Production management strategies to improve field pea root health in aphanomyces contaminated soils

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Project Title: Production management strategies to improve field pea root health in aphanomyces contaminated soils

Project Location(s):

- Scott Saskatchewan
- Melfort Saskatchewan
- Swift Current Saskatchewan
- Outlook Saskatchewan

Project start and end dates (month & year): April 2019 and completed February 2020

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Objective:

To demonstrate multiple management strategies to reduce the effect of aphanomyces on field pea root health through root health assessments and overall yield production.

Project Rationale:

Aphanomyces euteiches is an important disease of field peas that is caused by a complex of root pathogens. Cultural and chemical controls are available to reduce the adverse impact of this disease on root development, growth and yield, but none of these practices when used individually are highly effective. Utilizing multiple control strategies including herbicides, seed treatment, fertilizer rates and foliar nutrient applications to limit the effects of aphanomyces may prove the most effective to improve pea root health. This demonstration will help producers identify which management strategies will result in the greatest increase in plant health and consequentially crop yield. The economics of each strategy will be analyzed to aid producers in determining which practice is most productive and cost- effective.

Methodology:

This trial was initiated in the spring of 2019 at four facilities throughout Saskatchewan- WARC (Scott), ICDC (Outlook), NARF (Melfort) and WCA (Swift Current). Each trial was established in a factorial RCBD design with double wide plots with four replications. The factors evaluated were fertility, herbicide, seed treatment, and foliar nutrients for a total of ten treatments (Table 1). The land tested positive for aphanomyces in the spring via soil sample results from Discovery Seed Labs and Agvise for all the sites. At all locations, field peas were direct-seeded into the previous cereal stubble. Seeding difficulties occurred due to the compacted soil conditions that occurred at Melfort. Different yellow pea varieties were grown as per the availability but with a seeding rate of 85 seeds/m^2 and target depths of approximately 2- 2.5 inch depending on equipment and spring soil moisture. Times of the various field operations and crop assist products used at each location are shown in Table A1.

Treatment List:

Table 1. Production management strategies to improve field pea root health in aphanomyces contaminated soils treatment list for Scott, SK in 2019.

TRT	Pre-Seed Herbicide	Fertilizer (lb/ac)	Seed Treatment	Foliar Nutrient
1	Glyphosate	20 P only MAP[1] "Low"	No ST	N/A
2	Glyphosate	20 P only MAP	Vibrance Maxx + Intego	N/A
3	Glyphosate + Trifluralin	20 P only MAP	Vibrance Maxx	N/A
4	Glyphosate + Trifluralin	20 P only MAP	Vibrance Maxx + Intego	N/A
5	Glyphosate + Trifluralin	20 P only MAP	Vibrance Maxx + Intego	Rogue II (Fn)
6	Glyphosate	50 P, 20 K, 10 S[2] "High"	No ST	N/A
7	Glyphosate	50 P, 20 K, 10 S	Vibrance Maxx + Intego	N/A
8	Glyphosate + Trifluralin	50 P, 20 K, 10 S	Vibrance Maxx	N/A
9	Glyphosate + Trifluralin	50 P, 20 K, 10 S	Vibrance Maxx + Intego	N/A
10	Glyphosate + Trifluralin	50 P, 20 K, 10 S	Vibrance Maxx + Intego	Rogue II

Gly= Glyphosate, Tri= Trifluralin, Fertilizer "Low"; "High", ST= Seed Treatment, VM= Vibrance Maxx, I= Intego, Fn= Foliar Nutrient

[1] Low (20P) – application of 20 lb/ac of actual phosphorus (total of 4 lb/ac of nitrogen)

[2] High (50P, 20K, 10S)- application of 50 lb/ac of actual phosphorus, 20 lb/ac of actual potassium, 10 lb/ac of actual sulphur (total of 20lb/ac of nitrogen)

Data Collection:

Plant densities were determined by counting numbers of emerged plants on 2 x 1meter row lengths per plot approximately four weeks after crop emergence. Disease root rating assessments occurred three or four and seven or eight weeks after planting (WAP) on five plants per plot. Timing of ratings depended on soil moisture levels at each location. At seven weeks after seeding the crop stage of the peas was early to mid-flowering. A root disease scale from 0 – 5 was used, where 0 = no symptoms, 1= some clear symptoms observed, 2= symptoms without rot spread more than half of the root; 3= root rot observed on half the root, 4= root rot spread on more than half the root, and 5= root rot spread to the whole root. Yields were determined from cleaned harvested grain samples and corrected to the required moisture content. An economic analysis was conducted to determine which treatment is most economically efficient. Weather data was collected from Environment Canada.

Growing Conditions:

Mean monthly temperatures and precipitation amounts for all locations are listed in Table 2 and 3. The 2019 season was cooler than the long-term average at all sites. Rainfall was below average for all sites except Scott and Swift Current. There was some irrigation applied to the Outlook site which included 8 mm in May, 62.5 mm in June, 45.5 mm in July and 12.5 mm in August.

Table 2. Mean monthly temperature from April to September 2019 at Saskatchewan Trial Locations.

