018 until September 2018

As per previous years, fertiliser was applied by drill with the 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 applications were all applied by hand with the S sieved through a 2 mm screen. The phosphate rock used for the 2018-2019 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 fertiliser 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.

A total of 375 mm of irrigation water was supplied to the trial site by centre pivot, with the first application occurring in late September 2018. Initially applications were somewhat sporadic and applied 15-20 mm of water per application (Figure 1). Applications became more regular in 2019 with 10 mm of water applied approximately every 3-5 days until mid-March. This resulted in a total of 25 irrigation events, more than double the 8 - 10 flood irrigation events that was typical under the previous border dyke system.

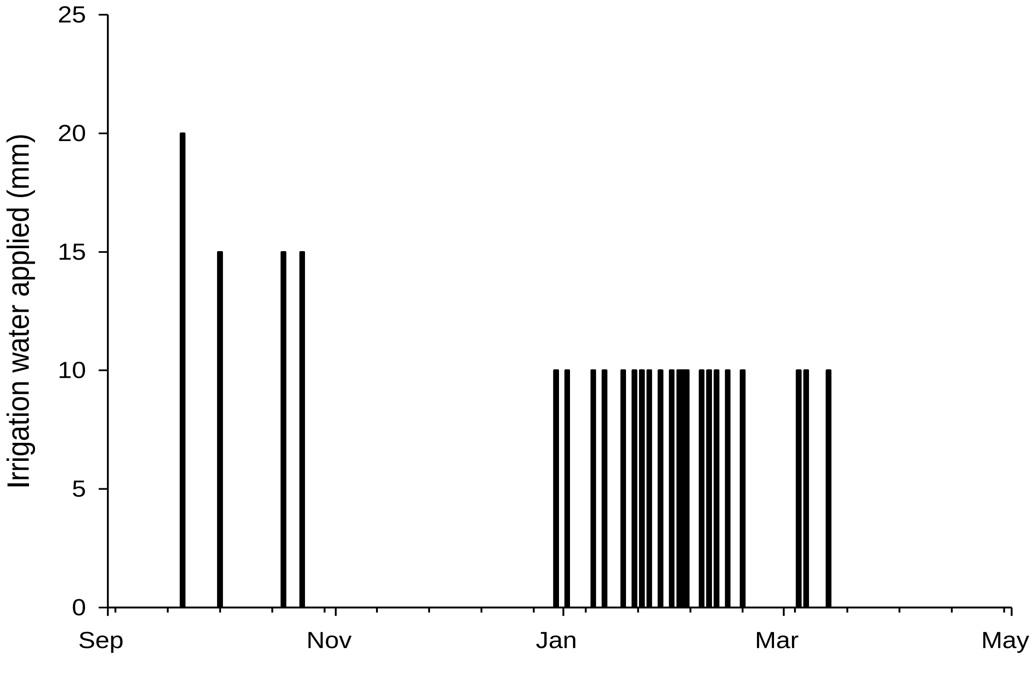

Figure 1. Volumes of irrigation water applied to Winchmore long term fertiliser trial.

4. Results and Discussion

4.1 Pasture production

With the trial being re-fenced as part of the transition to over-head irrigation, there was no grazing possible from March 2018 to September 2018. This had a noticeable effect on pasture composition with a visible increase in cocksfoot (*Dactylis glomerata L*) and a decrease in clover (*Trifolium repens*). Despite this, annual pasture production for the 2018 - 2019 season was similar to that produced in 2017-2018 (Table 1; Figure 2). The fertiliser treatments overall averaged 11.6 t DM ha^{-1}, which was slightly below the long-term average of 12.0 t DM ha^{-1} with applied fertiliser. The No P treatment produced 7.3 t DM ha^{-1} which is above the long-term average of 5.4 t DM ha^{-1} for this treatment. The application of fertiliser significantly increased pasture production (P<0.001; Table 1). There was also a significant fertiliser effect on total annual production (P=0.032; Table 1) with the 375 SSP treatment being significantly greater than the 175 RPR and 188 SSP treatments.

