SASKATCHEWAN pulse Growers

SPG Project Annual Progress Report

1. SPG project details

Project File number: AGR1509
Project title: Developing phosphorus management recommendations for soybean production in Saskatchewan
Reporting period: April 1, 2015 – March 31, 2016
Approved Project Date: March, 2015
Report prepared by: Chris Holzapfel, Indian Head Agricultural Research Foundation (Email:)
Date submitted to SPG: March 23

2. Specify project activities undertaken during this reporting period. *Please note that changes from the original work plan will require consultation with, and written approval from SPG.*

a.) Methodology: *Include strategy, experimental design, tests, materials, sites, etc.*

The first year of soybean field trials were established at four locations in Saskatchewan: 1) Indian Head (Black soil zone), 2) Melfort (Moist Black soil zone) 3) Scott (Moist Dark Brown soil zone) and 4) Outlook (Dark Brown soil zone). The treatments evaluated were 3 phosphorus rates (22, 45 or 90 kg P_2O_5 ha^{-1}), three placement methods (seed-placed, side-banded or pre-seed broadcast) plus a control. The 10 treatments were arranged in a Randomized Complete Block Design with four replicates. This protocol was originally developed by Don Flaten and a team of researchers in Manitoba for a Pulse Science Cluster 2 project.

Seeding equipment, plot size and basic crop management varied from site-to-site depending on equipment and the specific environmental conditions encountered; however, all factors other than those being evaluated were held constant within each site. All other crop inputs (i.e. seeding rate, inoculant, and pest control products) were based on current recommendations and intended to be non-limiting. The variety was 2310 YR and the soybeans were always double inoculated (seed-applied plus 1-2x label rate of granular). Weeds were controlled with registered herbicide applications tailored to each site and the plots were mechanically combined when mature and dry.

The data collected included background soil testing, emergence counts at approximately 2, 3 and 4 weeks after planting, above-ground biomass measurements during pod fill (specific crop stage varied from site to site), plant tissue P concentrations and total P uptake, seed yield, seed P concentrations and total P exports. At Outlook, emergence counts were only completed once and not all laboratory results are available at this time; however, all samples have been submitted and are currently being processed through AgVise laboratories (Northwood, ND).

All available response data from the first year of field trials was analysed using the mixed procedure of SAS with data from each site analysed separately. The effects of P treatments were considered fixed and the effect of replicate was considered random. Treatment means were separated using Tukey's studentized range test and contrasts were used to compare specific groups of treatments (control vs. fertilized, seed-placed vs. side-banded, seed-placed vs. broadcast and side-banded vs. broadcast). Orthogonal contrasts were utilized to investigate whether the responses to P rate were non-significant, linear or curvilinear separately for each placement method. All treatment effects and differences between means were considered significant at $P \leq 0.05$.

Pertinent site information and agronomic details are provided for each site in Table 1.

Table 1. Pertinent site and agronomic information for soybean phosphorus fertility study in 2015.

Agronomic Factor / Data Collection	Indian Head 2015	Outlook 2015	Melfort 2015	Scott 2015
Previous crop	Spring Wheat	Spring Wheat	Oat	Spring Wheat
Tillage System	no-till	cultivator/harrow	rototilled	no-till
Row spacing	30 cm	25 cm	19 cm	25 cm
Opener width	1.9 cm	disc	disc	2.5 cm
Seeding date	May 21	May-26	May-21	May-20
Seeding rate	55 seeds m^{-2}	53 seeds m^{-2}	55 seeds m^{-2}	55 seeds m^{-2}
Emergence counts	Jun-11 Jun-18 Jun-25	Jun-19	Jun-4 Jun-11 Jun-18	Jun-3 Jun-10 Jun-17
In-crop herbicide 1	890 g glyphosate ha^{-1} + 50 g imazethapyr ha^{-1} Jun-8	1334 g glyphosate ha^{-1} June-22	1334 g glyphosate ha^{-1} Jul-2	1780 g glyphosate ha^{-1} Jun-12
In-crop herbicide 2	890 g glyphosate ha^{-1} Jul-4	1334 g glyphosate ha^{-1} Jul-15	1334 g glyphosate ha^{-1} Jul-16	—
Biomass harvest	Aug-26	Aug-27	date not available	Jul-28
Seed harvest	Oct-10	Oct 13	Oct-16	Oct-1

b.) List and explain any deviations from the approved objectives:

All activities are proceeding on schedule with no major deviations from the original research plan and proposed milestones.

c.) Research results in the reporting period. *(Describe progress towards meeting objectives. Please use revised objectives if approved revisions have been made to original objectives.*

Objectives	**Progress**
To investigate soybean response to P fertilizer rates and placement methods in Saskatchewan to improve P management recommendations for the growing number of soybean producers in this province.	The first year of field trials has been completed and all available response data has been summarized and analyzed. Any conclusions regarding the specific objectives of this project are very much preliminary and subject to change.
add additional lines as required	

d.) Discussion: *Provide discussion and interpretation necessary to the full understanding (including on-farm use of information, if any) of progress made during this reporting period and the relevance of any findings. Detail any major concerns or project setbacks.*

All available response data to date has been analysed and is presented in the following section. Only limited discussion and interpretation of results are offered as we are still waiting on some data and this is only the first year of a 3-year study.

