PENICILLIUM BILAJI (PB50) AND PHOSPHORUS FERTILIZER RESPONSES OF YIELD OF WHEAT AND BARLEY GROWN ON STUBBLE AND SUMMERFALLOW

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Abstract

At nine locations, selected throughout the Brown, Dark Brown and Black soil zones, wheat and barley were grown on summerfallow (9 locations), cereal (8 locations) and oilseed stubble (6 locations). In total, 46 experimental plots with barley or wheat as crop were established. Soil analyses were carried out and for all locations and P fertilizer was recommended by soil testing guidelines. Wheat and barley were: (1) inoculated with a phosphorus solubilizing fungi, PB50, at time of seeding, (2) received P fertilizer at recommended rate, or (3) remained untreated. At four sites the rhizosphere soil of cereal inoculated with PB50 and untreated plants were sampled between 6 and 8 weeks after planting and the number of P solubilizing fungi determined. All rhizosphere soil of inoculated and uninoculated plants contained P solubilizing fungi. Total grain plus straw yield for wheat varied from between 1316 kg/ha in the Brown soil zone to 6597 kg/ha in the Black soil zone. Total yield for barley varied between 1217 kg/ha and 6472 kg/ha. Corresponding grain yield varied between 332 and 2676 kg/ha for wheat and between 266 and 3069 kg/ha for barley. P fertilization significantly increased total yield of wheat or barley at 7 sites (15% of the time) of all sites tested. PB50 significantly reduced total yield of wheat or barley at three sites (7% of the time), and increased total yield of wheat at one site (2%). P fertilization increased grain yield by wheat or barley at 7 sites (13% of the time), whereas PB50 reduced grain yield for barley and wheat at one site (4% of the time). Although all sites showed inadequate available P levels in the spring as determined by soil test analysis, at 85% of the time wheat and barley did not respond to P fertilization. This can partially be explained by the poor growth conditions at some sites or to the inadequacy of the method used to determine plant available P.

Introduction

Various soil organisms are known to be able to solubilize phosphate. These organisms produce various organic acids which induce the solubilization of phosphate and with the presence of vesicular-arbuscular mycorrhizae, increased P uptake by affected plants has been observed (Asea et al., 1988). One of the genus which is be able to solubilize various forms of P is *Penicillium*. Although many *Penicillium* spp. and other P-solubilizing microorganisms are present in native soils of Western Canada (Kucey, 1983), *P. bilaji* appears to be one of the more effective P solubilizing soil microorganisms (Kucey, 1987; Kucey and Leggett, 1989).

Through various research projects, mainly carried out in Alberta, a new biological product PB50 was developed what contains the fungi *P. bilaji* . Experiments under controlled and field conditions with cereals and oilseeds showed increased yield and P uptake after inoculation the seeds with PB50 at time of seeding (Kucey, 1987; Kucey and Leggett, 1989).

To test the beneficial effect of PB50 on yield of cereals, various experiments were conducted in 1989 in the different soil zones of Saskatchewan on summerfallow, cereal and oilseed stubble. Rhizosphere soil was collected from uninoculated and inoculated wheat and barley and analyzed for the number of P solubilizing fungi present.

Materials and Methods

Experimental sites were selected for low available soil P based on soil test analysis of soil sampled from 15 different locations (Table 1). The sites with three cropping histories (previously in summerfallow, a cereal or oilseed stubble) at one location had common borders. If no such common border could be found, the number of croppings histories at the location was reduced to two. Treatments were arranged in a randomized complete split plot design, replicated four times. Each subplot measured 2.1 by 10 m. Main plot treatments were wheat (Katepwa) or barley (Harrington). Subplot treatments were control, P fertilization and seed inoculated with PB50. Phosphorus was applied at a rate of 30 kg P_2O_5/ha and each plot received 65 kg N/ha in the form of ammonium nitrate. The inoculation of the seed with PB50 occurred just before seeding using the procedure recommended by Philom Bios, Saskatoon. Seed box and boots were cleaned and further rinsed with 95% ethanol after seeding the PB50 inoculated seed of wheat and barley. Seeding rate was 100 and 80 kg/ha for wheat and barley, respectively. Seeding occurred between May 12 and May 18.