Location	Year	May	June	July	August	September	Average
		----------------------------*Mean Temperature (°C)* -------------------					
Outlook	2019	9.9	16.0	18.0	16.2	NA	15.0
	Long-term	***11.5***	***16.1***	***18.9***	***18.0***	**NA**	**16.1**
Scott	2019	*9.1*	*14.9*	*16.1*	*14.4*	11.3	11.7
	Long-term	***10.8***	***14.8***	***17.3***	***16.3***	**11.2**	**14.1**
Swift Current	2019	*9.5*	*15.8*	*17.7*	*16.8*	NA	14.9
	Long-term	***11***	***15.7***	***18.4***	***17.9***	**NA**	**15.8**
Melfort	2019	8.8	15.3	16.9	14.9	11.2	13.4
	Long-term	**10.7**	**15.9**	**17.5**	**16.8**	**10.8**	**14.3**

Table 3. Precipitation amounts vs long-term (30 year) means for the 2019 growing seasons at Saskatchewan Trial Locations.

Location	Year	May	June	July	August	September	Sum Total
		----------------------------*Precipitation (mm)* -------------------					
Outlook	2019	13.2	90.2	43.8	39.6	NA	186.6
	Long-term	***42.6***	***63.9***	***56.1***	***42.8***	**NA**	**205.4**
Scott	2019	12.7	97.7	107.8	18	41.8	278
	Long-term	***38.9***	***69.7***	***69.4***	***48.7***	**26.5**	**253.2**
Swift Current	2019	13.3	156	11.1	42.6	NA	223
	Long-term	***42.1***	***66.1***	***44***	***35.4***	**NA**	***187.6***
Melfort	2019	18.8	87.4	72.7	30.7	43.0	252.6
	Long-term	**42.9**	**54.3**	**76.7**	**52.4**	**38.7**	**265.0**

Results & Discussion

Plant Densities

Crop emergence slightly varied among locations with Melfort < Swift Current < Scott < Outlook increasing in average plant densities. In general, all sites had an acceptable level of establishment with a minimum plant density of 55 plants/m^2 (Table 4). Melfort had stand establishment issues due to soil compaction variability within the study. This resulted in varied emergence throughout the early spring. However, the plants were able to recover and maturity between plots were similar, indicating a minimal difference in emergence timing.

Table 4. Observed field pea plant densities (plants/m^2) influenced by herbicide, fertilizer, and seed treatment in aphanomyces infected soils at Scott, Outlook, Swift Current, and Melfort SK, 2019.

	Scott	**Outlook**	**Swift Current**	**Melfort**
	Plant Density (plants/m^2)			
Gly + 20 P	70	88	64	63
Gly + 20 P+ VM + I	63	81	69	64
Tri + 20P + VM	74	80	75	67
Tri + 20P + VM + I	74	90	70	55
Tri + 20P + VM + I + FN	69	80	68	62
Gly + 50 P, 20 K, 10 S	66	96	55	58
Gly + 50 P, 20 K, 10 S + VM + I	70	82	66	55
Tri+ 50 P, 20 K, 10 S + VM	70	76	78	58
Tri+ 50 P, 20 K, 10 S + VM + I	67	71	73	61
Tri+ 50 P, 20 K, 10 S + VM + I + FN	75	86	74	60
LSD (0.05)	NS	NS	NS	NS

Gly= Glyphosate, Tri= Trifluralin, Fertilizer “Low”; “High”, ST= Seed Treatment, VM= Vibrance Maxx, I= Intego, Fn= Foliar Nutrient
NS = not significant

Disease Root Ratings

Disease rating 3 WAP were relatively low across all sites with disease levels less than half the roots infected (< 2 out of 5). Disease ratings where the highest at Scott 3 WAP with disease pressure greatest with Gly + 20 P. There was less than a 25% difference from the most infected to the least infected diseased roots observed. Root disease symptoms did not occur at Outlook and was rated < 2 (disease present on less than half to a quarter of the root) at Swift Current and Melfort at 3 WAP (Table 5). Disease pressure was limited at 3 WAP largely due to the dry conditions that persisted at all the sites early on in the growing season (Table 3).

Disease pressure was the greatest at Scott compared to the three other sites. Precipitation exceeded the long-term average by 28 and 38.4 mm in June and July at Scott (Table 3). The increased precipitation likely contributed to the higher root rot reported. There was 63% more disease pressure 8 WAP compared to 3 WAP. The most diseased plants occurred when low fertilizer (20 P) + Gly was used compared to the higher fertilizer applications (50 P, 20 K, 10 S). The least diseased roots were reported with the combination of Gly + 50 P, 20 K, 10 S + VM + I and Tri+ 50 P, 20 K, 10 S + VM + I + FN.

Disease ratings at Outlook were slightly lower than compared to Scott and did not exhibit the same trend noted above. The combination of Tri+ 50 P, 20 K, 10 S + VM + I had slightly more disease than the other combinations and the disease pressure was lowest for the low fertility (20 P) treatments (Table 5). Disease pressure among all treatments was relatively low with less than 8% difference between the most infected and least infected roots. Disease ratings at Swift Current were slightly lower than Outlook and all treatments had very similar root disease ratings that equaled 2.7 to 3.5 (root disease was slightly less than half to slightly greater than half of the root). As ratings were so similar between treatments there can be no trend detected. Disease ratings at Melfort were the lowest regardless of the heavy rainfall that occurred in June (33 mm above long- term average) and on average precipitation in July (Table 3). The disease ratings fluctuated between 0 and 1 (no symptoms to some clear symptoms observed). As symptoms were very minor it is difficult to detect any trends.