Table 1. Seasonal and annual pasture production from the irrigated Winchmore long-term fertiliser trial for 2018-2019 (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). Note the Ex. No P comparison covers the applied fertiliser treatments only.

Treatment	Kg P ha^{-1} year^{-1}	Winter	Spring	Summer	Autumn	Total
No P	0	188	2382	3118	1607	7295
188 kg SSP ha^{-1}	17	459	4096	4074	2340	10969
250 kg SSP ha^{-1}	23	486	4300	4363	2665	11814
175 kg RPR ha^{-1}	23	532	3911	4064	2537	11043
375 kg SSP ha^{-1}	34	502	4087	4978	2970	12537
All $LSD_{0.05}$		87	652	9174	506	1365
All F-Statistic		**<0.001**	**<0.001**	**0.012**	**<0.001**	**<0.001**
Ex. No P $LSD_{0.05}$		80	360	906	584	1100
Ex. No P F-Statistic		0.281	0.183	0.147	0.170	**0.032**

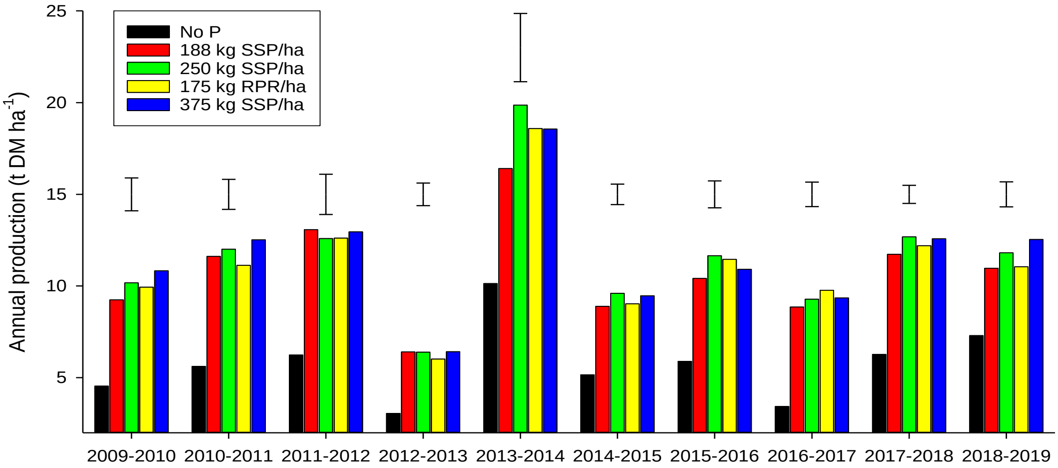

Figure 2. Annual pasture production over 10 years for the long-term irrigated fertiliser trial at Winchmore (t DM ha^{-1}). Bars indicate LSD (P<0.05)

The pasture production with applied fertiliser peaked in early December whereas without P fertiliser production did not peak until late December (Figure 3). There was a slight drop in production over the summer months, before a slight rise in production for the 250 and 375 kg SSP treatments in March and April. The March increase in production was significant for the 375 kg SSP treatment compared with the 188 kg SSP and 175 kg RPR treatments. For the June harvest the 188 kg SSP treatment grew significantly less that the other three P fertiliser treatments.