All currently available soil test results are presented in Table 2.

Table 2. Soil test results for 2015 soybean P fertility trials at Indian Head, Outlook, Melfort and Scott. Samples were collected in the early spring and submitted to AgVise laboratories for various analyses.

Soil Test Parameter	Indian Head 2015	Outlook 2015[Z]	Melfort 2015	Scott 2015
NO_3-Nitrogen (0-60 cm)	15 kg ha^{-1}	53 kg ha^{-1}	84 kg ha^{-1}	53 kg ha^{-1}
Olsen Phosphorus (0-15 cm)	5 ppm	7 ppm	22 ppm	13 ppm
Potassium (0-15 cm)	676 ppm	290 ppm	618 ppm	310
Sulphur (0-60 cm)	18 kg ha^{-1}	179 kg ha^{-1}	87 kg ha^{-1}	92 kg ha^{-1}
Organic Matter (0-15 cm)	5.6%	—	11.3%	4.3
pH (0-15)	7.7	8.0	6.3	5.1

Mean monthly temperatures and precipitation amounts for the 2015 growing season are presented in Table 3. Overall, it was a relatively warm and dry start to the season; however conditions improved in late June / early July and precipitation amounts were generally above average in August and September. Of the sites, moisture was most limited at Scott where precipitation was below normal for May, June and July but improved in August.

Table 3. Mean monthly temperatures and precipitation amounts along with long-term (1981-2010) averages for the 2015 growing season at Indian Head, SK.

Year	May	June	July	August	September	Avg. / Total
	---------- Mean Temperature (°C) ----------					
Indian Head-15	10.3	16.2	18.1	17.0	22.2	16.8
Indian Head-LT	10.8	15.8	18.2	17.4	11.5	14.7
Outlook-15	10.4	17.3	19.2	17.4	12.6	15.4
Outlook-LT	11.5	16.1	18.9	18.0	12.3	15.4
Melfort-15	9.9	16.4	17.9	17.0	11.9	14.6
Melfort-LT	10.7	15.9	17.5	16.8	10.8	14.3
Scott-15	9.4	16.0	18.1	16.8	11.0	14.3
Scott-LT	10.8	15.3	17.1	16.5	10.4	14.0
	---------- Precipitation (mm) ----------					
Indian Head-15	15.6	38.3	94.6	58.8	67.8	275.1
Indian Head-LT	51.8	77.4	63.8	51.2	35.3	279.5
Outlook-15	9.3	38.6	135.4	57.5	47.9	288.7
Outlook-LT	39.0	63.9	56.1	42.8	32.8	234.6
Melfort-15	7.1	54.8	149.8	57.4	70.0	339.1
Melfort-LT	39.8	54.3	76.7	52.4	34.3	257.5
Scott-15	4.1	19.4	46.4	74.5	49.6	194.0
Scott-LT	34.8	61.8	72.1	45.7	32.9	247.3

Emergence measurements were targeted for approximately 2, 3 and 4 weeks after seeding; however the actual dates varied across sites (i.e. measurements were delayed by approximately 1 week at Indian Head) and the plants were only counted once at Outlook. While plant populations varied widely across locations for the initial measurements, any observed treatment effects were relatively consistent across dates. Results for the first two measurement periods are provided in the Appendices (Tables A-1 and A-2) and final plant populations are presented in Table 4 below. The overall F-test was not significant at the desired level ($P \leq 0.05$) at any sites; however, there were indications of minor reductions in emergence with seed-placed fertilizer at some locations. At Melfort, the linear orthogonal contrast for seed-placed P was significant ($P = 0.001$) while at Scott both the seed-placed vs. side-band ($P = 0.041$) and seed-placed linear ($P = 0.050$) contrasts were significant. At Indian Head, overall variability was low and plant populations were equal for all treatments. At Outlook, no statistical tests were significant at the desired level; however, overall variability was high and there was a tendency for reduced plants at the highest rate of seed-placed P (Sp-quadratic; $P = 0.069$). While the contrasts provided subtle evidence of reduced emergence with high rates of seed-placed P at some locations, with high variability and no significant F-tests these results are not conclusive.

Table 4. Treatment means, overall F-test and contrast results for soybean emergence at T3 (~4 weeks after planting). Means within a column followed by the same letter do not significantly differ (Tukey's studentized range test, $P \leq 0.05$).

