Winchmore long-term fertiliser trial: 2019-2020 annual update

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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 was recently 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 May 2020 was assessed seven times, using the rate of growth technique with movable pasture cages. Production on the fertilised plots averaged 10.0 t DM ha^{-1} for this period, which is below the long-term annual average of 12.0 t DM ha^{-1}. Production for the No P treatment was significantly less at 5.1 t DM ha^{-1}, which is similar to the long-term average of 5.4 t DM ha^{-1}. 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 relationship between soil Olsen P and relative yield for the last 2 seasons under overhead irrigation, has been below that previously measured under border irrigation, indicating the possibility of a different relationship for the two irrigation types. Considerably more data over several years is required to confirm this hypothesis

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 2019 – 2020 growing season.

3. Methods

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

All treatments received their fertiliser on 2nd September 2019. 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 2019-2020 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.

Pasture production is measured by the rate of growth technique using movable pasture exclusion cages (Radcliffe 1974) with approximately 6 - 8 cuts per year. This season there were 7 pasture production measurements. It must be noted that as a consequence of the Covid-19 outbreak measurements normally taken over the March-April 2020 period were delayed until the first week of May. Soil samples to 75 mm were collected seasonally and after laboratory analysis archived for future studies. Seasonal botanical composition of grass, clover and weeds is also tracked (Lynch 1966).

4. Results and Discussion

4.1 Irrigation scheduling

A total of 264 mm of irrigation water was supplied to the trial site by centre pivot (Figure 1), with the first application being recorded in October 2019. There were 30 applications in total with an average of 9 mm of water (range = 2 mm – 20 mm) applied at each application. Irrigation generally ensured that 90+mm of rain and irrigation water was available monthly for pasture growth. The exceptions were September 2019, before irrigation commenced and April/May 2020. This compares with the approximately 350 - 400 mm typically applied under the flood irrigation system used previously.

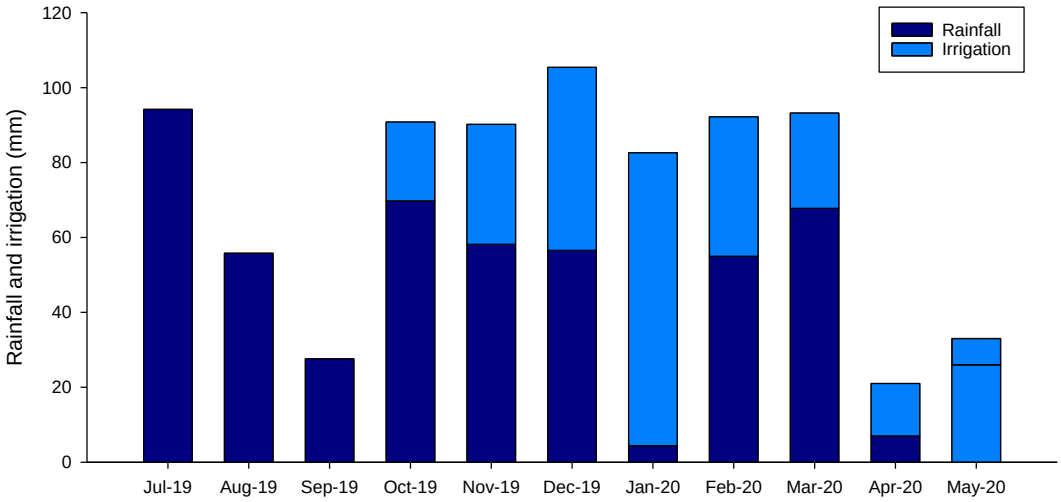

Figure 1. Monthly rainfall and volumes of irrigation water (mm) applied to Winchmore long term fertiliser trial over the 2019-2020 season.

