

Production Management Strategies to Improve Field Pea Root Health in *Aphanomyces*-Contaminated Soils

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Introduction

Aphanomyces Root Rot (ARR), caused by the pathogen *Aphanomyces euteiches*, is the most serious root disease faced by Saskatchewan field pea growers, and can lead to high yield losses, especially in wet years. Once a field has been infected with *A. euteiches*, little can be done to treat the crop and save yield. Proactive management strategies that improve pea root health may reduce the impact of *A. euteiches* when infection takes place. No single practice such as herbicide or seed treatment use, foliar nutrient application, or increasing fertility rates has been proven as a silver bullet for managing this difficult root rot. However, certain combinations of these management strategies may improve root health and reduce the impact of *A. euteiches* infection more than others. The aim of this research was to demonstrate the impact of different combinations of root health management strategies on *A. euteiches* infection, pea yield, and economic returns to give field pea growers strategies to manage ARR on their farms.

Key Findings

- Root rot disease ratings were low at all sites in the early season in 2019 and throughout 2021 due to dry conditions. Root disease infection was high at the mid-season assessment at Scott in 2019 due to high June and July rainfall and at Outlook in 2021 due to higher soil moisture from irrigation.
- The different combinations of fertilizer (20 lb P/ac versus 50 lb P, 20 lb K, and 10 lb S/ac), herbicide (glyphosate versus trifluralin), seed treatment (none, versus Vibrance® Maxx, versus Vibrance® Maxx plus Intego™), and a foliar nutrient (Rogue II™) did not significantly increase or decrease root rot ratings at any site in any year.
- Root rot infection ratings tended to be lower with higher fertility treatments; however, results were not significant.
- Yield results were significant only at Scott in 2019. Yield differences were attributed to fertility, as high fertility treatments yielded 9 bushels per acre (bu/ac) more than low fertility treatments.
- Yield trends (not statistically significant) indicated a 3 to 16 bu/ac yield benefit from higher fertility rates compared to the low fertility treatments at six of eight site-years.
- Seed treatment was included in the highest yielding treatment combination at four of eight site-years, with Vibrance® Maxx and Intego™ showing a benefit over Vibrance® Maxx alone at two of four winning sites.
- Trifluralin was included in the highest yielding treatment combination in two of eight site-years. Foliar nutrient application was not a part of the highest yielding treatment combination at any site-year.
- The most profitable treatment when combining the average of all site-years was glyphosate with 50 lb P, 20 lb K, and 10 lb S/ac.
- Recommendations for growing peas in *A. euteiches*-infected soil

include use of fertilizer rates above 20 lb P/ac, suggesting 50 lb P, 20 lb K, and 10 lb S/ac as a starting point. Application of herbicides to reduce weed pressure and seed treatments in cold, wet springs is also recommended.

Research Methodology

This research took place in 2019 and 2021 at research facilities in Scott, Outlook, Melfort, and Swift Current, Saskatchewan. Field trials were setup in a factorial randomized complete block design (RCBD) with double wide plots and four replications for each treatment. See Table 1 for treatment descriptions, including pre-seed herbicide, fertilizer, seed treatments, and foliar nutrients.

Soil was tested for *A. euteiches* each spring before seeding and *A. euteiches* was detected at each site in both years. Yellow peas were direct seeded into standing stubble, at 85 seeds/m² (8 seeds/ft²). Seed depth was 2 to 2.5 inches depending on site equipment and moisture. The pea variety used differed at each site based on local seed availability (Table 2).