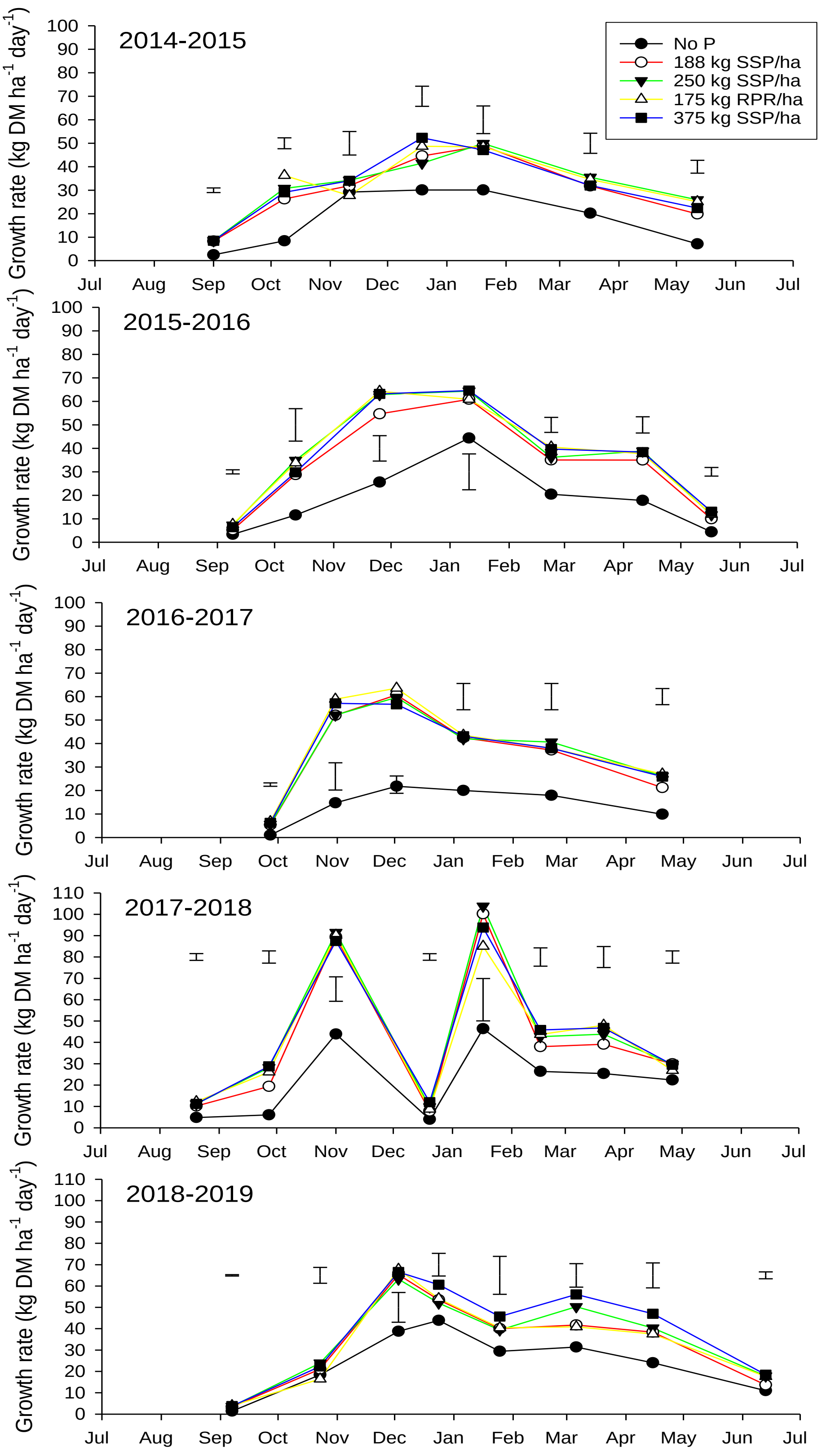

Figure 3. Daily pasture growth over 5 years for the long-term irrigated fertiliser trial at Winchmore (kg DM ha^{-1} day^{-1}) Bars indicate LSD (P<0.05). NB the growth rate shown is the daily growth rate from the previous measurement to the date shown in the graphs.

4.2 Species composition

Pastures were grass-dominant over the whole season as a result of the visible increase in Cocksfoot. The lack of clover is thought to be a result of the lack of grazing over the March to September 2018 period. There were significantly fewer weeds where fertiliser had been applied.

Table 2: Seasonal and treatment effects on pasture species fractions from the Winchmore long-term irrigated fertiliser trial for 2018-2019 (% 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).

