1.1 Yield of PB50 Inoculated and Phosphorus Fertilized Wheat

G. Androsoff, C. van Kessel and R. Karamanos

(Project funded by the Agricultural Development Fund)

ABSTRACT

Four locations in the Brown (Leader, Sceptre, Kindersley, and Gull Lake), two in the Dark Brown (Regina and Outlook (irrigated)), five in the Black (Blaine Lake, Dubuc, Glenavon, Langbank, and Star City) and two in the Dark Gray soil zones (Nipawin and Porcupine Plain) were selected in the spring of 1990. Selection of the locations was based upon the available P status in the soil. With a few exceptions, all locations required P fertilization. At each location, the experiment was carried out on fields that were either on summerfallow, cereal stubble or oilseed stubble, all in close vicinity to one another. The experiment was laid out as a randomized complete block design with the following treatments 1) Control, 2) PB50 only, 3) 11.2 kg/ha of P_2O_5, 4) PB50 + 11.2 kg/ha P_2O_5, 5) 22.4 kg/ha of P_2O_5 and, 6) PB50 + 22.4 kg/ha P_2O_5, replicated four times. Nitrogen and in some cases P and S was applied at blanket rates when necessary. At all sites Katepwa spring wheat was used as the test crop.

Crop yields (grain and grain + straw) were determined and fluctuated widely among the 13 locations due to the variable precipitation received in 1990. At one site, a significant ($P < 0.05$) P fertilizer response on grain yield was observed. Whereas significant responses did occur at other sites, it was not directly related to P fertilizer and/or PB50. At most of the sites, however, no P fertilizer and/or PB50 response was observed.

The concentration of P in the tissue, sampled at the Feekes 2 to 3 stage, was found to be not significantly different between the various treatments at most of the sites tested. If a significant difference was observed, the P fertilizer application caused the increase in P concentration.

With the exception of two sites, the average amount of kg P/ha removed from the field through the grain was less than the total amount of the full rate of applied P and at some sites, half or less P was removed.

INTRODUCTION

The *Penicillium bilaji*, isolated from Alberta soils, has shown to be an effective agent to solubilize P under controlled conditions (Kucey, 1983; Kucey, 1987; Kucey and Leggett, 1989). Although many soil microorganism are known to be capable to solubilize P, this particular fungi appears to be one of the more effective P solubilizing organism currently known.

To test the effectiveness of *P. bilaji* under field conditions, a field program was initiated in 1989 to further evaluate the potential use of this fungi as a partially substitute for P fertilization in Saskatchewan.The evaluation occurred simultaneously with the response of P fertilizer on grain yield of wheat and barley. In 1989, no positive yield responses due to inoculation of the seed with PB50 were observed (Bullock et al., 1990). However, the positive P fertilizer response on grain yield only occurred on 13% of the sites selected for field testing (7 out of 46 sites).

As a continuation of a project to evaluate the possible partially substitution of P fertilizer for PB50 and the response of P fertilization, a new set of field trials were conducted in the various soil regions of Saskatchewan.

MATERIALS AND METHODS

Experimental sites were selected for low available soil P based on soil test analysis of soils sampled in early spring from numerous locations throughout the province. The final selection of the sites and the available P levels are reported in Table 1.1.1. Some of the sites showed available P levels which would not require any additional P fertilization

Table 1.1.1 Spring levels of available P in upper 0 to 15-cm of soil

Location	Crop history	P (kg/ha of P_2O_5)
Gull Lake	Summerfallow	19.8
	Cereal stubble	18.7
Sceptre	Summerfallow	11.0
	Cereal stubble	15.4
Kindersley	Summerfallow	29.7
	Cereal stubble	41.8
	Oilseed stubble	45.1
Regina	Summerfallow	16.5
	Cereal stubble	25.3
	Oilseed stubble	36.3
Leader	Summerfallow	14.3
	Cereal stubble	18.7
Star City	Summerfallow	24.2
	Cereal stubble	18.7
	Oilseed stubble	18.7
Dubuc	Summerfallow	14.3
	Cereal stubble	16.5
	Oilseed stubble	15.4
Glenavon	Summerfallow	24.2
	Cereal stubble	28.6
	Oilseed stubble	37.4
Outlook	Cereal stubble	15.4
Langbank	Summerfallow	24.2
	Cereal stubble	13.2
Nipawin	Summerfallow	20.9
	Cereal stubble	16.5
	Oilseed stubble	20.9
Porcupine Plain	Summerfallow	17.6
	Cereal stubble	8.8
	Oilseed stubble	22.0
Blaine Lake	Summerfallow	16.8
	Cereal stubble	11.2
	Oilseed stubble	21.3

(i.e Kindersley) but were included as the location contained all three cropping histories or the site had been tested for PB50 and P fertilizer responses during the previous year.