Treatment [z] / Effect / Contrast	Indian Head	Outlook	Melfort	Scott
	---------- T3 Emergence (plants m^{-2}) ----------			
0 P	48.8 a	56.5 a	49.9 a	47.5 a
22 P – Sp	46.8 a	60.3 a	44.3 ab	40.9 a
22 P – Sb	49.0 a	71.3 a	36.9 ab	33.0 a
22 P – Bc	50.3 a	61.3 a	50.3 a	45.3 a
45 P – Sp	48.6 a	82.3 a	42.2 ab	24.1 a
45 P – Sb	44.7 a	64.8 a	36.2 ab	48.5 a
45 P – Bc	44.9 a	66.3 a	46.1 ab	43.3 a
90 P – Sp	43.9 a	42.3 a	23.6 b	30.8 a
90 P – Sb	50.3 a	75.0 a	38.3 ab	47.8 a
90 P – Bc	51.1 a	68.0 a	39.4 ab	36.4 a
S.E.M.	2.46	12.41	5.33	6.36
	---------- Pr > F (p-value) ----------			
Overall F-test	0.396	0.641	0.058	0.132
Check vs rest	0.679	0.488	0.080	0.209
Sp vs Sb	0.440	0.395	0.920	0.041
Sp vs Bc	0.257	0.726	0.060	0.071
Sb vs Bc	0.712	0.614	0.074	0.790
Sp – linear	0.198	0.445	0.001	0.050
Sp – quadratic	0.629	0.069	0.478	0.111
Sb – linear	0.776	0.382	0.221	0.539
Sb – quadratic	0.212	0.834	0.129	0.519
Bc – linear	0.683	0.506	0.126	0.207
Bc – linear	0.243	0.800	0.727	0.872

[z] P = kg P_2O_5 ha^{-1}; Sp – seed-row placement; Sb – side-band; Bc – pre-seed broadcast

Above-ground biomass yields were measured during the reproductive growth stages; however, the actual time during pod filling varied across sites resulting in significant variation in the range of yields observed from location to location (Table 5). The only significant treatment effects or contrast comparisons occurred at Outlook where the overall F-test was significant ($P = 0.032$) where highest above-ground biomass yields were observed with 22 kg P_2O_5 ha^{-1} in the side-band and the lowest occurred with 90 kg P_2O_5 ha^{-1} placed in the seed-row. The only contrasts that were significant were for side-banded versus both seed-placed and broadcast P whereby side-banded P resulted in higher biomass yields (averaged across P rates) than the other placement options. None of the orthogonal contrasts were significant for any P placement methods which suggested that the observed differences may have been somewhat random.

Table 5. Treatment means, overall F-test and contrast results for soybean above-ground biomass production. Means within a column followed by the same letter do not significantly differ (Tukey's studentized range test, $P \leq 0.05$).

Treatment [z] / Effect / Contrast	Indian Head	Outlook	Melfort	Scott
	---------- Above-ground Biomass (kg ha^{-1}) ----------			
0 P	7849 a	7708 ab	4087 a	2190 a
22 P – Sp	7538 a	7648 ab	4478 a	1974 a
22 P – Sb	8768 a	10965 a	3997 a	1598 a
22 P – Bc	8333 a	7478 ab	2887 a	1852 a
45 P – Sp	8555 a	8573 ab	4539 a	1523 a
45 P – Sb	7242 a	7845 ab	4362 a	2057 a
45 P – Bc	8227 a	7888 ab	4405 a	2231 a
90 P – Sp	8924 a	6515 b	4331 a	1699 a
90 P – Sb	7800 a	10640 ab	4215 a	2473 a
90 P – Bc	8333 a	8443 ab	3961 a	1634 a
S.E.M.	590.0	929.8	504.1	217.9
	---------- Pr > F (p-value) ----------			
Overall F-test	0.588	0.032	0.499	0.067
Check vs rest	0.587	0.438	0.934	0.208
Sp vs Sb	0.412	0.005	0.525	0.092
Sp vs Bc	0.933	0.626	0.092	0.337
Sb vs Bc	0.460	0.015	0.281	0.449
Sp – linear	0.117	0.365	0.802	0.097
Sp – quadratic	0.895	0.261	0.521	0.177
Sb – linear	0.590	0.122	0.772	0.116
Sb – quadratic	0.899	0.962	0.846	0.085
Bc – linear	0.642	0.482	0.636	0.138
Bc – linear	0.732	0.777	0.791	0.521

[z] P = kg P_2O_5 ha^{-1}; Sp – seed-row placement; Sb – side-band; Bc – pre-seed broadcast

Phosphorus concentrations of the above-ground biomass yields are presented for all sites where data was available at the time of writing in Table 6. Treatment effects on tissue P concentrations were significant at Indian Head (P = 0.046) but not at Melfort or Scott (P = 0.24-0.37). While the multiple comparisons test did not identify any specific differences amongst treatment means at Indian Head, there was an overall linear increase in tissue P concentrations for all three placement methods.

Table 6. Treatment means, overall F-test and contrast results for soybean tissue P concentrations. Means within a column followed by the same letter do not significantly differ (Tukey's studentized range test, *P* ≤ 0.05).