Table 5. Observed root rot disease ratings at 3 and 7 weeks after planting (WAP) influenced by herbicide, fertilizer, seed treatment and foliar nutrients applied on field peas seeded in aphanomyces infected soils at Scott, Outlook, Swift Current, and Melfort SK, 2019.

	Scott		**Outlook**		**Swift Current**		**Melfort**	
	Field Pea Disease Rating at 3 & 7 WAP							
Gly + 20 P	1.95	4.75	0	4.3	1.75	3.0	1	0.27
Gly + 20 P+ VM + I	1.55	5	0	4.1	1.45	3.05	1.0	0.33
Tri + 20P + VM	1.55	4.5	0	4.2	1.65	3.05	1.2	0.37
Tri + 20P + VM + I	1.9	4.75	0	4.1	1.35	2.65	1.07	0.1
Tri + 20P + VM + I + FN	1.55	5	0	4.35	1.45	3.45	1	0.05
Gly + 50 P, 20 K, 10 S	1.55	4.5	0	4.2	1.8	2.99	1.05	0.8
Gly + 50 P, 20 K, 10 S + VM + I	1.45	3.75	0	4.4	1.6	2.9	1.15	0.92
Tri+ 50 P, 20 K, 10 S + VM	1.8	4.5	0	4.35	1.55	3.1	1.22	0.32
Tri+ 50 P, 20 K, 10 S + VM + I	1.8	4.5	0	4.45	1.65	3.1	1.1	1.15
Tri+ 50 P, 20 K, 10 S + VM + I + FN	1.6	3.75	0	4.25	1.55	3.25	1.15	0.67
LSD (0.05)	NS	NS	NS	NS	NS	NS	S	NS

Gly= Glyphosate, Tri= Trifluralin, Fertilizer “Low”; “High”, ST= Seed Treatment, VM= Vibrance Maxx, I= Intego, Fn= Foliar Nutrient
NS = not significant

Yield

Yield was not significantly influenced by any of the inputs applied, except at Scott (P =0.0132). Yields at Scott were the lowest compared to all four sites. The very low yields were likely attributed to the intense root disease pressure recorded (Table 5). The highest yields were achieved by adding higher rates of fertilizer (50 P, 20 K, 10 S) to result in a 9 bu/ac yield gain compared to when low fertilizer (20 P) was applied (Table 6). The effect of foliar nutrients, seed treatment, and herbicide are less clear and so is the interaction between these inputs with fertility. The effect of seed treatment, herbicide, foliar nutrient and fertility used alone and in combination become less clear at the three remaining sites as no significant effect was reported. However, certain trends may be noted at each site and when combined as a group.

In Outlook, where the disease levels were similar but slightly lower than at Scott, had much higher yields (on average 44 bu/ac higher). This could indicate that the disease pressure had less of an influence on overall yields at Outlook than at Scott and therefore the effects of the inputs are less obvious at Outlook. The three highest yielding treatments differed by herbicides applied (glyphosate vs. trifluralin), fertility (high vs. low), seed treatment used (Untreated vs Vibrance Maxx vs. Vibrance Maxx and Intego) and the absence and presence of a foliar nutrient applied (Table 6). The highest yields were achieved when two or more inputs (Gly + high fertility, Tri + low fertility and Tri + high fertility) were used in combination (Table 6). The lowest yields occurred when Gly + low fertility (20 P) were used with a 6 bu/ac yield loss.

The three highest yielding input combinations reported at Outlook were two of the lowest yielding at Swift Current. The combination of Tri + low fertility + VM and Gly + high fertility had the lowest yields while the combination of Tri + high fertility + VM, Gly + low fertility + VM + I and Tri + low fertility +VM +I + Fn had the highest yields (Table 6). A common denominator between the three highest yielding treatments was the application of a seed treatment of Vibrance Maxx (VM) with and without Intego (I).

The yield trends at Melfort once again varied from the three previous sites in which the three highest yielding treatments were (1) Gly + high fertility, (2) Gly + low fertility+ VM + I, and (3) Tri+ high fertility + VM. The common factor between the three high yielding treatments where when glyphosate was used in combination with high fertility or seed treatment (VM + I). The lowest yielding treatments were when glyphosate was used with a low fertility (Table 6).

Each location demonstrated a slightly different yield response to the input combinations. To investigate if there was a common thread between all non-responsive sites, yield was combined and compared to the responsive site. Yield (reported at relative yield increases) were compared to the lowest yielding combination of Gly + low fertility (20P) (Figure 1). Three out of five treatments with low fertility resulted in a yield gain while all five treatments with a high fertility component resulted in a yield gain. The high fertility treatments on average resulted in a 26% increase in yield compared to the low fertility treatments. The use of seed treatment and foliar nutrients were quite variable and do not appear to have a consistent effect on yield, particularly when averaged across all three non-responsive sites as Gly + high fertility resulted in the greatest yield gains.