Rhizosphere soil was collected in June or July from the uninoculated plots non-P fertilized plots and from the plots of which seed was inoculated with PB50. At Melville and Gull Lake sampling occurred when wheat and barley were in the 3-4 Feekes growth stage.

At Dubuc, the rhizosphere soil was collected during late flowering which corresponded to 10.5-11 Feekes growth stage. The number of phosphorus solubilizing fungi was determined using the method recommended by Philom Bios.

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

Results and Discussion

From four sites, Melville, Gull Lake (Potter), Gull Lake (Connick) and Dubuc rhizosphere soil was collected from the uninoculated and PB50 treated seed plots and the number of phosphorus solubilizing fungi determined (Table 2). Although all rhizosphere soil collected from uninoculated and inoculated plants contained phosphorus solubilizing fungi, inoculation of seeds with PB50 increased the number of phosphorus solubilizing fungi in rhizophere soil on summerfallow and on oilseed stubble. Inoculation, however, decreased the number of phosphorus solubilizing fungi in the rhizophere soil on cereal stubble. As *P. bilaji* is isolated from an Alberta soil, it was not unexpected to find this *Penicillium* in the uninoculated rhizosphere soil. Inoculating seed with PB50 increased the number of *P. bilaji* from a low of 10 per g oven dry soil to a maximum of 15.5×10^3 per g of oven dry soil.

Table 1. Spring available nutrients for experimental plots.

Location	Cropping history	NO_3 (0-60 cm)	P (0-15 cm)	K (0-15 cm)
		kg/ha		
Melville	Summerfallow	94	15	330
	Cereal stubble	30	25	285
	Oilseed stubble	78	24	190
Medstead	Summerfallow	65	17	265
	Oilseed stubble	14	19	129
Gull Lake (Connick)	Summerfallow	59	21	288
	Cereal stubble	81	38	378
Star City	Summerfallow	118	16	278
	Cereal stubble	31	21	189
	Oilseed stubble	45	23	125
Langbank	Summerfallow	127	19	380
	Cereal stubble	138	16	350
Regina	Summerfallow	71	17	398
	Cereal stubble	83	18	585
	Oilseed stubble	78	10	338
Watrous	Summerfallow	61	31	428
	Cereal stubble	29	19	325
	Oilseed stubble	44	27	548
Dubuc	Summerfallow	99	22	216
	Cereal stubble	30	10	248
	Oilseed stubble	31	14	305
Gull Lake (Potter)	Summerfallow	83	12	720
	Cereal stubble	52	23	320

Table 2. Number of colonizing forming P solubilizing fungi.

Site	Crop	Treatment	Cropping history: Summerfallow		Cereal stubble		Oilseed stubble	
			P solubilizing fungi	PB50	P solubilizing fungi	PB50	P solubilizing fungi	PB50
			---- colony forming units/g oven-dry soil/10^2 ----					
Melville	Wheat	Uninoculated	83.1	4.5	173	4.3	44.8	0.8
Melville	Wheat	PB50-inoculated	189	15.4	8.7	1.9	96.6	17.5
Gull Lake (Connick)	Wheat	Uninoculated	294	0.5	148	18.9		
Gull Lake (Connick)	Wheat	PB50-inoculated	124	18.4	143	29.9		
Gull Lake (Potter)	Wheat	Uninoculated	50.9	0.5	124	0.3		
Gull Lake (Potter)	Wheat	PB50-inoculated	19.3	2.6	39.7	4.6		
Dubuc	Wheat	Uninoculated	29.6	0.5	716	2.1	35.6	0.5
Dubuc	Wheat	PB50-inoculated	942	155	151	21.5	117	13.7
Melville	Barley	Uninoculated	216	1.1	23.7	2.7	44.2	0.7
Melville	Barley	PB50-inoculated	137	13.8	36.2	7.6	50.9	7.7
Gull Lake (Connick)	Barley	Uninoculated	94.8	3.3	64.4	23.1		
Gull Lake (Connick)	Barley	PB50-inoculated	197	22.9	97.7	22.1		
Gull Lake (Potter)	Barley	Uninoculated	21.5	0.1	31.8	0.4		
Gull Lake (Potter)	Barley	PB50-inoculated	52.9	4.7	34.9	4.3		
Dubuc	Barley	Uninoculated	59.1	1.7	477	10	98.2	2.3
Dubuc	Barley	PB50-inoculated	49	4.6	171	11.5	41.9	3.6
Mean	Wheat/Barley	Uninoculated	106	2	220	8	56	1
		PB50-inoculated	319	48	86	14	107	16