4.2 Pasture production

Annual pasture production for the 2019 - 2020 season was less than that produced in 2017-2018 and 2019-2020 seasons (Table 1; Figure 2). The fertiliser treatments overall averaged 10.0 t DM ha^{-1}, considerably less than the long-term average of 12.0 t DM ha^{-1}. The No P treatment produced 5.1 t DM ha^{-1}, which is similar to the long-term average of 5.4 t DM ha^{-1}. The application of fertiliser significantly increased pasture production

(P<0.001; Table 1), however there was no significant fertiliser rate effect on pasture production.

Table 1. Seasonal and annual pasture production from the irrigated Winchmore long-term fertiliser trial for 2019-2020 (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	0.13	1.88	2.11	0.99	5.11
188 kg SSP ha^{-1}	17	0.37	3.43	4.11	1.42	9.33
250 kg SSP ha^{-1}	23	0.76	3.45	3.90	1.53	9.64
175 kg RPR ha^{-1}	23	0.84	3.67	3.82	1.57	9.90
375 kg SSP ha^{-1}	34	0.90	3.43	4.74	1.92	10.98
All LSD $_{0.05}$		0.38	0.55	0.96	0.80	2.03
All F-Statistic		**0.003**	**<0.001**	**<0.001**	0.223	**<0.001**
Ex. No P LSD $_{0.05}$		0.18	0.57	1.00	0.90	2.15
Ex. No P F-Statistic		0.067	0.727	0.218	0.648	0.384

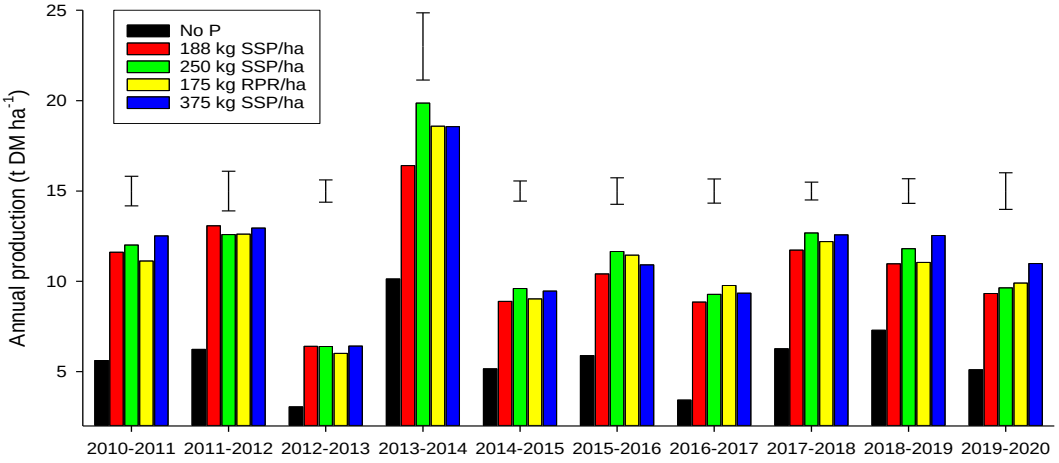

Figure 2. Annual pasture production over 10 years for the long-term irrigated fertiliser trial at Winchmore (t DM ha^{-1}). Bars indicate LSD (P<0.05).