Table 1. Treatment list of pea root health management strategies in *Aphanomyces euteiches*-contaminated soils

Treatment Number	Treatment Factors				Treatment Abbreviation
	Pre-Seed Herbicide	Fertilizer (lb/ac)	Seed Treatment	Foliar Nutrient	
1	Glyphosate	20 P only MAP1	No ST	N/A	Gly+20P
2	Glyphosate	20 P only MAP	Vibrance® Maxx + Intego™	N/A	Gly+20P+VM+I
3	Glyphosate + Trifluralin	20 P only MAP	Vibrance® Maxx	N/A	Gly+Tri+20P+VM
4	Glyphosate + Trifluralin	20 P only MAP	Vibrance® Maxx + Intego™	N/A	Gly+Tri+20P+VM+I
5	Glyphosate + Trifluralin	20 P only MAP	Vibrance® Maxx + Intego™	Rogue II™	Gly+Tri+20P+VM+I+Fn
6	Glyphosate	50 P, 20 K, 10 S2	No ST	N/A	Gly+50P,20K,10S
7	Glyphosate	50 P, 20 K, 10 S	Vibrance® Maxx + Intego™	N/A	Gly+50P,20K,10S+VM+I
8	Glyphosate + Trifluralin	50 P, 20 K, 10 S	Vibrance® Maxx	N/A	Gly+Tri+50P,20K,10S+VM
9	Glyphosate + Trifluralin	50 P, 20 K, 10 S	Vibrance® Maxx + Intego™	N/A	Gly+Tri+50P,20K,10S+VM+I
10	Glyphosate + Trifluralin	50 P, 20 K, 10 S	Vibrance® Maxx + Intego™	Rogue II™	Gly+Tri+50P,20K,10S+VM+I+Fn

Gly=glyphosate, Tri=trifluralin, ST=Seed Treatment, VM=Vibrance® Maxx, I=Intego™, Fn=Foliar Nutrient
 1 20 P treatment: application of 20 lb/ac of actual phosphorus (4 lb/ac of nitrogen from MAP fertilizer)
 2 50 P, 20K, 10S treatment: application of 50 lb/ac of actual phosphorus, 20 lb/ac of actual potassium, 10 lb/ac of actual sulphur (20lb/ac of nitrogen in blend from MAP and AMS fertilizers)

Table 2. Variety, Seeding and Harvest Dates by Location in 2019 and 2021

Activity	Location							
	Scott		Outlook		Swift Current		Melfort	
	2019	2021	2019	2021	2019	2021	2019	2021
Variety	Abarth		CDC Inca		CDC Inca		AAC Carver	CDC Spectrum
Seeding date	May 28	May 12	May 9	May 18	May 17	May 17	May 27	May 27
Harvest	Sept 5	Aug 5	Aug 21	Aug 13	Aug 20	Aug 20	Sept 23	Aug 17

Why these treatments?

- Increased fertilizer rates:** Previous studies on the impact of phosphate fertilizer and arbuscular mycorrhizal fungi (AMF) on *A. euteiches* in pea roots showed AMF increase plant phosphorus uptake, improve plant vigour, and increase root disease tolerance. Increased plant P concentration may reduce development of *Aphanomyces* root rot in peas.
- Trifluralin herbicide:** Previous research had shown improved pea yield on *A. euteiches*-infected soil with use of dinitroaniline herbicides such as trifluralin. Dinitroaniline herbicides may inhibit production of root-infecting zoospores, which delays root infection by two weeks, allowing peas to grow stronger before infection.
- Seed treatments:** Vibrance® Maxx seed treatment provides early season protection from other diseases that affect the root health of field peas including *Fusarium spp.*, *Pythium spp.*, and *Rhizoctonia spp.* Use of this seed treatment is expected to improve root health and reduce the impact of *A. euteiches*. Intego™ Solo seed treatment directly suppresses *A. euteiches*.
- Foliar nutrients:** Little research exists to support the impact of foliar nutrient applications on pea root health in *A. euteiches*-infected soils. The rationale for applying foliar nutrients is to improve overall plant health and vigour to in turn reduce the impact of *Aphanomyces* root rot.