Table 6. Field pea yield (bu/ac) grown under different management strategies including pre-seed herbicide, fertilizer, seed treatment and foliar nutrients in aphanomyces infected soils at Scott, Outlook, Swift Current, and Melfort SK, 2019.

	Scott	**Outlook**	**Swift Current**	**Melfort**
	Yield (bu/ac)			
Gly + 20 P	17	64	34	40
Gly + 20 P+ VM + I	17	64	38	53
Tri + 20P + VM	19	69	34	47
Tri + 20P + VM + I	17	65	36	45
Tri + 20P + VM + I + FN	20	67	38	48
Gly + 50 P, 20 K, 10 S	27	71	33	55
Gly + 50 P, 20 K, 10 S + VM + I	26	66	36	47
Tri+ 50 P, 20 K, 10 S + VM	30	65	38	49
Tri+ 50 P, 20 K, 10 S + VM + I	25	67	35	47
Tri+ 50 P, 20 K, 10 S + VM + I + FN	27	68	37	49
LSD (0.05)	S	NS	NS	NS

Gly= Glyphosate, Tri= Trifluralin, Fertilizer “Low”; “High”, ST= Seed Treatment, VM= Vibrance Maxx, I= Intego, Fn= Foliar Nutrient

NS = not significant; S= significant

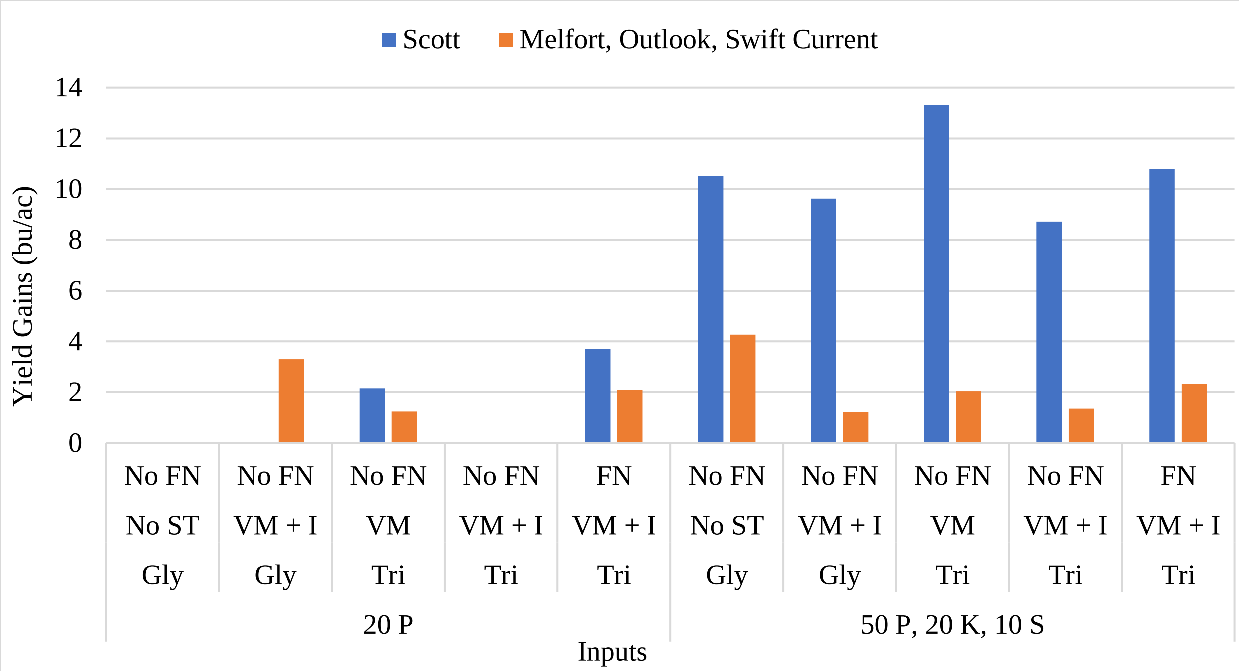

Figure 1. Comparison of the lowest yielding input combination of Glyphosate (Gly) + low fertility (20 P) with no seed treatment (ST) and no foliar nutrient (Fn) to the yields recorded at Scott and the three non-responsive sites (Melfort, Outlook and Swift Current SK) under aphanomyces infected soils.

The most common factor that influenced disease severity and field pea yields was the cultural practice of applying higher fertilizer rates (50 P, 20 K, 10S). The effects of fertilizer, particularly inorganic phosphate, and arbuscular mycorrhizal fungi (AMF) on aphanomyces in pea roots has been studied in previous research (Bodker et al. 1998; Thygesen et al. 2004). Arbuscular mycorrhizas are known to enhance plant uptake of phosphate and improve overall plant vigor (Linderman 1994). This enhanced plant development may increase the buffering or tolerance capacity of field pea roots against soil-borne pathogens (Dehne 1982). Additionally, increased phosphorus concentration in the plant is correlated to a reduction in disease development in peas (Bodker et al. 1998). Thygesen et al. (2004) also found that advanced plant root growth combined with the presence of arbuscular mycorrhizal resulted in increased tolerance to pea root- rot diseases. The current results correspond with the previous research in which higher rates of fertilizer (P) resulted in slightly reduced disease pressure and higher yields at Scott and to a lesser effect at when averaged at Melfort, Swift Current and Outlook SK.