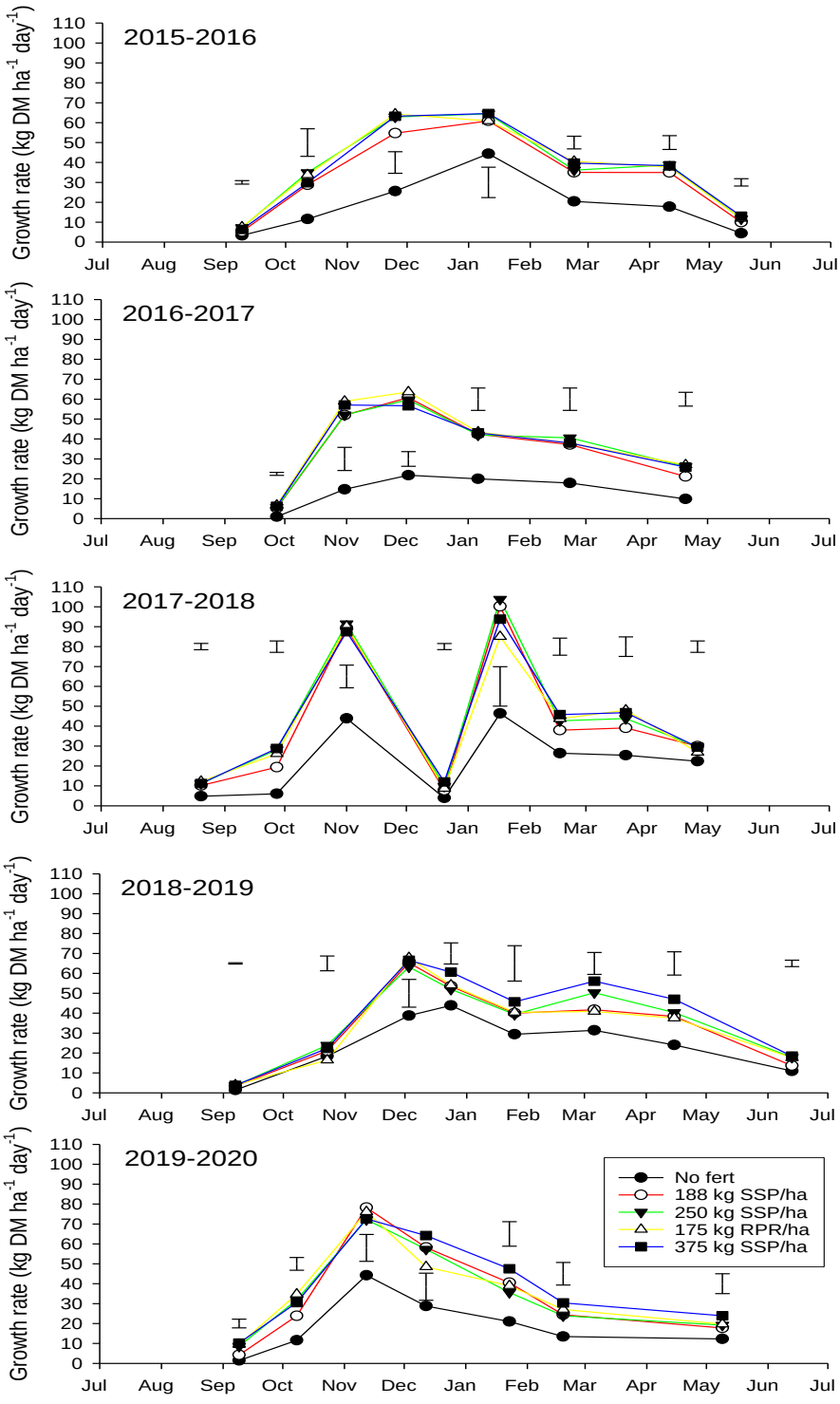

Figure 3. Daily pasture growth over 5 years for the long-term irrigated fertiliser trial at Winchmore (kg DM ha^{-1} day^{-1}) Bars indicate LSD ($P<0.05$). NB the growth rate shown is the daily growth rate from the previous measurement to the date shown in the graphs.

Pasture production peaked in November 2019 before a slow but steady drop until mid-February (Figure 3). Daily growth rates for the no-fertiliser treatment were significantly lower than the fertilised treatments over the peak growth months of October to January.

There were no significant differences in daily growth rates for the February and May harvests, while for the September harvest, the no fertiliser and 188 kg SSP treatments grew less than the RPR and 375 kg SSP treatments.

4.3 Species composition

As with the 2018-2019 season, pastures were grass-dominant over the whole season. The lack of clover is thought to be a continuation of the increase in cocksfoot resulting from the lack of grazing over the March to September 2018 period. This low incidence of clover is of concern, however there have been several incidences of low clover over the last 30 years (Figure 4), followed by a clover recovery.