	23 October 2018			3 December 2018		
	Grass	Clover	Weeds	Grass	Clover	Weeds
No P	93	0.3	6.4	85	1.0	14.1
188 kg SSP ha^{-1}	98	1.5	0.5	93	2.2	4.8
250 kg SSP ha^{-1}	98	0.8	1.0	91	4.7	4.9
175 kg RPR ha^{-1}	99	0.4	1.0	90	4.6	5.9
375 kg SSP ha^{-1}	99	0.6	0.8	96	2.2	1.8
$LSD_{0.05}$	4	2.1	3.2	9	3.2	7.2
F-Statistic	0.062	0.740	**0.007**	0.156	0.107	**0.031**

	5 March 2019		
	Grass	Clover	Weeds
No P	98	0.8	0.8
188 kg SSP ha^{-1}	99	0.4	0.3
250 kg SSP ha^{-1}	99	0.3	0.5
175 kg RPR ha^{-1}	99	0.3	0.1
375 kg SSP ha^{-1}	99	0.1	0.4
$LSD_{0.05}$	1	0.6	0.6
F-Statistic	0.160	0.156	0.312

4.3 Soil Analysis

The results of the soil samplings completed prior to fertiliser application (September 2018) and in November 2018, February and May 2019 are presented in Table 3. Plots receiving P fertiliser application had higher calcium (Ca), Olsen P and sulphate sulphur (SO_4-S), than the No P plots in September 2018. These trends for Olsen P and SO_4-S contents were also apparent in November with the trend continuing for Olsen P in both the February and May 2019 samplings. There was no fertiliser rate effect with Olsen P at the September sampling but there were significant differences at the November, February and May ones, with Olsen P for the 375 SSP treatment being significantly higher and the 188 SSP being significantly lower. The Olsen P concentration for the 375 kg SSP ha^{-1} treatment in

September 2018 was lower than that measured in winter 2015, but similar to that measured in 2017 and 2006-2007 (Figure 4).

Table 3. Soil test results from the Winchmore long-term irrigated fertiliser trial for the 2017-2018 season. 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	pH	Ca (QT units)	P (µg ml^{-1})	K (QT units)	Mg (QT units)	Na (QT units)	SO_4-S (mg L^{-1})
September 2018							
No P	5.7	8	8	11	21	5	6
188 kg SSP ha^{-1}	5.7	10	24	9	21	5	13
250 kg SSP ha^{-1}	5.6	10	34	7	19	5	14
175 kg RPR ha^{-1}	5.7	10	28	9	21	5	14
375 kg SSP ha^{-1}	5.7	11	57	7	19	5	14
LSD $_{0.05}$	0.2	0.7	25	3	3	1	6
F-Statistic	0.920	**<0.001**	**0.013**	**0.043**	**0.217**	0.832	**0.021**
November 2018							
No P	5.9	8	10	17	23	6	5
188 kg SSP ha^{-1}	5.6	9	32	10	23	8	11
250 kg SSP ha^{-1}	5.6	10	38	12	22	7	15
175 kg RPR ha^{-1}	5.5	10	37	12	23	7	20
375 kg SSP ha^{-1}	5.6	11	81	8	21	7	11
LSD $_{0.05}$	0.1	1	4	4	2	1	7
F-Statistic	**0.002**	**0.001**	**<0.001**	**0.002**	0.283	**0.019**	**0.010**
February 2019							
No P			5				8
188 kg SSP ha^{-1}			20				12
250 kg SSP ha^{-1}			29				12
175 kg RPR ha^{-1}			26				15
375 kg SSP ha^{-1}			67				13
LSD $_{0.05}$			3				5
F-Statistic			**<0.001**				0.141
May 2019							
No P			5				7
188 kg SSP ha^{-1}			21				12
250 kg SSP ha^{-1}			34				11
175 kg RPR ha^{-1}			27				17
375 kg SSP ha^{-1}			70				12
LSD $_{0.05}$			7				5
F-Statistic			**<0.001**				0.011