Plant stand density, root disease level, yield, and profitability were assessed to compare the effect of the ten different treatments on pea root health. Plant stand counts were taken four weeks after emergence on 2 x 1 meter row lengths per plot (ten per treatment). Root disease was rated at the six-node stage, which took place three weeks after planting (WAP) in 2019 and 5 WAP in 2021. A second rating was done at 7 to 8 WAP, at early to mid-flowering. Disease ratings were performed on five plants per plot. Roots were rated on a scale from 0-5. See Table 3 for the symptom criteria for each rating level. Yield was based on cleaned harvested grain samples corrected to 16% moisture. Net profit of each treatment was calculated to compare economic benefits between treatments.

Table 3. Rating scale for assessment of root rot disease severity

Rating	Rating Level Symptom Criteria
0	No symptoms
1	Some clear root rot symptoms
2	Root rot symptoms on less than half of the root
3	Root rot on half the root
4	Root rot on more than half of the root
5	Root rot spread to entire root

Growing Season Conditions

Soil moisture is required for ARR to develop in pea roots. Warm temperatures also contribute to infection to a lesser degree. Rainfall was below average at all locations for both years except for Scott and Swift Current in 2019 (Table 4). On top of rainfall, Outlook received 128.5 mm of irrigation in 2019 and 213 mm in 2021 to match crop demand. Rainfall was higher in 2019 at all sites as 2021 was a record dry season. Based on these conditions, disease ratings should be higher in 2019 than in 2021. Regarding temperature, the 2019 season was cooler than the long-term average at all sites, whereas 2021 was above average.

Table 4. Precipitation amounts vs long-term (30 year) means for the 2019 growing seasons at Saskatchewan Trial Locations.

Location	Year	May	June	July	August	Sept	Average
		Mean Precipitation (mm)					
Outlook*	2019	13.2	90.2	43.8	39.6	NA	186.6
	2021	44.5	10.3	13.8	37.7	0.2	106.5
	Long-term	43.2	69.3	57.6	44.2	32.7	247.0
Scott	2019	12.7	97.7	107.8	18	41.8	278
	2021	43.9	43.8	10.4	51.3	NA	150.1
	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
	2021	35	29.6	38.9	55.8	NA	159.3
	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
	2021	31.4	37.6	0.2	69.3	7.5	146
	Long-term	42.9	54.3	76.7	52.4	38.7	265.0

*Plus irrigation

Table 5. Mean monthly temperature from April to September 2019 at Saskatchewan Trial Locations.

Location	Year	May	June	July	August	Sept	Average
		Mean Temperature (°C)					
Outlook	2019	9.9	16.0	18.0	16.2	NA	15.0
	2021	10.2	18.6	21.6	17.9	NA	17.1
	Long-term	11.5	16.1	18.9	18	NA	16.1
Scott	2019	9.1	14.9	16.1	14.4	11.3	11.7
	2021	8.9	17.3	19.6	17.2	NA	13.3
	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
	2021	9.5	18.4	21.7	18	NA	16.9
	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
	2021	9.6	18.2	20.1	16.9	14	15.8
	Long-term	10.7	15.9	17.5	16.8	10.8	14.3

Results

Plant Stand Density

Plant stand density was adequate for all site years and was higher in 2021 than in 2019. Plant counts did not vary between the herbicide, fertilizer, and seed treatments at any site in either year.

Root Disease Ratings

Severity and incidence of ARR varied among years and between locations at both disease ratings (3 to 5 WAP and 8 WAP) (Table 6). Treatments did not differ in disease ratings for any individual site or year. Root disease in the 3 to 5 WAP rating was similar between years due to similar levels of early season precipitation. Disease pressure was higher for the second disease rating in 2019 than 2021 due to the onset of drought conditions in 2021. In both seasons disease ratings were higher at Scott and Outlook than Melfort and Swift Current.

In 2019, the disease ratings taken 3 WAP were at disease levels (0 to 5) less than 2, whereas ratings taken at 7 to 8 WAP were above 3 at most sites. The increase in root disease is likely due to higher rainfall in June and July compared to May. Scott had the highest root rot levels at both disease ratings. At 3 WAP disease levels at Scott were rated between 1.5 and 2.0, with the highest levels in treatment 1 (Gly + 20 P). Disease levels at Swift Current were between 1.4 and 1.8. Melfort was at 1.0 to 1.2, with no root disease present at Outlook.