Table 2: Seasonal and treatment effects on pasture species fractions from the Winchmore long-term irrigated fertiliser trial for 2019-2020 (% 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).

	13 June 2019		8 October 2019		23 January 2020		9 May 2020	
	Grass	Clover	Grass	Clover	Grass	Clover	Grass	Clover
No P	98	2	98	2	98	1	99	1
188 kg SSP ha^{-1}	99	1	99	1	95	5	98	2
250 kg SSP ha^{-1}	98	2	99	1	98	3	99	1
175 kg RPR ha^{-1}	98	2	99	1	95	5	98	2
375 kg SSP ha^{-1}	99	2	99	1	98	2	100	0
LSD 0.05	2.2	2.2	1.8	1.8	3.6	3.7	1.6	1.5
F-Statistic	0.877	0.877	0.935	0.935	0.130	0.128	0.441	0.486

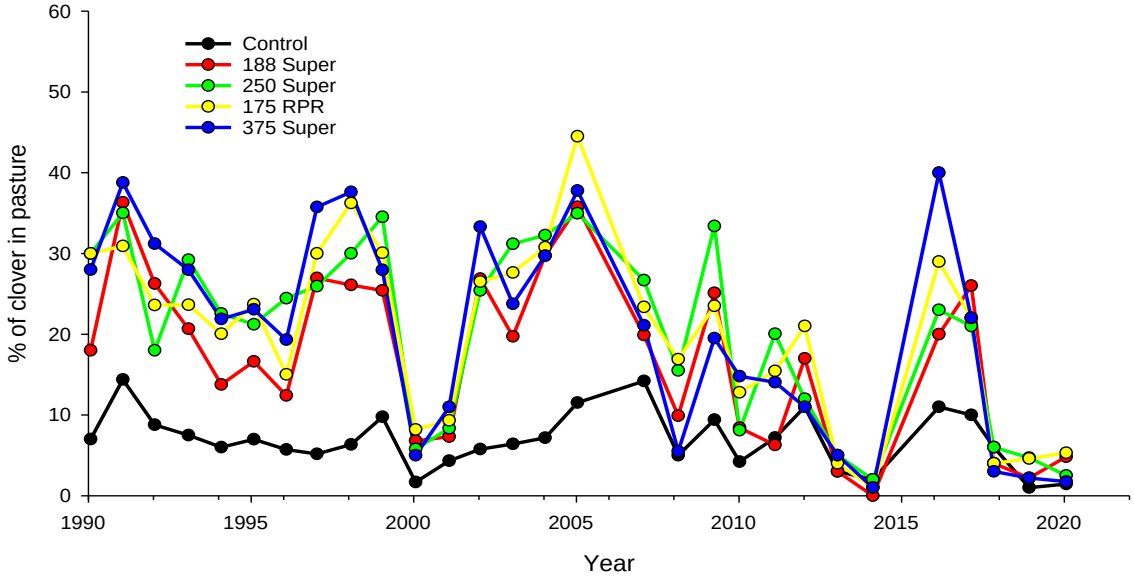

Figure 4. Long term effect of fertiliser application on clover content over the summer months (December – January).

4.4 Soil Analysis

The results of the analysis of soil samples prior to fertiliser application (August 2019), November 2019, February 2020 and May 2020 are presented in Table 3. Plots receiving P fertiliser had higher Olsen P than the no P plots at all sampling dates except the 188 kg SSP treatment in May 2020. They also had higher sulphate S (SO_4-S) than the no P plots in both August and November 2019. In May 2020, the soil SO_4-S was higher for the 250 and 375 kg SSP ha^{-1} and the RPR treatments than the no P treatment. The no P plots did however have significantly higher pH levels (P = 0.042) than where P fertiliser had been applied. The pH of 5.7 for the no P plots was the same as that measured in September 2018.