The sites with three cropping histories; summerfallow, cereal stubble and oilseed stubble, at one location had common borders. During the months of May, spring wheat (Katepwa) was seeded at Langbank, Regina, Star City, Kindersley, Outlook (irrigation), Dubuc, Leader, Glenavon, Gull Lake, Porcupine Plain, Sceptre, and Nipawin. The following six treatments were included in the experimental design: (1) no P added; (2) PB50 inoculated spring wheat; (3) half rate P fertilization (11.2 kg/ha of P_2O_5); (4) half rate of recommended P fertilization plus PB50 inoculated spring wheat; (5) full rate of recommended P fertilization (22.4 kg/ha of P_2O_5); (6) full rate of recommended P fertilization plus PB50 inoculated spring wheat. Experimental plot sizes were 2 x 10 m by m. Seeding rate was 84 kg/ha. All sites received an N application according to recommendations by the Saskatchewan Soil Testing Laboratory.

At selected sites, leaf samples were taken during the Feekes two and three growth stages and analyzed for percent P and N. Similar P and N analyses were performed on grain.

All sites were harvested at physiological maturity which occurred at all sites during the last two weeks in August. Harvest area of each plot was 1 by 5 m. Plants were dried, weighed, threshed and the grain weighed.

RESULTS AND DISCUSSION

Although the moisture conditions through most parts of the Province were normal or above normal, the yield at Sceptre and Leader were far below average and were considered as a crop failure. The experiments on cereal stubble at Porcupine Plain and at Blaine Lake on oilseed stubble were abandoned due to spray damage.

Overall, a large range in grain yields were found and whereby the highest yields were recorded in the Black and Gray soil zones, the lowest in the Brown soil zone.

Sufficient precipitation in most areas of the province reduced largely the effect of summerfallow on grain yield although significant increases were found at Blaine Lake and Nipawin.

At one of the 27 sites tested (Porcupine Plain, on oilseed stubble) a significant response due to P fertilizer and PB50 was found (Table 1.1.2). At this particular site, the highest grain yield was recorded for the treatment corresponding to the half rate of P plus PB50 (1817 kg/ha). The grain yield, however, was not significantly different from all other treatments which received the half or full rate of P fertilizer. Four more sites (Porcupine Plain on summerfallow, Langbank on summerfallow, Langbank on cereal stubble, and Kindersley on cereal stubble) showed significant differences between treatments but none of the treatments which received P and or either PB50 had significant higher grain yield than the control.

At five sites (out of 20 sites tested) significant differences between treatments in the percent N in the tissue were found (Table 1.1.3). At all those sites, the treatments receiving the full rate of P fertilizer plus PB50 showed the highest concentration of N with the half rate of P plus PB50 showing intermediate values. With the exception at Glenavon on cereal stubble, the inoculation of PB50 plus the half or full rate of P resulted in higher N concentrations. As no yield data were recorded in the spring, it is unclear if the higher N concentrations were caused by enhanced growth and N uptake after inoculation of the seed with PB50 or that the non-PB50 seeds showed increased growth thereby diluting the concentration of N in the tissue.

At seven sites, a significant difference was found between treatments for the percent P in the tissue. Generally, the application of P fertilizer increased the concentration of P in the tissue and was often further enhanced through the application of PB50. As with the percent of N in the tissue, it is unclear if the higher P concentrations were due to enhanced P uptake or that the non-PB50 seeds showed increased growth thereby diluting the concentration of P in the tissue.

kg/ha × .015 ≈ bu/ac

Table 1.1.2 Total grain yield at the various sites as affected by P fertilization, PB50 and cropping history