A chemical management strategy of applying a dinitroaniline herbicide such as trifluralin was also found to be an effective strategy in previous studies (Katan and Eshel 1973; Grau and Reiling 1976; Teasdale et al. 1997; Harvey et al. 1975). Harvey et al. (1975) reported higher yields when peas were grown in aphanomyces infected soils treated with trifluralin. It was concluded that the root disease and disease severity was reduced with application of trifluralin to result in higher yields. A more recent study by Teasdale et al. (1997) reported that an application of a dinitroaniline herbicide would inhibit the production of motile zoospores, the infecting propagule of the pathogen. The study indicated that the inhibition of the pathogen motility resulted in a 2- week delay of the infection. This delay resulted in additional plant growth that allowed the peas to better withstand the effects of subsequent disease development. The effects of trifluralin in the current study was less effective than previous studies reported but overall trends indicate that infection may have been slightly delayed. The variability in efficacy recorded at all of the sites could be attributed to application errors and soil condition restrictions. In order for trifluralin to be effective as a spring pre-seed application it must be applied and incorporated within 24 hours after application due to it's high sensitively to volatilization. The depth, angle and timing of incorporation may also influence the efficacy of trifluralin. Environmental conditions such as soil temperature and soil moisture also influence the rate of activity and degradation. Furthermore, depth of seed placement and amount of plant residue may play a role in its efficacy. The effect of trifluralin on both disease levels and yield was quite variable amongst all sites and could be attributed to the multiple factors explained above. Although the application of trifluralin did not significantly influence disease pressure or yield, the combination of trifluralin and high fertility rates may have a promising effect. It was anticipated that combining the two above management strategies would further reduce disease severity and improve yield production. This combination resulted in the two highest yields at Scott, the highest at Swift Current and the third and fourth highest yields at Outlook. Combining multiple techniques may prove useful as the combination of delayed infection and improved disease tolerance may result in more robust plants.

The use of seed treatment that targets root rot complexes was anticipated to improve the buffering capacity of peas to aphanomyces. However, the effects of seed treatments were quite variable and the only time a positive trend was reported was at Swift Current. The efficacy of the seed treatment may have been influenced by the environmental conditions as the spring was quite dry at all locations. The use of seed treatments is best utilized under wet, moist conditions conducive for disease development within the first few weeks of application. As moisture in all locations was delayed until June, the benefits of a seed treatment had likely dissipated by mid-summer and therefore had little bearing on the degree of aphanomyces infection on peas.

The least effective method to managing aphanomyces on field peas was the application of a foliar nutrient. There is little research to support the effects of a foliar nutrient and this study has provided little evidence of its intended benefits. The application of foliar nutrients may help improve late season vigor but overall its effect was minimal and variable amongst all locations.

Economic Analysis

The most profitable and effective input combination to manage aphanomyces was the application of trifluralin + high fertility (50 P, 20 K, 10 S) + Vibrance Maxx. This combination was equally as profitable as the Gly + high fertility (50 P, 20 K, 10 S), however, this combination holds less promise to improve field pea tolerance to aphanomyces.

When all the non-responsive sites were combined the most profitable combination was once again Gly + high fertility (50 P, 20 K, 10 S). When all the sites were combined the most profitable combination was Gly + high fertility (50 P, 20 K, 10 S) followed by trifluralin + high fertility (50 P, 20 K, 10 S) + Vibrance Maxx.

Table 7. Economic analysis (net profit) of field pea yield grown under different management strategies including pre-seed herbicide, fertilizer, seed treatment and foliar nutrients in aphanomyces infected soils at Scott, Outlook, Swift Current, and Melfort SK, 2019.

	Scott	**Melfort, Outlook & Swift Current**	**All Sites Combined**
		Net Profit ($/ ac)	
Gly + 20 P	127.24	415.24	325.24
Gly + 20 P+ VM + I	93.24	408.24	327.24
Tri + 20P + VM	118.17	397.17	325.17
Tri + 20P + VM + I	84.17	372.17	300.17
Tri + 20P + VM + I + FN	95.52	374.52	302.52
Gly + 50 P, 20 K, 10 S	**192.34**	**426.34**	**372.34**
Gly + 50 P, 20 K, 10 S + VM + I	149.34	365.34	311.34
Tri+ 50 P, 20 K, 10 S + VM	**192.27**	381.27	336.27
Tri+ 50 P, 20 K, 10 S + VM + I	131.27	356.27	302.27
Tri+ 50 P, 20 K, 10 S + VM + I + FN	133.62	349.62	295.62

Gly= Glyphosate, Tri= Trifluralin, Fertilizer “Low”; “High”, ST= Seed Treatment, VM= Vibrance Maxx, I= Intego, Fn= Foliar Nutrient
NS = not significant; S= significant

Conclusions and Recommendations

In general, plant densities were acceptable at all locations and had a minimum density of 55 plants/m^2. Disease ratings 3 WAP were relatively low across all sites with disease levels less than half of the roots infected. Disease pressure at Scott 3 WAP were the highest among all sites and the greatest disease symptoms were observed with glyphosate + 20 P. Root disease symptoms did not occur at Outlook and was rated < 2 (disease present on less than half to a quarter of the root) at Swift Current and Melfort at 3 WAP. Disease pressure was limited at 3 WAP largely due to the dry conditions that persisted at all the sites early on in the growing season. Disease ratings were highest at Scott and increased by 63% compared to 3 WAP. The most diseased plants occurred when low fertilizer (20 P) + Gly was used compared to the higher fertilizer applications (50 P, 20 K, 10 S). Disease ratings at the three remaining sites ranged from very low (0-1) to moderate (2-4) with Outlook exhibiting the second highest disease ratings. The trends observed at the three locations varied amongst each other and in comparison, to the most diseased site (Scott SK). In general, it is difficult to confirm a treatment effect based on the disease ratings alone.