Treatment [z] / Effect / Contrast	Indian Head	Outlook	Melfort	Scott
	---------- Tissue Phosphorus Concentration (% P) ----------			
0 P	0.238 a	—	0.238 a	0.190 a
22 P – Sp	0.250 a	—	0.230 a	0.210 a
22 P – Sb	0.225 a	—	0.228 a	0.220 a
22 P – Bc	0.238 a	—	0.228 a	0.215 a
45 P – Sp	0.250 a	—	0.235 a	0.205 a
45 P – Sb	0.258 a	—	0.253 a	0.195 a
45 P – Bc	0.250 a	—	0.250 a	0.193 a
90 P – Sp	0.280 a	—	0.258 a	0.213 a
90 P – Sb	0.273 a	—	0.260 a	0.198 a
90 P – Bc	0.285 a	—	0.253 a	0.225 a
S.E.M.	0.0129	—	0.0132	0.0104
	---------- Pr > F (p-value) ----------			
Overall F-test	0.046	—	0.370	0.235
Check vs rest	0.175	—	0.632	0.106
Sp vs Sb	0.435	—	0.556	0.555
Sp vs Bc	0.814	—	0.800	0.844
Sb vs Bc	0.584	—	0.736	0.433
Sp – linear	0.027	—	0.170	0.205
Sp – quadratic	0.699	—	0.322	0.497
Sb – linear	0.021	—	0.092	0.886
Sb – quadratic	0.687	—	0.829	0.344
Bc – linear	0.008	—	0.221	0.056
Bc – linear	0.397	—	0.920	0.669

[z] P = kg P_2O_5 ha^{-1}; Sp – seed-row placement; Sb – side-band; Bc – pre-seed broadcast

Phosphorus uptake during pod-filling was determined from the above-ground biomass yields and tissue P concentrations and results from all sites where data is available are presented in Table 7. For this variable, P was converted to P_2O_5 equivalent for easier interpretation. Results for total P_2O_5 uptake were generally similar to those for tissue P concentrations. While the overall F-test at Indian Head was not quite significant in this case (*P* = 0.065); orthogonal contrasts showed linear increases in uptake with seed-placed and broadcast but not side-banded P; however, averaged across application rates, total P_2O_5 uptake was similar for all placement methods. At Melfort and Scott, no treatment effects or contrasts were significant; thus there there were no indications of increased P uptake with fertilization.

Table 7. Treatment means, overall F-test and contrast results for soybean P uptake (based on above-ground biomass yields and P concentrations). Means within a column followed by the same letter do not significantly differ (Tukey's

studentized range test, *P* ≤ 0.05).

Treatment [Z] / Effect / Contrast	Indian Head	Outlook	Melfort	Scott
	---------- Phosphorus Uptake (kg P_2O_5 ha^{-1}) ----------			
0 P	42.5 a	—	22.5 a	9.6 a
22 P – Sp	42.9 a	—	23.8 a	9.5 a
22 P – Sb	45.2 a	—	20.8 a	7.9 a
22 P – Bc	45.6 a	—	15.2 a	9.1 a
45 P – Sp	48.5 a	—	24.4 a	7.1 a
45 P – Sb	42.5 a	—	25.3 a	9.1 a
45 P – Bc	47.2 a	—	25.2 a	9.9 a
90 P – Sp	56.8 a	—	25.2 a	8.1 a
90 P – Sb	48.9 a	—	25.0 a	11.1 a
90 P – Bc	54.3 a	—	22.8 a	8.4 a
S.E.M.	3.64	—	3.11	1.02
	---------- Pr > F (p-value) ----------			
Overall F-test	0.065	—	0.408	0.292
Check vs rest	0.135	—	0.865	0.513
Sp vs Sb	0.170	—	0.749	0.175
Sp vs Bc	0.898	—	0.174	0.301
Sb vs Bc	0.212	—	0.292	0.737
Sp – linear	0.003	—	0.538	0.190
Sp – quadratic	0.609	—	0.854	0.326
Sb – linear	0.226	—	0.406	0.143
Sb – quadratic	0.616	—	0.940	0.159
Bc – linear	0.017	—	0.451	0.432
Bc – linear	0.825	—	0.799	0.623

[Z] P = kg P_2O_5 ha^{-1}; Sp – seed-row placement; Sb – side-band; Bc – pre-seed broadcast

Treatment effects and means for soybean seed yield are presented in Table 8. Overall, yields were highest at Outlook (4222 kg ha^{-1}), followed by Melfort (3691 kg ha^{-1}), Indian Head (2724 kg ha^{-1}) and then Scott (1624 kg ha^{-1}). The overall F-test was not significant at Indian Head, Melfort or Scott but was at Outlook (*P* = 0.001). At Outlook, while the control did not yield lower than any of the fertilized treatments, there was a significant yield reduction when 90 kg P_2O_5 was applied in the seed-row. Further evidence of this existed in the contrasts which indicated lower overall yields with seed-placement relative to side-banding or broadcasting; however, this was only observed at the highest fertilizer rate. The overall comparison of the control to the combined fertilized plots was also significant at Outlook but, unexpectedly and partly due to the reduced yield 90 kg ha^{-1} seed-placed P_2O_5, yields were lower in the fertilized plots in this particular case. All sites considered these results are consistent with research in Manitoba which is showing that yield responses to P fertilizer applications have are rare with soybeans.

Table 8. Treatment means, overall F-test and contrast results for soybean seed yield. Means within a column followed by the same letter do not significantly differ (Tukey's studentized range test, *P* ≤ 0.05).