At 8 WAP in 2019, disease levels at Scott were between 3.8 and 5, indicating high disease incidence and severity. Root rot was higher in treatments 1 to 5, which received low fertility (20 P). At Outlook, disease levels were from 4.1 to 4.5, slightly higher in treatments 7 to

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10, which all had seed treatment (VM or VM + I) and high fertility (50P, 20K, 10S). At Swift Current, disease levels were at 2.7 to 3.5, and ranged from 0.1 to 1.2 at Melfort, with no detected trend at either site.

In 2021, cool spring temperatures delayed crop development and the first disease rating took place at 5 WAP. Disease levels were highest at Outlook, at 0.4 to 1.4, due to higher soil moisture from irrigation. The treatment with the highest root rot rating was treatment 2 (Gly + 20 P + VM + I). Scott's ratings ranged from 0.1 to 0.4 with Melfort's from 0 to 0.4. Treatment 1 (Gly + 20 P) was highest at Scott and

treatment 5 (Gly + Tri + 20 P + VM + I + Fn) was highest at Melfort. All treatments were rated 0 at Swift Current.

As in 2019, disease levels were higher in the second than the first disease rating. The 8 WAP ratings were again highest at Outlook (3.3 to 4), followed by Scott (1.4 to 2.6), and Melfort (0.1 to 1.1). No root rot was detected at Swift Current due to low soil moisture. As in the 5 WAP rating at Outlook, treatment 2 (Gly + 20 P + VM + I) had the highest disease levels, with treatment 7 (Gly + 50 P, 20 K, 10 S + VM + I) rated as the lowest. Disease was highest in treatment 1 (Gly + 20 P) at Scott, and in treatment 6 (Gly + 50 P, 20 K, 10 S) at Melfort.

Table 6. Observed root rot disease ratings by treatment at 3 to 5 and 7 to 8 weeks after planting (WAP) at Scott, Outlook, Swift Current, and Melfort, SK in 2019 and 2021

Treatments	2019								2021								Combined 2019		Combined 2021		Combined 2019+2021	
	Scott		Outlook		Swift Current		Melfort		Scott		Outlook		Swift Current		Melfort		I	II	I	II	I	II
	I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II
1. Gly + 20 P	2.0	4.8	0	4.3	1.8	3.0	1.0	0.3	0.4	2.6	1.0	3.8	0	0	0.2	0.6	0.4	3.3	0.5	2.3	0.4	2.4
2. Gly + 20 P + VM + I	1.6	5.0	0	4.1	1.5	3.1	1.0	0.3	0.1	2.1	1.4	4.1	0	0	0.0	0.4	0.4	3.3	0.5	2.2	0.3	2.4
3. Tri + 20P + VM	1.6	4.5	0	4.2	1.7	3.1	1.2	0.4	0.1	2.3	0.4	3.6	0	0	0.1	1.1	0.4	3.2	0.2	2.3	0.2	2.4
4. Tri + 20P + VM + I	1.9	4.8	0	4.1	1.4	2.7	1.1	0.1	0.2	1.7	1.2	3.6	0	0	0.1	0.4	0.4	3.1	0.5	1.9	0.3	2.2
5. Tri + 20P + VM + I + FN	1.6	5.0	0	4.4	1.5	3.5	1.0	0.1	0.2	2.1	0.6	4.0	0	0	0.4	0.4	0.4	3.1	0.4	2.2	0.3	2.4
6. Gly + 50 P, 20 K, 10 S	1.6	4.5	0	4.2	1.8	3.0	1.1	0.8	0.2	2.4	0.7	3.9	0	0	0.2	0.8	0.3	3.1	0.4	2.3	0.3	2.5
7. Gly + 50 P, 20 K, 10 S + VM + I	1.5	3.8	0	4.4	1.6	2.9	1.2	0.9	0.4	2.3	0.5	3.3	0	0	0.1	0.4	0.3	3.0	0.3	2.0	0.3	2.2
8. Tri + 50 P, 20 K, 10 S + VM	1.8	4.5	0	4.4	1.6	3.1	1.2	0.3	0.2	1.6	0.4	3.7	0	0	0.0	0.5	0.3	3.0	0.2	1.9	0.3	2.3
9. Tri + 50 P, 20 K, 10 S + VM + I	1.8	4.5	0	4.5	1.7	3.1	1.1	1.2	0.2	1.6	0.7	3.9	0	0	0.0	0.1	0.3	3.0	0.3	1.8	0.3	2.3
10. Tri + 50 P, 20 K, 10 S + VM + I + FN	1.6	3.8	0	4.3	1.6	3.3	1.2	0.7	0.1	1.4	0.6	3.8	0	0	0.1	0.4	0.3	2.9	0.3	1.8	0.3	2.2
LSD (0.05)	NS	NS	-	NS	NS	NS	NS	NS	NS	NS	NS	NS	-	-	NS	NS	NS	NS	NS	NS	NS	NS