Caution has to be observed with the interpretations of the number of *P. bilaji* per gram of soil. Currently no simple method is available to determine taxonomically the various species belonging to the genus of Penicillium. In this study the method recommended by Philom Bios was used whereby the determination of the presence or absence of *P. bilaji* was largely based upon visual observations and comparing the colour of a single colony of fungi present in the rhizosphere soil with the appearance of a *P. bilaji* colony obtained from a pure culture.

Total yield of wheat at the various locations ranged from a low of 1238 kg/ha on cereal stubble at Dubuc to a high of 6597 kg/ha on summerfallow at Star City (Table 3). Similar large differences were observed for total yield of barley. Valid statistical comparisons between the three cropping histories (summerfallow, oilseed and cereal stubble) are not possible as the locations of the three treatments were, for apparent reasons, not randomized. However, with the exception of wheat grown on oilseed and cereal stubble at Melville and wheat and barley grown on cereal stubble at Regina, the highest yield for wheat and barley was observed on summerfallow. With the exception of the Star City, yield of wheat and barley on oilseed and cereal stubble were comparable.

The application of P significantly increased total yield of wheat at 4 sites (9% of the time) and total yield of barley at 3 sites (7% of the time). Increases in grain yield of wheat were observed at 4 sites (9% of the time) and for barley at two sites (4% of the time). At time of seeding the available P levels were considered to be insufficient to support adequate plant growth and P fertilization was considered necessary. The response to P fertilization on yield was erratic. The highest level of available P was found at Gull Lake (Connick) on cereal stubble (Table 1). Although the observed grain yield of barley was below the long term average of 1998 kg/ha (Agriculture Statistics, 1988), P fertilization increased grain yield significantly. In contrast, the amount of available P on summerfallow at Star City was only 16 kg/ha, but no response to P fertilization was observed even the highest grain yields were observed at this site. This is in contrast with results reported by Zentner and Campbell (1988) who found a significant increase of 11-12% after application of P fertilizer on summerfallow and wheat stubble at Swift Current.

At two sites, on cereal stubble at Regina and summerfallow at Dubuc, PB50 significantly reduced total yield of barley. At one site, on summerfallow at Watrous, total yield of wheat was reduced significantly after inoculating the seed with PB50. Grain yield was reduced significantly at Dubuc. The only significantly increase in total yield of barley was observed on summerfallow at Medstead. PB50 did not increase total yield of grain yield at any of the sites tested. One possible explanation for this absence of a yield response may be the presence of indigenous P solubilizing fungi in Saskatchewan soils. Enumerating the number of P solubilizing fungi showed a presence of between 5000 and 22000 colony forming units of P solubilizing organism per gram of oven dry soil (Table 2). If the presence of this number of indigenous P solubilizing organism can be confirmed in further studies, the possible increase in yield due to inoculation might be small. The second explanation of the absence of a positive response due to inoculation may be the adequate P availability for plant uptake at time of seeding. No effect on P fertilization was observed at 85% of the time. It might be unlikely that a positive effect of PB50 will be observed. However, in this study positive effects of P fertilization on yield occurred without a positive effect by PB50 inoculation.