Treatment [Z] /	Indian Head	Outlook	Melfort	Scott

Effect / Contrast	Seed Yield (kg ha^{-1})			
0 P	2632 a	4419 a	3536 a	1775 a
22 P – Sp	2689 a	4380 a	3636 a	1947 a
22 P – Sb	2818 a	4317 a	3574 a	1408 a
22 P – Bc	2707 a	4295 a	3908 a	1605 a
45 P – Sp	2669 a	4120 a	3895 a	1226 a
45 P – Sb	2736 a	4277 a	3721 a	1799 a
45 P – Bc	2766 a	4227 a	3611 a	1637 a
90 P – Sp	2762 a	3619 b	3521 a	1500 a
90 P – Sb	2715 a	4240 a	3765 a	1812 a
90 P – Bc	2741 a	4324 a	3745 a	1527 a
S.E.M.	59.3	105.8	245.7	153.2
	Pr > F (p-value)			
Overall F-test	0.599	< 0.001	0.720	0.079
Check vs rest	0.113	0.045	0.340	0.306
Sp vs Sb	0.311	0.006	0.985	0.366
Sp vs Bc	0.519	0.006	0.614	0.803
Sb vs Bc	0.707	0.963	0.627	0.510
Sp – linear	0.146	< 0.001	0.970	0.061
Sp – quadratic	0.859	0.246	0.121	0.231
Sb – linear	0.680	0.228	0.295	0.429
Sb – quadratic	0.123	0.599	0.816	0.447
Bc – linear	0.214	0.567	0.678	0.313
Bc – linear	0.263	0.215	0.623	0.776

[z] P = kg P_2O_5 ha^{-1}; Sp – seed-row placement; Sb – side-band; Bc – pre-seed broadcast

Treatment effects on P concentrations in the seed are presented (for sites where data is available) in Table 9. At Indian Head, while there was no yield response to P fertilization, seed P concentrations increased linearly with P rates for all application methods and was higher overall with fertilization. At Melfort, while the overall F-test was significant the only notable difference amongst the treatments was substantially higher P concentrations with 90 kg ha^{-1} of broadcast P_2O_5. This resulted in an overall linear increase in seed P concentrations for broadcast P ($P < 0.001$) but not side-banded or seed-placed P ($P = 0.51$-0.81) and significantly higher overall P concentrations with broadcast over side-banded P ($P = 0.050$). At Scott, while the check vs. rest contrast was not significant, there was evidence of higher P concentrations with seed-placement relative to side-banding or broadcasting. However, with seed placement the response was quadratic whereby seed P concentrations peaked at 22 kg P_2O_5 ha^{-1} but declined with further rate increases.

Table 9. Treatment means, overall F-test and contrast results for soybean seed phosphorus concentrations. Treatments within a column followed by the same letter do not significantly differ (Tukey's studentized range test, $P \leq 0.05$).

Treatment [Z] / Effect / Contrast	Indian Head	Outlook	Melfort	Scott
	---------- Seed Phosphorus Concentration (% P) ----------			
0 P	0.488 b	—	0.548 b	0.558 ab
22 P – Sp	0.510 ab	—	0.553 b	0.630 a
22 P – Sb	0.518 ab	—	0.533 b	0.590 ab
22 P – Bc	0.520 ab	—	0.493 b	0.563 ab
45 P – Sp	0.530 ab	—	0.525 b	0.605 ab
45 P – Sb	0.538 ab	—	0.520 b	0.528 b
45 P – Bc	0.518 ab	—	0.540 b	0.593 ab
90 P – Sp	0.568 ab	—	0.558 ab	0.575 ab
90 P – Sb	0.578 a	—	0.530 b	0.540 b
90 P – Bc	0.565 ab	—	0.640 a	0.563 ab
S.E.M.	0.0257	—	0.0229	0.017
	---------- Pr > F (p-value) ----------			
Overall F-test	0.020	—	< 0.001	0.009
Check vs rest	0.010	—	0.827	0.314
Sp vs Sb	0.561	—	0.241	0.001
Sp vs Bc	0.907	—	0.399	0.037
Sb vs Bc	0.486	—	0.050	0.166
Sp – linear	0.002	—	0.806	0.952
Sp – quadratic	0.890	—	0.352	0.011
Sb – linear	0.001	—	0.513	0.173
Sb – quadratic	0.748	—	0.393	0.917
Bc – linear	0.005	—	< 0.001	0.752
Bc – linear	0.936	—	0.002	0.209

[Z] P = kg P_2O_5 ha^{-1}; Sp – seed-row placement; Sb – side-band; Bc – pre-seed broadcast

Where available, results for phosphorus exports in the harvested soybean seed are presented in Table 10. Phosphorus was also converted to P_2O_5 for this parameter for easier interpretation. At Indian Head, neither the overall F-test nor the multiple comparisons test detected any individual treatment differences; however, the check vs. rest contrast showed higher overall P exports with fertilizer and the orthogonal contrasts showed a linear increase with increasing P rates for seed-placement and side-banding but not broadcast P. At Melfort, the overall F-test and contrast comparisons were not significant but the orthogonal contrasts indicated a linear increase in P exports with broadcast P (P = 0.011). This was largely due to the elevated seed P concentrations at the highest P rate that was observed at this location as opposed to any effect on yield. While the overall F-test for seed P exports was significant at Scott (P = 0.038), the response was such that values tended to decline when rates of seed-placed P were increased to 45 kg P_2O_5 ha^{-1} or beyond. This appeared to be due to subtly (not significant) lower yields with the higher rates of seed-placed P at this location.