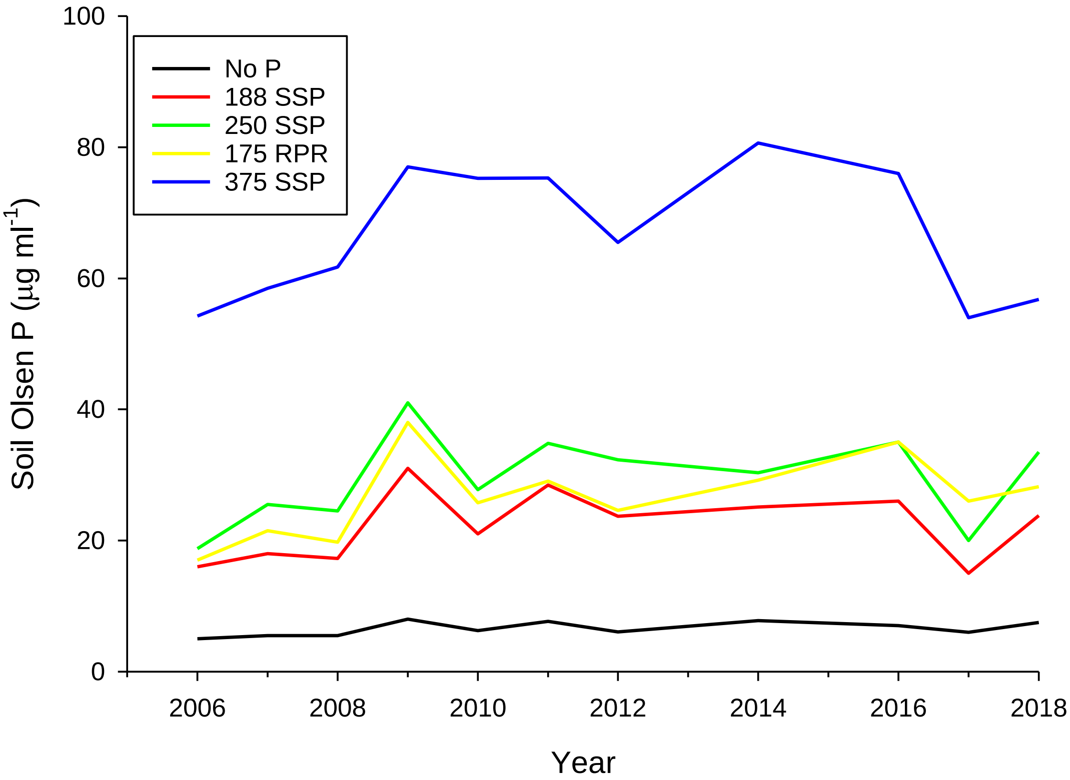

Figure 4. Soil Olsen P (0-75mm depth) values measured in winter each year from the long-term irrigated fertiliser trial at Winchmore

The soil S concentrations for all fertiliser treatments were above optimum (10-12 ppm; Morton & Roberts 2009) in all samplings for all fertiliser treatments, but consistently below optimum for the No P treatment. Potassium (K) concentrations were significantly lower where fertiliser had been applied but still at or above the 5 - 8 recommended by Morton & Roberts (2009). While magnesium (Mg) concentrations in the soil were above that required for pasture (8-10) they were below that recommend for ewes in spring (25-30).

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 5). 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 before declining slightly in 2018. The reasons for the drops in pH in 2007, 2010 and 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, and were below 5.7 in November 2018, the application of a small amount of lime with the intention of lifting pH to the range of 5.8 - 6.0 recommended by Morton & Roberts (2009) by should be considered.