Cropping history	Treatment	Location										
		Dubuc	Kindersley	Regina	Star City	Glenavon	Nipawin	Gull Lake	Outlook	Porcupine Plain	Blaine Lake	Langbank
		kg ha^{-1}										
Summer-fallow	Control	1733	1566	2888	2521	2930	3141	2084		1507	2519	2656
	PB50	1779	1539	3049	2204	2983	3189	2236		1119	2554	2199
	1/2 P	1928	1661	2835	2406	2889	3354	2162		1504	2390	2399
	1/2 P + PB50	1804	1752	2656	2386	3030	3068	2170		1351	2304	2160
	Full P	1826	1578	3031	2222	2991	3088	2060		1188	2329	2756
	Full P + PB50	1721	1947	2645	2198	3250	2801	2298		1410	2545	2177
		ns*	ns	ns	ns	ns	ns	ns		223	ns	382
Cereal stubble	Control	1447	1019	2145	1370	2523	1965	1358	3002		2110	2108
	PB50	1780	897	2100	1079	2587	1985	1242	3041		1947	1920
	1/2 P	1702	1173	2429	1283	2708	1633	1405	3573		2168	2153
	1/2 P + PB50	1570	1025	2651	1107	2741	1960	1420	3379		2136	1974
	Full P	1723	755	2260	1078	2712	1985	1238	3321		2021	1875
	Full P + PB50	1553	1160	2433	1299	2443	1885	1445	3294		2095	1869
		ns	208	ns	ns	ns	ns	ns	ns		ns	132
Oilseed stubble	Control	1829	999	2353	1926	2790	2719			1465		
	PB50	1612	813	2586	1924	3151	2814			1448		
	1/2 P	1601	842	2399	1998	2549	2946			1797		
	1/2 P + PB50	1926	875	2515	1836	2732	2579			1817		
	Full P	1824	764	2401	2003	2838	2815			1682		
	Full P + PB50	2032	854	2428	2027	2484	3149			1703		
		ns	ns	ns	ns	ns	ns			282		

* Significance at the P <0.05 level.

Table 1.1.3 Concentration of % N and % P in wheat tissue sampled at Feekes 3-4 stages

History	Treatment	Dubuc		Kindersley		Regina		Star City		Glenavon		Nipawin		Gull Lake		Porcupine Plain		Blaine Lake		Langbank	
		% N	% P	% N	% P	% N	% P	% N	% P	% N	% P	% N	% P	% N	% P	% N	% P	% N	% P	% N	% P
Summer-fallow	Control	5.73	0.42	5.37	0.36	4.75	0.35	5.96	0.34	5.71	0.44	5.64	0.33	5.03	0.34	5.18	0.38			5.25	0.29
	PB50	5.62	0.41	5.51	0.43	4.75	0.37	6.00	0.34	5.69	0.43	5.53	0.34	5.09	0.31	5.20	0.37			5.41	0.33
	1/2 P	5.79	0.46	5.58	0.45	4.95	0.39	5.99	0.35	6.03	0.49	5.73	0.40	5.31	0.38	5.29	0.43			5.35	0.34
	1/2 P + PB50	5.73	0.44	5.75	0.45	4.84	0.34	5.91	0.34	5.86	0.52	5.71	0.40	5.26	0.38	5.36	0.47			5.56	0.36
	Full P	5.69	0.45	5.61	0.48	5.01	0.43	6.05	0.36	6.04	0.49	5.81	0.41	4.85	0.34	5.41	0.50			5.45	0.40
	Full P + PB50	5.73	0.45	5.69	0.46	4.92	0.39	5.61	0.39	5.80	0.48	5.87	0.45	5.43	0.40	5.45	0.45			5.49	0.41
		ns*	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	0.04	0.17	0.03			ns	0.04
Cereal stubble	Control	5.06	0.30			4.57	0.27	5.56	0.40	5.42	0.38							4.63	0.32	5.17	0.37
	PB50	5.02	0.33			4.37	0.26	5.88	0.41	5.52	0.42							4.76	0.34	5.35	0.40
	1/2 P	5.07	0.32			4.88	0.31	6.00	0.38	5.61	0.43							4.79	0.32	5.06	0.38
	1/2 P + PB50	5.34	0.33			4.84	0.32	5.87	0.41	5.54	0.44							4.75	0.32	5.30	0.42
	Full P	5.11	0.32			4.86	0.29	5.98	0.37	5.72	0.45							4.84	0.33	5.50	0.42
	Full P + PB50	5.44	0.35			4.88	0.31	5.91	0.40	5.73	0.45							4.68	0.32	5.54	0.46
		0.22	ns			ns	ns	ns	ns	0.16	0.02							ns	ns	ns	0.05
Oilseed stubble	Control	5.13	0.29			5.34	0.41	5.40	0.29	5.56	0.42					5.15	0.34				
	PB50	5.14	0.28			5.31	0.42	5.67	0.30	5.64	0.44					5.12	0.35				
	1/2 P	5.39	0.32			5.26	0.43	5.53	0.29	5.52	0.44					5.36	0.43				
	1/2 P + PB50	5.31	0.32			5.26	0.46	5.91	0.34	5.49	0.45					5.27	0.40				
	Full P	5.23	0.32			5.37	0.46	5.67	0.32	5.44	0.44					5.36	0.42				
	Full P + PB50	5.41	0.36			5.14	0.46	5.97	0.37	5.49	0.47					5.41	0.42				
		ns	0.01			ns	ns	0.31	0.03	ns	ns					0.20	ns				