Table 10. Treatment means, overall F-test and contrast results for phosphorus exports (based on seed P concentrations and yield). Means within a column followed by the same letter do not significantly differ (Tukey's studentized range test, $P \leq 0.05$).

Treatment [z] / Effect / Contrast	Indian Head	Outlook	Melfort	Scott
	---------- Phosphorus Exports (kg P_2O_5 ha^{-1}) ----------			
0 P	30.8 a	—	43.9 a	22.8 ab
22 P – Sp	31.3 a	—	46.3 a	28.1 a
22 P – Sb	32.4 a	—	43.3 a	18.9 ab
22 P – Bc	32.7 a	—	44.4 a	20.6 ab
45 P – Sp	32.7 a	—	46.8 a	17.1 b
45 P – Sb	33.9 a	—	44.4 a	21.8 ab
45 P – Bc	33.2 a	—	44.6 a	22.2 ab
90 P – Sp	35.8 a	—	45.1 a	19.4 ab
90 P – Sb	36.2 a	—	45.6 a	22.4 ab
90 P – Bc	33.7 a	—	54.9 a	19.5 ab
S.E.M.	1.78	—	3.46	1.94
	---------- Pr > F (p-value) ----------			
Overall F-test	0.083	—	0.325	0.038
Check vs rest	0.042	—	0.492	0.414
Sp vs Sb	0.382	—	0.514	0.763
Sp vs Bc	0.955	—	0.440	0.636
Sb vs Bc	0.352	—	0.160	0.863
Sp – linear	0.004	—	0.865	0.031
Sp – quadratic	0.642	—	0.488	0.752
Sb – linear	0.004	—	0.628	0.756
Sb – quadratic	0.764	—	0.841	0.368
Bc – linear	0.123	—	0.011	0.301
Bc – linear	0.430	—	0.216	0.894

[z] P = kg P_2O_5 ha^{-1}; Sp – seed-row placement; Sb – side-band; Bc – pre-seed broadcast

e.) List summary of findings, implications, and briefly discuss any conclusions.

Overall, the first year of this project was successful with relatively high soybean yields and all work progressing on schedule. While there were no statistically significant yield increases associated with P fertilization; there was some evidence of reduced plant stands and/or yield reduction with high rates of seed-placed P. Slight reductions in plant density with high rates of seed-placed P at Scott and Melfort did not translate into any yield penalties; however, at Outlook, the lowest yields were attained with 90 kg ha^{-1} placed in the seed-row. While there were no positive yield responses to P fertilization detected, at Indian Head seed P concentrations increased linearly with increasing P rate for all application methods and there was an increase in the amount of P exported in the seed with seed-placement and side-banding but not broadcast P. These results are still preliminary but are not inconsistent with those from a study in Manitoba utilizing the same protocol where yield increases with fertilizer have been rare and reductions in emergence have generally only been observed on coarse soils and the highest application rate. Despite the lack of yield response to P, soybeans require large quantities of this nutrient and application rates should reflect these needs in order to maintain soil productivity over the long-term. Soybeans also respond well to residual P so building up soil levels in the preceding years may be beneficial and, in general, this is a good crop to grow on fields testing

high in residual P.

3. Non-confidential abstract/summary: *This must include overall project objectives, a brief mention of methodology and research design, and a summary of findings for use in publications and on the SPG website. Maximum 500 words in lay language. Please note that this summary will be used as such and no additional permission will be sought from the project applicant to publish the summary.*

A project was initiated in 2015 to investigate soybean response to phosphorus (P) fertilizer rates and placement options under field conditions in Saskatchewan. Field trials are located at Indian Head, Outlook, Melfort and Scott and the treatments are a combination of 3 P fertilizer rates (22, 45 and 90 kg P_2O_5 ha^{-1}) and 3 placement options (seed-placed, side-banded and pre-seed broadcast) plus a control. The specific field protocols being followed were originally developed at the University of Manitoba and are also being implemented at various locations throughout that province. Preliminary results showed some evidence of reduced plant populations with 45-90 kg ha^{-1} of seed-placed P at Melfort and Scott while, at Outlook, effects on emergence weren't significant but yields were lowest at 90 kg P_2O_5 ha^{-1} of seed-placed P. At Indian Head, there were no effects of P rate or placement method on emergence. Regardless of residual soil P levels or placement method, there were no positive yield responses to P fertilization at any sites. Regardless of the observed response to fertilizer, soybeans are recognized as large users of P and, in the current study, average P exports at individual sites ranged from 21-45 kg P_2O_5 (not including Outlook which is expected to have the highest P exports). At Indian Head, P concentrations increased linearly with P fertilizer rates for all placement methods while P exports (determined from seed yields and P concentrations) increased with application rate for seed-placed and side-banded but not broadcast P. This work is continuing at all four locations over the next two growing seasons (2016 and 2017) with funding provided by the Saskatchewan Pulse Crop Development Board.