Table 3. Total yield and grain yield of wheat and barley.

	Crop	Treatment	Melville CARLSON Total yield	Melville CARLSON Grain yield	Medstead CASSON Total yield	Medstead CASSON Grain yield	Gull Lake CONNICK Total yield	Gull Lake CONNICK Grain yield	Star City COWELL Total yield	Star City COWELL Grain yield	Langbank DUMONCEAUX Total yield	Langbank DUMONCEAUX Grain yield
			(kg/ha)									
Summerfallow	Wheat	Control	1978	920	4375	1972	3144	1244	6597	2676	3945	1529
		P	4185**	1804**	5048	2149	3579	1470*	6526	2480	3725	1511
		PB50	2823	1289	3999	1724	2994	1183	6293	2624	3966	1604
	Barley	Control	4448	1525	3634	1550	4080	1614	6407	2759	3969	1510
		P	5166	1794*	4372**	1830	3910	1529	6028	2862	4316	1627
		PB50	4338	1608	4176**	1744	3693	1451	6472	3069	4009	1496
Oilseed stubble	Wheat	Control	3242	1433	3510	1565			4610	2006		
		P	3135	1340	4269*	1788			5324*	2335*		
		PB50	2797	1277	3042	1361			4590	1945		
	Barley	Control	3693	1428	3005	1263			5051	2505		
		P	3977	1541*	3597**	1517			5122	2387		
		PB50	3465	1364	3205	1185			5018	2501		
Cereal stubble	Wheat	Control	3427	1305			2693	1104	2599	975	1740	675
		P	4270*	1577			2807	1078	2821	1022	2094	847
		PB50	3812	1477			2533	958	2651	944	1679	642
	Barley	Control	4680	1423			3014	956	2570	1018	1957	609
		P	4784	1478			3630*	1273*	2707	985	1851	572
		PB50	4346	1249			3253	1151	2691	1057	2001	491
Wheat	CV (%)		20	23	12	13	11	10	8	9	14	13
Barley	CV (%)		12	18	7	10	9	13	8	12	10	16

Table 3. Continued.

			Regina McALLISTER		Watrous McARTHUR		Dubuc NIELSEN		Gull Lake POTTER	
	Crop	Treatment	Total yield	Grain yield	Total yield	Grain yield	Total yield	Grain yield	Total yield	Grain yield
			(kg/ha)							
Summerfallow	Wheat	Control	3108	1201	2165	1019	2401	982	3057	1094
		P	3516	1358	2009	962	2898	1122	3072	1056
		PB50	3055	1192	1625*	882	2943	1213	3099	1103
	Barley	Control	2949	1053	3033	1191	4455	1771	3113	1219
		P	3258	1133	3001	1075	4305	1692	2911	1063
		PB50	3119	1111	2915	1188	3953*	1433*	2867	1099
Oilseed stubble	Wheat	Control	1825	789	4930	471	2089	775		
		P	2070	886	5562	559	1886	691		
		PB50	1759	740	5386	521	1817	717		
	Barley	Control	2312	806	3570	230	2164	744		
		P	2156	830	4262	312	2573	965		
		PB50	1995	708	3314	266	2211	921		
Cereal stubble	Wheat	Control	4679	1290	1495	628	1421	566	1316	375
		P	4312	1669*	1616	645	1405	570	1393	427
		PB50	3473*	1325	1172	475	1238	517	1327	332
	Barley	Control	4721	1658	1607	439	1217	590	1635	570
		P	4290	1367	1720	502	1591	732	1709	579
		PB50	4988	1687	1533	474	1281	590	1576	452
Wheat	CV (%)		12	21	22	26	19	21	12	11
Barley	CV (%)		20	29	23	30	13	16	17	22

*, ** Significantly different from the control at the 0.05 and 0.01 probability level.

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