* Significance at the P <0.05 level.

In order to establish if the concentration in the tissue would be an indication about the available P status of the soil and further to see whether low P concentration in the spring would result in lower grain yield, wheat tissue was analyzed for P concentration in the spring. Because no significant P responses for grain yield were observed, it remains unclear if this method can be used as an indicator for the available P status in the soil.

At all, except two sites for N and three sites for P, no significant differences in the concentration of N and P in the grain were observed (Table 1.1.4). If a difference between treatments did occur, it appeared to be a random event and no distinct pattern could be found. Furthermore, higher concentration of N and P in the tissue did not seem to correlate with higher concentrations of N and P in the grain. For example, a significantly higher N and P concentration in the tissue of wheat grown on oilseed stubble at Star City did not translate in any significant difference in N and P concentration in the grain.

Total N accumulation in the grain varied between a low of 30.7 kg/ha at Star City for cereal stubble to a high of 102.0 kg/ha at Nipawin on summer fallow (Table 1.1.4). At only two sites, Porcupine Plain on oilseed stubble and Langbank on summerfallow, significant differences between treatments were found. Of these two sites, only at Porcupine Lake was the increase in total N due to P fertilization. At the other site, the control showed no significant lower total N yield than any of the other treatments.

At three sites (Outlook, Porcupine Lake on oilseed stubble, and Langbank on summerfallow) significant differences in total P accumulation were observed. At Outlook and Porcupine Plain the increase was caused by the application of P whereas at Langbank the total P accumulation appeared to be independent of P and PB50.

With the exception of Outlook (irrigated), Glenavon and a few occasions at some of the other sites, the total amount of kg P/ha removed from the field by means of the grain was less than the total amount of the full rate of P applied (22.4 kg P_2O_5 = 10.2 kg P/ha). At some sites, half or even less than half of this amount was removed from the field.