4. List any technology transfer activities undertaken in relation to this project: *Include conference presentations, posters, papers published, etc.*

The current results have not been presented at any producer meetings or shared through the agricultural press at the time of writing this report; however, the research was introduced and field trials shown at several field days. At Indian Head, the trial was shown to approximately 70 retail agronomists on July 10 and to approximately 200 producers and agronomists on July 21 where John Heard (MAFRI) was invited to discuss P fertilizer considerations for soybeans. The trial was also highlighted at a Faba bean and Soybean tour at Melfort on July 29 which was attended by 75 people.

5. List any changes expected to industry contributions, in-kind support, collaborations or other resources.

There are no confirmed or anticipated changes to industry contributions, in-kind support, collaborations or other resources specifically attributable to this project.

6. Appendices: *Include any additional materials supporting the previous sections, e.g. detailed data tables, maps, graphs, photos, specifications, literature cited, acknowledgments.*

Project Rationale and Review of the Literature

The current research was initiated to determine the best phosphorus fertilizer rates and placement options for soybean production in Saskatchewan in order to help growers produce this crop in the most economically, agronomically and environmentally sustainable manner possible. While still a relatively minor crop province-wide, southeast Saskatchewan saw rapid adoption of this crop and, since then, producers throughout the province have expressed interest in this crop and have been experimenting with it. In Manitoba farmers have adopted soybeans as a major component of their crop rotation, with more than 1 million acres planted in 2013 up to a reported 1.3 million acres in 2015. In Saskatchewan, 2015 soybean acres were estimated at approximately 300,000 acres, up over 11% from the previous year. Soybeans are larger users of P; therefore, sustainable production requires sound management of this nutrient. A study conducted near Carman, Manitoba showed that soybeans require approximately 1.35 lb P2O5 per bushel to grow and, at harvest, remove approximately 1.1 lb P_2O_5 per bushel (Heard 2006). For a 40 bus/ac, or 2700 kg/ha, soybean crop, this is a total P requirement of approximately 50 kg P_2O_5/ha. As such, appropriate P fertilization strategies must be developed and used to ensure high yields of soybeans and other crops in our rotations.

Research in Illinois showed that soybean root distribution was not affected by P fertilizer rate or placement when the fertilizer was broadcast or deep banded prior to seeding (Farmaha et al. 2012), thereby indicating that soybeans are not particularly efficient at seeking out fertilizer P bands with their roots. However, soybeans do yield more in soils with high P fertility than low P fertility (eg. 10-15 more bushels per acre in southern Minnesota, Randall 2012) and this crop makes excellent use of the soil's P reserves (Kalra & Soper 1967). This may be due to the fact that soybeans take up a large portion of their P late in the growing season (Heard 2005) using a fully developed network of roots and mycorrhizal fungi. Currently, there is conflicting evidence as to whether or not soybeans respond better to banded or broadcast P fertilizer or to P fertilizer at all.

Given our relatively cold soils and short growing season compared to more traditional soybean regions like southern Ontario or the US Midwest, farmers in the Canadian Prairies typically place P in or near the seed-row at planting to ensure availability early in the season. However, soybeans are considered sensitive to seed-placed fertilizer, so applying the required amounts of P fertilizer in or near the seed may reduce plant stands. In Argentina, Salvagiotti et al. (2013) found that broadcast or side-banded monoammonium phosphate did not affect plant establishment or nodulation while seed-placement of this fertilizer consistently reduced both variables but did not affect seed yield. Preliminary studies in Manitoba in 2013 and 2014 showed substantial plant stand reductions from seed-placed P in coarse textured soils, but only at 80 lb P_2O_5 per acre with no significant impact on plant stands in clay soils (Bardella et al. 2014). This suggests that soybeans may be less sensitive to seed-placed P in western Canadian soils than anticipated, but caution is still advised particularly in coarse textured soils. Given this uncertainty about seedling sensitivity and the fact that soybeans are large users of P, growers may either face long-term fertility issues or risk seedling injury and possible yield reductions if solely reliant on seed-placed P for this crop. Research in Iowa has shown that soybeans respond to P fertilizer when soil-test P is low and that P uptake tended to be higher with side-banded versus broadcast P; however, again, fertilizer placement did not affect yield (Borges and Mallarino 2000). Due to concerns of seedling toxicity and soybean's inconsistent response to banded P, broadcast P has occasionally been recommended for soybeans and is a particularly good fit to those using planters. The concern is that broadcasting may not be as agronomically efficient as subsurface banding and doing so may leave the P fertilizer vulnerable to runoff losses to surface water, especially if broadcast in fall.

The current project aims to expand upon the current research base by investigating soybean response to P fertilizer rates and placement methods in Saskatchewan with the overall objective of improving P management recommendations for the growing number of soybean producers in this province.

Literature Cited

Bardella, G., Heard, J., Lange, D., Lawley, Y., Grant, C. and Flaten, D. 2014. 4R P Management for soybeans in the northern frontier: Rate and placement effects on plant stand and seed yield. Proc. Manitoba Agronomists Conference. University of Manitoba. Winnipeg, Manitoba. [Online] Available:

http://umanitoba.ca/faculties/afs/agronomists_conf/posters.html [18 Dec. 2014].