Yield was not significantly influenced by any of the inputs applied, except at Scott (P =0.0132). The highest yields at Scott were achieved by adding higher rates of fertilizer (50 P, 20 K, 10 S) to result in a 9 bu/ac yield gain compared to when low fertilizer (20 P) was applied. The effect of foliar nutrients, seed treatment, and herbicide are less clear and so is the interaction between these inputs with fertility. The effect of seed treatment, herbicide, foliar nutrient and fertility used alone and in combination become less clear at the three remaining sites as no significant effect was reported. The yield at the three non-responsive sites were combined and compared to the response site (Scott, SK). Yield gains were compared to the lowest yielding combination of Gly + low fertility (20P). The high fertility treatments on average resulted in a 26% increase in yield compared to the low fertility treatments. The combination of higher fertility with trifluralin was anticipated to provide the greatest yield and crop tolerance to aphanomyces. This combination resulted in the two highest yields at Scott, the highest at Swift Current and the third and fourth highest yields at Outlook. In contrast, the use of seed treatment and foliar nutrients were quite variable and do not appear to have a consistent effect on yield, particularly when averaged across all three non-responsive sites as Gly + high fertility resulted in the greatest yield gains. All sites were combined to determine the most profitable combination: Gly+ high fertility (50 P, 20 K, 10 S) followed by trifluralin + high fertility (50 P, 20 K, 10 S) + Vibrance Maxx.

When looking at disease management options in terms of effectiveness and profitability the three most important strategies should include (1) proper fertilization (higher than the current standard of 20 lb/ac of P_2O_5), (2) applications of trifluralin to reduce disease and weed pressure and (3) the application of seed treatments in a wet, cold spring. As this was a dry spring with little disease in the early growing season the effects of seed treatment may not have been reported to its fullest potential. Combining multiple techniques may prove useful as the combination of delayed infection and improved disease tolerance may result in more robust plants. Additional research is required to confirm the most effective and profitable combination of field peas grown under aphanomyces infected soils.

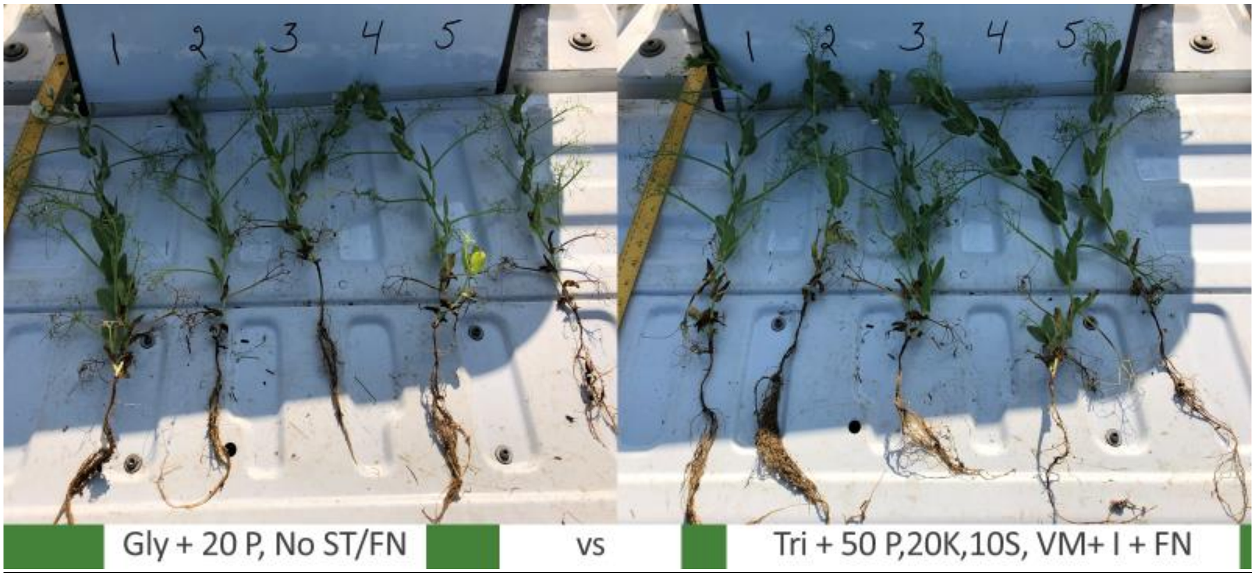

Figure 2. Comparison at 8 WAP of field pea roots grown on aphanomyces infected soils treated with Glyphosate and 20 lb/ac of P_2O_5 (left) compared to trifluralin, high fertility application rates (50 P, 20K, 10S), Vibrance Maxx + Intego and foliar nutrients (right).