The soil SO_4-S concentrations for all fertiliser treatments were below optimum (10-12 ppm; Morton & Roberts 2009) in August 2019, but increased after fertiliser application to above optimum by the November 2019 sampling, remaining so at the February and May 2020 samplings. Where no fertiliser was applied, the soil SO_4-S remained sub-optimum. Potassium (K) concentrations were above the 5 - 8 recommended by Morton & Roberts (2009) in August 2019. 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).

Table 3. Soil test results from the Winchmore long-term irrigated fertiliser trial for the 2019-2020 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)	Olsen P (µg ml^{-1})	K (QT units)	Mg (QT units)	Na (QT units)	SO_4-S (mg L^{-1})
August 2019							
No P	5.7	9	7	13	24	6	5
188 kg SSP ha^{-1}	5.5	10	26	13	22	7	9
250 kg SSP ha^{-1}	5.6	10	37	11	22	6	7
175 kg RPR ha^{-1}	5.6	10	31	11	22	6	10
375 kg SSP ha^{-1}	5.6	10	82	11	21	6	7
LSD $_{0.05}$	0.15	1	6	4	3	0.8	3
F-Statistic	**0.042**	0.069	**<0.001**	0.755	0.166	**0.032**	**0.013**
November 2019							
No P			4				6
188 kg SSP ha^{-1}			22				13
250 kg SSP ha^{-1}			33				22
175 kg RPR ha^{-1}			25				13
375 kg SSP ha^{-1}			69				22
LSD $_{0.05}$			2				4
F-Statistic			**<0.001**				**<0.001**
February 2020							
No P			10				7
188 kg SSP ha^{-1}			26				19
250 kg SSP ha^{-1}			41				18
175 kg RPR ha^{-1}			32				15
375 kg SSP ha^{-1}			79				33
LSD $_{0.05}$			12				16
F-Statistic			**<0.001**				0.058
May 2020							
No P			12				7
188 kg SSP ha^{-1}			18				12
250 kg SSP ha^{-1}			28				14
175 kg RPR ha^{-1}			24				14
375 kg SSP ha^{-1}			68				17
LSD $_{0.05}$			10				6
F-Statistic			**<0.001**				**0.044**

Where fertilizer has been applied there has been a steady increase in Olsen P levels in the soil over the last 30 odd years (Figure 5), with the increase being greater for the 375 kg SSP treatment than for the other P treatments.