Borges, R. and Mallarino, A.P. 2000. Grain yield, early growth, and nutrient uptake of no-till soybean as affected by phosphorus and potassium placement. Agron. J. 92: 380-388.

Farmaha, B., Fernandez, F. and Nafziger, E.D. 2012. Distribution of soybean roots, soil water, phosphorus and potassium concentrations with broadcast and subsurface-band fertilization. Soil Sci. Soc. Am. J. 76: 1079-1089.

Heard, J. 2006. Nutrient uptake and partitioning by soybeans in Manitoba. Proc. Manitoba Agronomists Conference. University of Manitoba. Winnipeg, Manitoba. [Online] Available: http://www.umanitoba.ca/faculties/afs/MAC_proceedings/2006/proceedings.html [27 Nov. 2014].

Kalra, Y.P. and Soper, R.J. 1967. Efficiency of rape, oats, soybeans, and flax in absorbing soil and fertilizer phosphorus at seven stages of growth. Agron. J. 60: 209-212.

Randal, G. 2012. Fertility Management of Soybeans. Proc. Manitoba Agronomists Conference. University of Manitoba. Winnipeg, Manitoba. [Online] Available: http://umanitoba.ca/faculties/afs/agronomists_conf/MAC%20Proceedings%202012.html [27 Nov. 2014].

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Additional Results Tables

Table A-1. Treatment means, overall F-test and contrast results for soybean emergence at T1 (~2 weeks after planting). Means within a column followed by the same letter do not significantly differ (Tukey's studentized range test, $P \leq 0.05$).

Treatment [Z] / Effect / Contrast	Indian Head	Outlook [Y]	Melfort	Scott
	---------- T1 Emergence (plants m^{-2}) ----------			
0 P	45.9 a	—	3.2 a	31.0 a
22 P – Sp	46.3 a	—	3.9 a	21.4 a
22 P – Sb	47.0 a	—	1.1 a	25.1 a
22 P – Bc	47.4 a	—	3.2 a	22.4 a
45 P – Sp	45.3 a	—	2.1 a	13.3 a
45 P – Sb	44.7 a	—	0.0 a	25.9 a
45 P – Bc	43.3 a	—	0.4 a	24.9 a
90 P – Sp	39.6 a	—	0.7 a	23.6 a
90 P – Sb	48.8 a	—	1.1 a	29.5 a
90 P – Bc	49.6 a	—	1.8 a	19.2 a
S.E.M.	3.09	—	1.23	4.36
	---------- Pr > F (p-value) ----------			
Overall F-test	0.565	—	0.208	0.259
Check vs rest	0.964	—	0.174	0.085
Sp vs Sb	0.233	—	0.098	0.047
Sp vs Bc	0.242	—	0.602	0.453
Sb vs Bc	0.982	—	0.245	0.199
Sp – linear	0.119	—	0.060	0.291
Sp – quadratic	0.463	—	0.625	0.013
Sb – linear	0.559	—	0.230	0.989
Sb – quadratic	0.604	—	0.097	0.298
Bc – linear	0.477	—	0.240	0.105
Bc – linear	0.383	—	0.262	0.651

[Z] P = kg P_2O_5 ha^{-1}; Sp – seed-row placement; Sb – side-band; Bc – pre-seed broadcast

[Y] Data not available

Table A-2. Treatment means, overall F-test and contrast results for soybean emergence at T2 (~3 weeks after planting). Means within a column followed by the same letter do not significantly differ (Tukey's studentized range test, $P \leq 0.05$).

Treatment [Z] / Effect / Contrast	Indian Head	Outlook [Y]	Melfort	Scott
	T2 Emergence (plants m^{-2})			
0 P	49.2 a	—	41.2 a	47.5 a
22 P – Sp	49.0 a	—	36.6 a	39.4 a
22 P – Sb	50.7 a	—	26.0 a	33.7 a
22 P – Bc	51.1 a	—	41.9 a	44.6 a
45 P – Sp	50.7 a	—	33.4 a	25.1 a
45 P – Sb	48.4 a	—	28.8 a	46.5 a
45 P – Bc	47.2 a	—	35.9 a	40.8 a
90 P – Sp	45.3 a	—	18.3 a	28.3 a
90 P – Sb	52.1 a	—	28.5 a	47.0 a
90 P – Bc	52.9 a	—	30.3 a	35.0 a
S.E.M.	2.86	—	5.53	6.06
	Pr > F (p-value)			
Overall F-test	0.749	—	0.095	0.126
Check vs rest	0.877	—	0.720	0.142
Sp vs Sb	0.388	—	0.157	0.028
Sp vs Bc	0.390	—	0.080	0.075
Sb vs Bc	0.997	—	0.005	0.646
Sp – linear	0.339	—	0.624	0.025
Sp – quadratic	0.403	—	0.228	0.136
Sb – linear	0.545	—	0.173	0.620
Sb – quadratic	0.671	—	0.118	0.429
Bc – linear	0.457	—	0.830	0.135
Bc – linear	0.446	—	0.820	0.976

[Z] P = kg P_2O_5 ha^{-1}; Sp – seed-row placement; Sb – side-band; Bc – pre-seed broadcast
[Y] Data not available