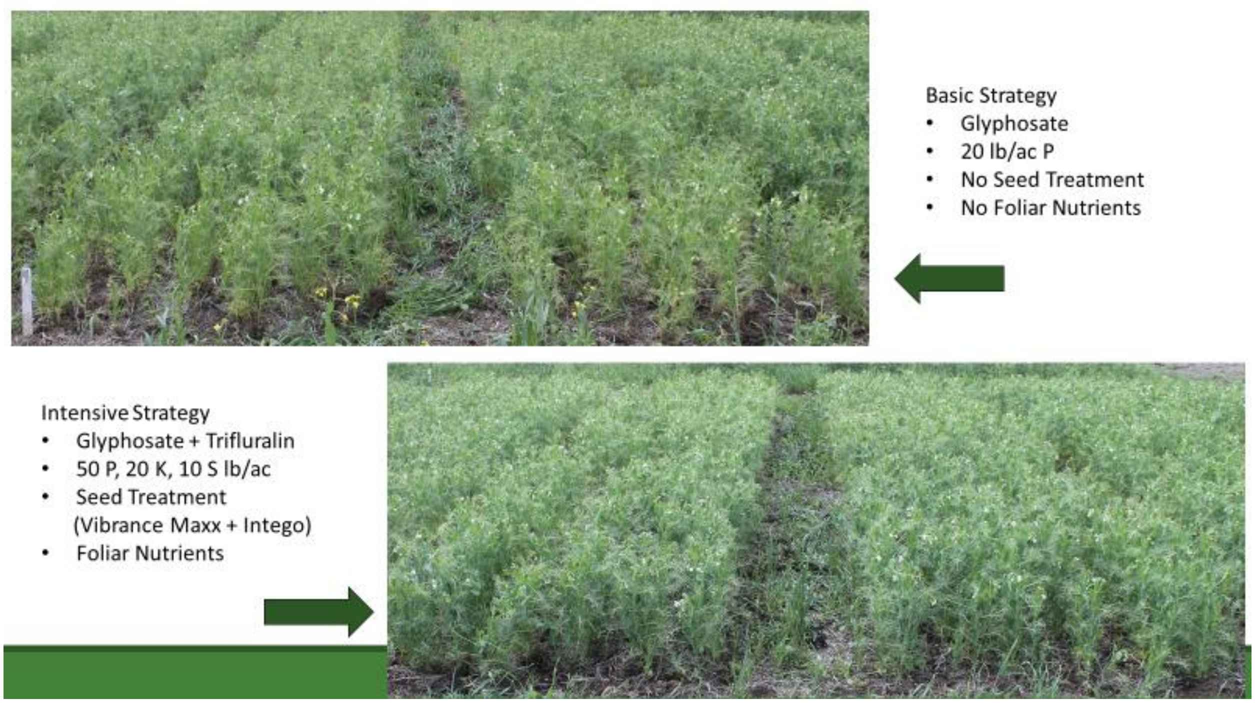

Figure 3. Comparison at 8 WAP of field peas grown on aphanomyces infected soils treated with Glyphosate and 20 lb/ac of P_2O_5 (left) compared to trifluralin, high fertility application rates (50 P, 20K, 10S), Vibrance Maxx + Intego and foliar nutrients (right).

Supporting Information

Acknowledgements

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Appendices

Appendix A

Table A1. Times of operations and crop input products utilized by all locations.

Activity	Location			
	Scott	**Outlook**	**Swift Current**	**Melfort**
Stubble Selection	Canola	Wheat	Durum	Wheat
Pre-seed Herbicide Application	May 24 (Glyphosate 540 @ 1L/ac + Trifuralin 480 EC @ 0.65 L/ac)	May 6 (Glyphosate 540 @ 1L/ac + Trifuralin 480 EC @ 0.65 L/ac)	May 16 (Trifluralin 480 EC @ 690 ml/ac)	May 23 (Trifuralin 480 EC @ 930 ml/ac) + May 30 (Glyphosate 540 1 L/ac)
Seed Treatment	May 28 (Vibrance Maxx @ 325ml/100kg & Vibrance Maxx + Intego @ 325ml/100kg	May 9 (Vibrance Maxx RFC @100 ml/100 kg + INTEGO Solo @ 19.6 ml/100 kg	May 17 (Vibrance Maxx @ 325ml/100kg & Vibrance Maxx + Intego @ 325ml/100kg	May 27 (Vibrance Maxx @ 325ml/100kg & Vibrance Maxx + Intego @ 325ml/100kg
Variety	Arbarth	CDC Inca	CDC Inca	AC Carver
Seeding date	May 28	May 9	May 17	May 27
In-crop Herbicide Application	June 27 (Viper ADV @ 400 ml/ac + UAN @ 0.81 L/ac)	Viper ADV @ 400 ml/ac + UAN @ 0.81 L/ac	June 12 (Viper ADV @ 400 ml/ac + UAN @ 0.81 L/ac)	June 27 (Viper ADV @ 400 ml/ac) + July 5 (Assure II 300 ml/ac)
In-crop Fungicide Application	N/A	Priaxor @ 180 ml/ac	N/A	July 12 (Acapella @ 325 ml/ac)
Desiccation	Aug 20 (Roundup 540 @ 1 L/ac + Aug 28 Reglone Ion @ 0.83 L/ac)	Aug 15 (Reglone Ion @ 0.83 L/ac @ 20gpa	N/C	Sept 16 (Glyphosate 540 @ 0.67 L/ac + Heat LQ @ 59 ml/ac)
Harvest	Sept 5	Aug 21	Aug 20	Sept 23