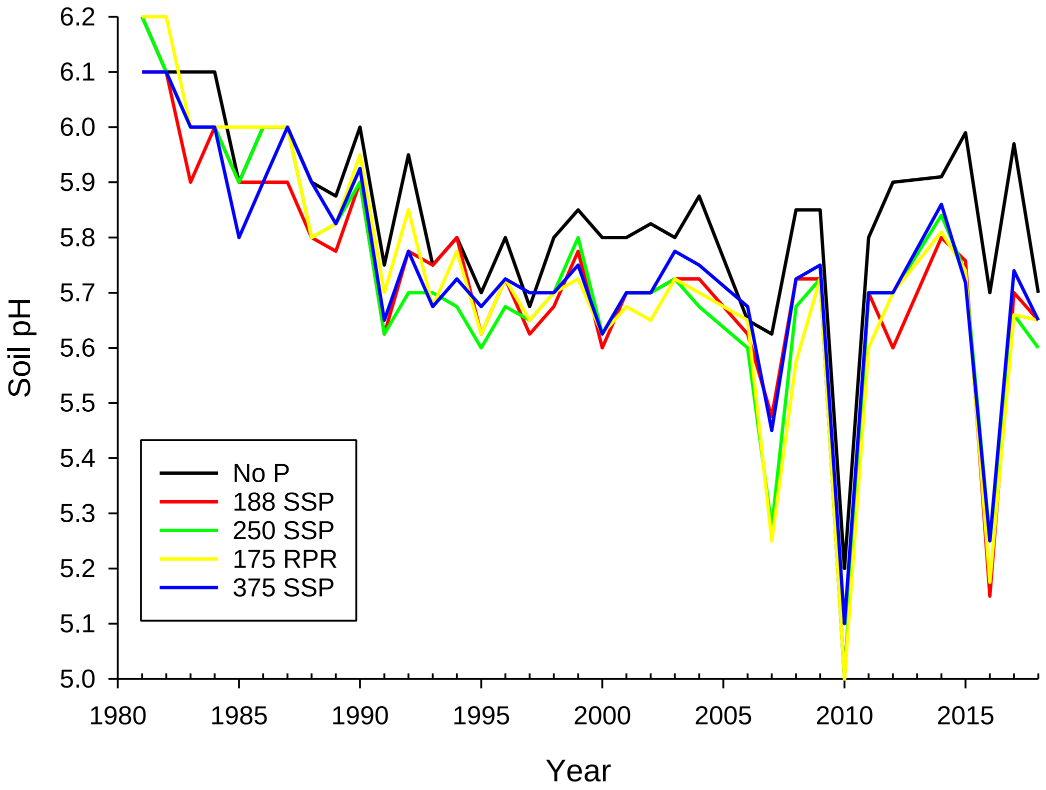

Figure 5. Soil pH values (0-75mm depth) measured in winter each year from the long-term irrigated fertiliser trial at Winchmore

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 under irrigation. The relative yields from this year's production are well below this relationship for all fertilised treatments (Figure 6); they are however just within the spread of data used to generate the long-term response curve (Figure 7).