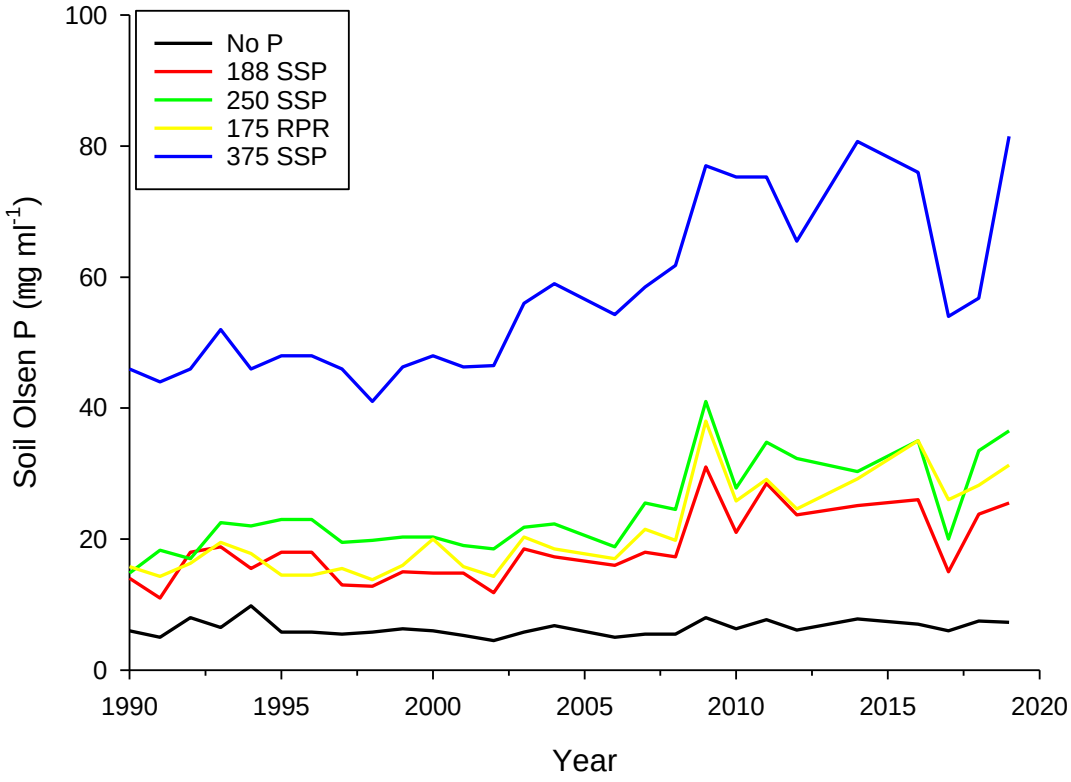

Figure 5. Soil Olsen P concentrations (0-75mm depth) values measured in winter each year from the long-term irrigated fertiliser trial at Winchmore.

In contrast, and as expected, there has been a slow decline in soil pH over the last 30 odd years (Figure 6). However, 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 since the early 1990s.

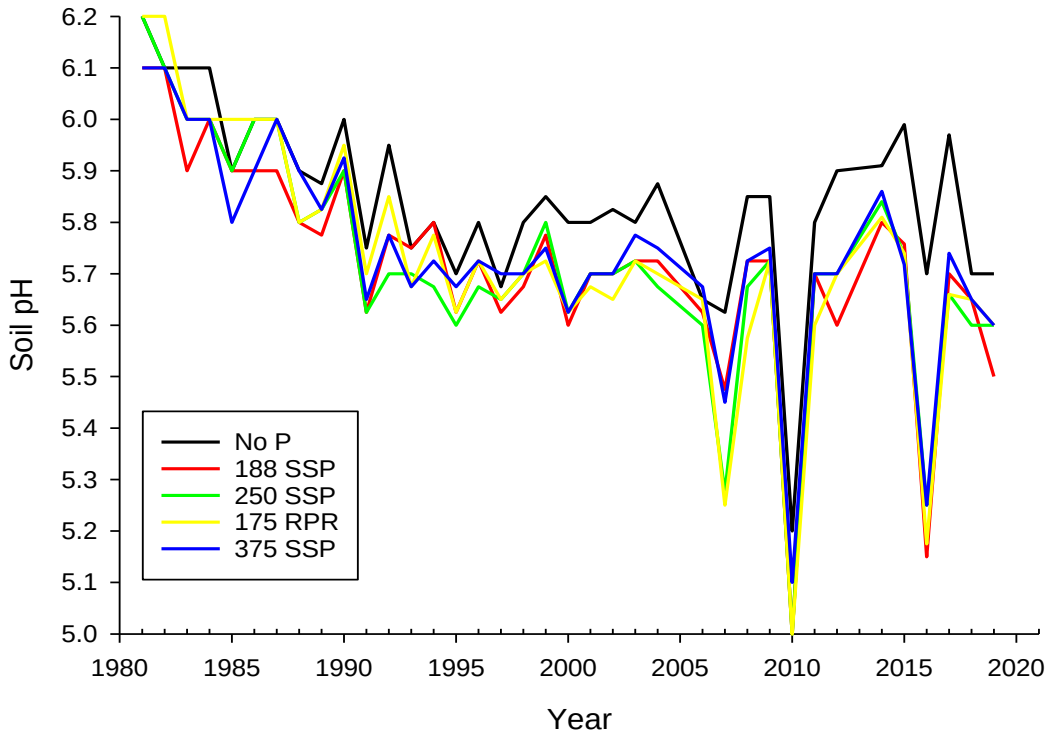

Figure 6. Soil pH values (0-75mm depth) measured in winter each year from the long-term irrigated fertiliser trial at Winchmore.