NA = Not applied
NC = Observation not captured

Abstract

A study was initiated to demonstrate multiple management strategies to reduce the effect of aphanomyces on field pea root health through root health assessments and overall yield production. The demonstration was arranged as a randomized complete block design, doubled wide, with four replicates at Scott, Outlook, Swift Current and Melfort SK 2019. The factors evaluated were herbicide (glyphosate vs. trifluralin), seed treatment (none vs. Vibrance Maxx vs. Vibrance Maxx + Intego), fertility (20 P_2O5 vs. 50 P_2O5, 20 K, 10S) and foliar nutrient application for a total of 10 treatments. Disease ratings 3 WAP were relatively low across all sites. Disease ratings were highest at Scott and increased by 63% at 7 WAP compared to 3 WAP. The most diseased plants occurred when low fertilizer (20 P) + Gly was used compared to the higher fertilizer applications (50 P, 20 K, 10 S). Disease ratings at the remaining sites (Melfort, Swift Current and Outlook) ranged from very low (0-1) to moderate (2-4) with Outlook exhibiting the second highest disease ratings. The trends observed at the three locations varied amongst each other and in comparison, to the most diseased site (Scott SK). In general, it is difficult to confirm a treatment effect based on the disease ratings alone. Yield was not significantly influenced by any of the inputs applied, except at Scott (P =0.0132). The highest yields at Scott were achieved by adding higher rates of fertilizer (50 P, 20 K, 10 S) compared to when low fertilizer (20 P) was applied. The average yield of the three non-responsive sites resulted a 26% increase when high fertilizer rates were used compared to low. The two most profitable combinations when averaged across all sites were Gly+ high fertility (50 P, 20 K, 10 S) and Tri + high fertility (50 P, 20 K, 10 S) + Vibrance Maxx. The most promising and profitability inputs to utilize are high rates of fertilizer, trifluralin and seed treatments. Combining multiple techniques may prove useful as the combination of delayed infection and improved disease tolerance may result in more robust plants. Additional research is required to confirm the most effective and profitable combination of field peas grown under aphanomyces infected soils.

Extension Activities:

The preliminary results of this study were presented at the Australian Seminar in Horsham, October 2019 with approximately 50 people in attendance. The results were also shared by Sherrilyn Phelps, Saskatchewan Pulse Growers at various grower extension events (+200 to date) as well as at the Agronomy Research Update 2019 (250 attendees), and at CropSphere (150 attendees). A fact sheet will also be generated and distributed on the WARC website as well as all Agri-ARM and WARC events to ensure the information will be transferred to producers.The trial at Swift current was promoted on a CKSW radio program called "Walk the Plots" that was broadcasted on a weekly basis throughout the summer and may also be highlighted by Bryan Nybo, Wheatland Conservation Area at the Swift Current Winter Pulse Meetings on February 27, 2020.

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<u>Finances</u>

Expenditure Statement

Expenditure information for *Production management strategies to improve field pea root health in aphanomyces contaminated soils* at Scott, Melfort, Swift Current and Outlook, SK in 2019. Saskatchewan Pulse Growers submitted application on behalf of the AgriARM sites (AP-19-04a).				
	Total funds required for the project	ADOPT Funds requested Year 1	ADOPT Funds requested Year 2	Total ADOPT Funds requested
Salaries and Benefits				
Students				
Postdoctoral / Research Associates				
Technical / Professional Assistants				
Consultant Fees & Contractual Services	$38650	$38650		$38650
Rental Costs				
Rentals				
Materials / Supplies				
Project Travel				
Field Work				
Collaborations/consultations				
Other (SPG in kind)				
Develop and format fact sheet	$4000			
Administration	$1000			
Travel for site visits/tours	$1500			
Total	$45150	$38,650		$38,650

The consultant fees and contractual services budget provided is based on four collaborating sites at $9,550 per site with an additional $450 directed to WARC for data analyses and reporting. The budget may be revised depending on the number of sites funded. Within the $38,650 the individual costs are:

1) Salaries - Technical/professional staff and student/term staff required to undertake field trials, project reporting and extension activities. Includes $9,600 for students and $14,400 for technical and professional assistants. An additional $450 will be allocated to WARC for data analysis and reporting.
2) Rental Costs: The rental costs will cover the cost to rent land with confirmed aphanomyces. This will be off-site for the locations. This will cost $1,500 per location.
3) Materials & supplies - Miscellaneous research supplies, land use, equipment depreciation and maintenance, crop inputs, and extension costs totalling an estimated $4,000.
4) Field work: As the rented land is located off-site, there will be costs associated with driving and transporting equipment to an off-site location, as well as costs to sanitize contaminated equipment. Each site is allocated $750.
5) Administration - To cover administration costs of the participating organizations ($1,200)