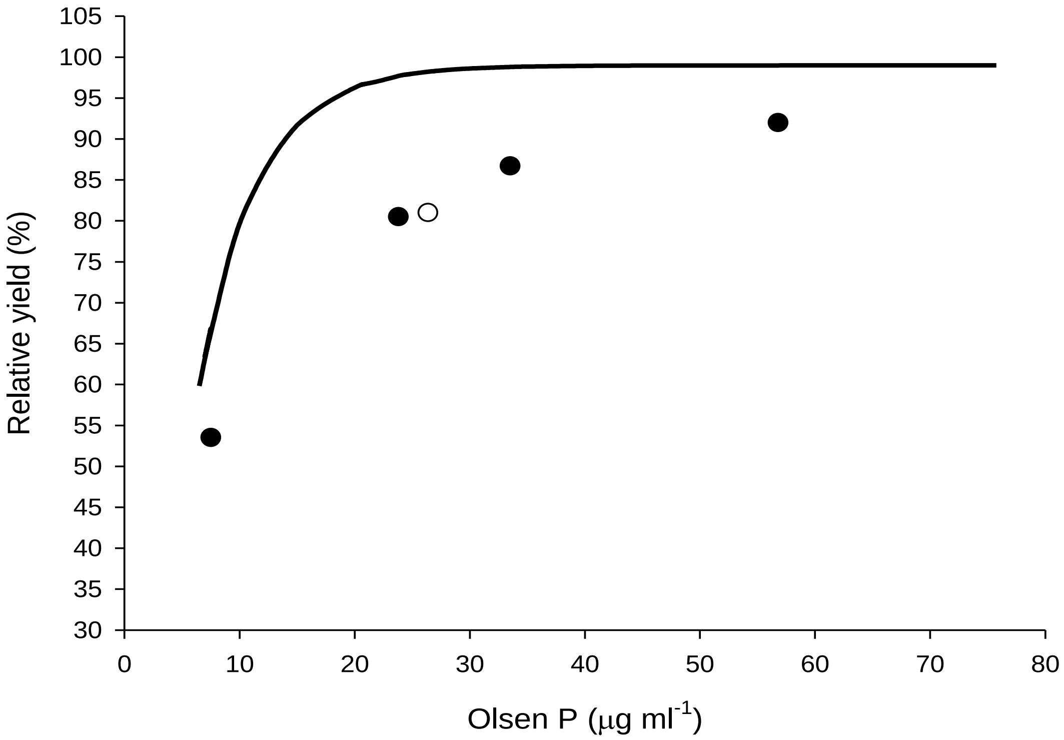

Figure 6. Relative yields for 2018-2019 production plotted with the long term (1981-2018) pasture response curve (solid line). ● indicates relative yields for No P and SSP treatments; ○ indicates RPR relative yield.

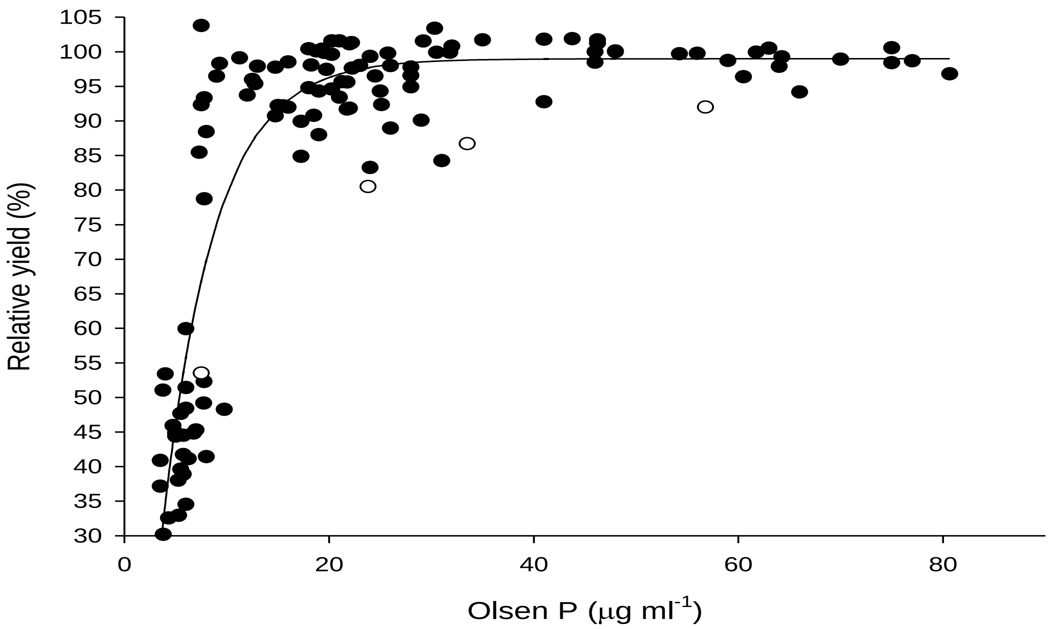

Figure 7. Scatter of points used to generate the long term (1981-2018) pasture response curve (solid line). ● indicates points used to generate response curve; ○ indicates RY with SSP for 2018-2019 season

6. Acknowledgements

We would like to acknowledge Geoff Farrar for his assistance as the "irrigation" and stock manager, and the Fertiliser Association of New Zealand 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.