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 border irrigation. The relative yields from this year's production are well below this relationship for all fertilised treatments (Figure 7), however they are similar to those measured in 2018-2019. This may indicate a different response curve to Olsen P under overhead irrigation to that previously measured under border irrigation. However, more measurements over several years are required to confirm this hypothesis.

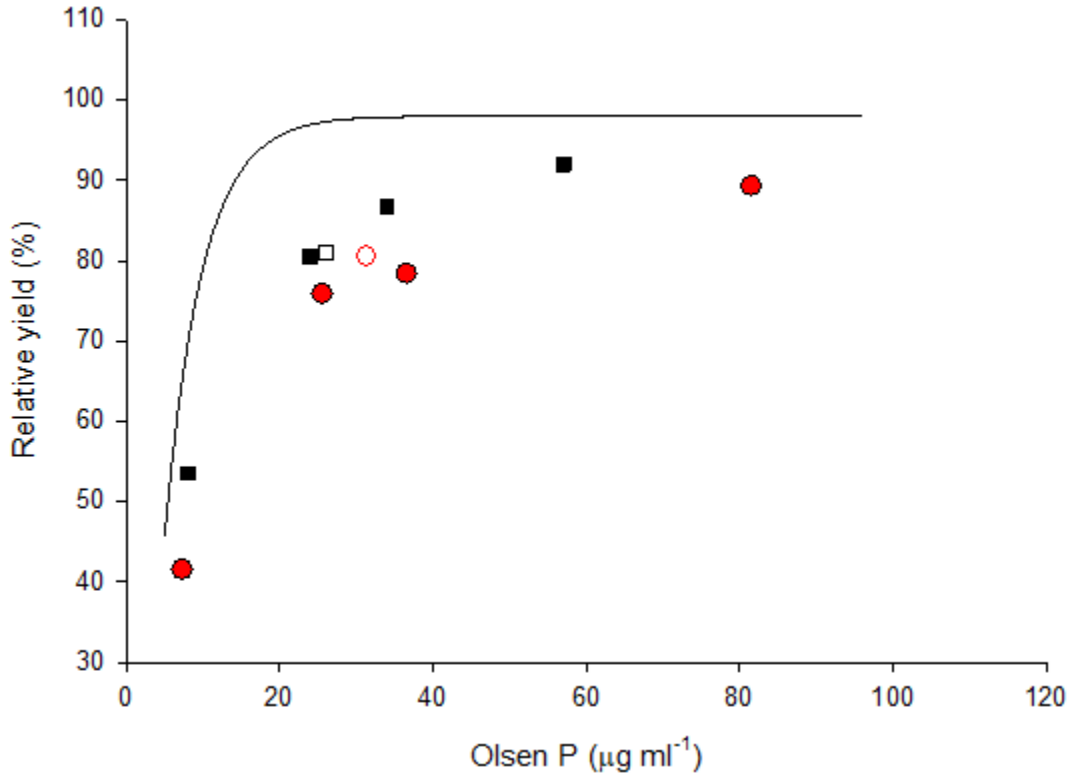

Figure 7. Relative yields for 2018-2019 and 2019-2020 DM production plotted with the long term (1981-2018) pasture response curve (solid line). ■ and ● indicate relative yields for No P and SSP treatments for the 2018-2019 and 2019-2020 seasons respectively while ☐ and ○ indicate RPR relative yields for the 2 years.

6. Acknowledgements

We would like to acknowledge Chris Olley, the farm owner for irrigation management; Geoff Farrar for his assistance with stock management; and the Fertiliser Association of New Zealand for their continued funding of this trial.

7. References

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