P not P_2O_5

Table 1.1.4. Concentration of N and P and total N and P in grain of wheat

Treatment	Glenavon cereal stubble				Star City cereal stubble				Regina cereal stubble				Blaine Lake cereal stubble				Gull Lake cereal stubble			
	% N grain	% P grain	Total N kg/ha	Total P kg/ha	% N grain	% P grain	Total N kg/ha	Total P kg/ha	% N grain	% P grain	Total N kg/ha	Total P kg/ha	% N grain	% P grain	Total N kg/ha	Total P kg/ha	% N grain	% P grain	Total N kg/ha	Total P kg/ha
Control	2.78	0.45	77.3	12.5	2.88	0.36	39.6	4.9	2.77	0.39	59.4	8.2	2.54	0.43	52.6	8.9	2.68	0.41	36.2	5.6
PB50	2.68	0.42	84.1	13.3	2.84	0.35	30.7	3.8	2.72	0.38	57.0	8.1	2.54	0.44	49.4	8.5	2.78	0.42	34.3	5.2
1/2 P	2.66	0.47	67.9	11.8	2.93	0.37	37.6	4.7	2.67	0.41	67.9	10.6	2.58	0.43	55.9	9.2	2.64	0.43	36.8	6.0
1/2 P + PB50	2.64	0.43	72.1	11.7	2.92	0.35	32.4	3.9	2.66	0.38	70.3	10.1	2.52	0.41	54.2	8.8	2.74	0.42	38.8	6.0
Full P	2.71	0.48	77.1	13.4	2.89	0.34	31.1	3.7	2.72	0.42	60.8	9.3	2.41	0.41	48.6	8.3	2.68	0.42	32.6	5.1
Full P + PB50	2.58	0.45	64.4	11.1	2.92	0.37	37.8	4.8	2.61	0.39	63.7	9.6	2.50	0.42	52.3	8.7	2.68	0.41	38.7	5.9
	ns*	0.03	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
	Glenavon oilseed stubble				Star City oilseed stubble				Porcupine Plain oilseed stubble				Dubuc oilseed stubble				Outlook cereal stubble			
Control	2.71	0.32	86.2	10.2	2.42	0.37	46.5	7.2	3.07	0.35	44.7	5.2	3.13	0.41	57.1	7.5	2.81	0.38	84.2	11.3
PB50	2.76	0.33	88.1	10.6	2.58	0.38	49.5	7.2	2.96	0.34	42.9	4.9	3.03	0.38	48.8	6.1	2.76	0.36	83.9	10.8
1/2 P	2.77	0.33	77.2	9.2	2.36	0.39	47.0	7.7	2.98	0.35	53.5	6.3	3.13	0.43	49.9	6.9	2.64	0.40	94.5	14.4
1/2 P + PB50	2.78	0.31	79.0	8.5	2.45	0.36	44.9	6.5	2.96	0.34	53.7	6.2	3.05	0.39	68.7	7.6	2.63	0.40	88.6	13.5
Full P	2.82	0.34	102.0	12.2	2.26	0.37	45.2	7.4	3.10	0.37	52.1	6.1	2.81	0.41	51.5	7.5	2.71	0.41	90.2	13.6
Full P + PB50	2.75	0.32	96.8	11.4	2.29	0.37	46.5	7.5	3.08	0.35	52.5	5.9	3.07	0.42	62.3	8.5	2.70	0.38	89.0	12.8
	ns	ns	ns	ns	0.1	ns	ns	ns	ns	ns	7.6	0.8	ns	ns	ns	ns	0.12	0.02	ns	1.6
	Glenavon summerfallow				Star City summerfallow				Langbank summerfallow				Kindersley summerfallow							
Control	2.68	0.41	67.2	10.3	2.88	0.36	72.6	9.0	2.53	0.40	67.7	10.4	2.82	0.32	44.1	5.0				
PB50	2.78	0.42	71.7	10.9	2.84	0.35	62.1	7.7	2.6	0.40	57.2	8.6	2.91	0.36	44.8	5.5				
1/2 P	2.64	0.43	71.5	11.5	2.93	0.37	70.1	8.8	2.54	0.38	61.1	9.1	2.84	0.34	47.1	5.6				
1/2 P + PB50	2.74	0.42	75.3	11.6	2.92	0.35	69.7	8.3	2.62	0.39	56.8	8.4	2.92	0.35	51.0	6.2				
Full P	2.69	0.42	73.2	11.3	2.89	0.34	64.0	7.5	2.55	0.40	70.6	10.9	2.90	0.34	45.6	5.3				
Full P + PB50	2.69	0.41	65.4	10.0	2.92	0.37	64.4	7.9	2.60	0.40	56.7	8.7	2.78	0.32	54.0	6.3				
	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	10.2	1.2	ns	0.03	ns	ns				

*Significance at the P<0.05 level

In general, P fertilizer and PB50 responses on grain yield for spring wheat were largely absent. The absence of a PB50 response if no P fertilizer response is observed would be more or less anticipated. The absence of an overall P fertilizer response suggest that with the changes in management techniques and the introduction of new crops, the recommendation for P fertilization will be revised. Steps which will make justified changes toward that direction are already being discussed.

ACKNOWLEDGMENTS

Financial support was provided by the Saskatchewan Agricultural Development Fund. We thank M. Nielsen for technical assistance.

LITERATURE CITED

Bullock, P, L. Cowell, and C. van Kessel. 1990. *Penicillium bilaji* (PB50) and phosphorus fertilizer responses of yield of wheat and barley grown on stubble and summerfallow. Proc. Soils and Crop Workshop, University of Saskatchewan, Saskatoon. pp. 81-88.

Kucey, R.M.N. 1983. Phosphate-solubilizing bacteria and fungi in various cultivated and virgin Alberta soils. Can. J. Soil Sci. 63:671-678.

Kucey, R.M.N. 1987. Increased phosphorus uptake by wheat and field beans inoculated with a phosphorus-solubilizing *Penicillium bilaji*. Appl. Environ. Microbiol. 53:2699-2703.

Kucey, R.M.N and M.E. Leggett. 1989. Increased yields and phosphorus uptake by Westar canola (*Brassica napus* L.) inoculated with a phosphate-solubilizing isolate of *Penicillium bilaji*. Can. J Soil Sci. 69:425-432.