Gly=glyphosate, Tri=trifluralin, ST=Seed Treatment, VM=Vibrance® Maxx, I=Intego™, Fn=Foliar Nutrient, NS = not significant

Yield

The only significant difference in yield between any of the root health management treatments was at Scott in 2019 (P=0.0132). Other site years had no significant yield differences between treatments (Table 7). Combined yields were higher in 2019 than in 2021, indicating that soil moisture was a key driver of yield response. Yield response to the treatment combinations differed by site and year. In 2019, the combined yield was higher for treatments 6 to 10, which had high fertility (50 P, 20 K, 10 S). In 2021, however, fertility did not have a pronounced impact on yield. Seed treatment and foliar nutrients did not influence the combined average yield.

In 2019, yield was lowest at Scott, at 21 bu/ac on average, likely due to high root disease levels. The higher fertility treatments (treatments 6 to 10) resulted in a 9 bu/ac yield advantage compared to the low fertility treatments (treatment 1 to 5). Treatment 1 (Gly + 20 P) had the lowest yield.

In 2019, Outlook had the highest yields among all sites at 67 bu/ac on average, despite high disease pressure in 2019. Treatment 6 (Gly + 50 P, 20 K, 10 S) had the highest yield, at 7 bu/ac above the lowest yielding treatment, which was treatment 1 (Gly + 20 P). While yielding the highest at Outlook, treatment 6 was the lowest yielding treatment at Swift Current in 2019, at 33 bu/ac. Average yield at Swift Current in 2019 was 36 bu/ac. The highest yield at Swift Current was 38 bu/ac, attained from treatments 2, 5, and 8 (Gly + 20 P + VM + I; Gly + Tri + 20 P + VM + I + Fn; and Gly + Tri + 50 P, 20 K, 10 S + VM), which all included seed treatments.

Yield average at Melfort was 48 bu/ac. The highest yielding treatments were treatments 6, 2, and 8 (Gly + 50 P, 20 K, 10 S, Gly +

20 P + VM + I, and Gly + Tri + 50 P, 20 K, 10 S + VM), which yielded 55, 53, and 49 bu/ac respectively. Each of these treatments included high fertility and/or seed treatment, whereas the lowest yielding treatment, treatment 1 (Gly + 20 P), contained neither and yielded only 40 bu/ac.

In 2021, average yields were lowest at Swift Current (27 bu/ac), followed by Scott (35 bu/ac), Outlook (40 bu/ac), and Melfort (53 bu/ac). There were no statistically significant differences in yield between treatments at any site; however, some treatment trends emerged. At Scott, the highest yielding treatment was treatment 9 (Gly + Tri + 50 P, 20 K, 10 S + VM + I), yielding 5 bu/ac more than the lowest yielding treatment, treatment 1 (Gly + 20 P).

At Outlook, disease pressure was higher; however, as in 2019, yield was maintained. Yields were higher under the high fertility treatments (6 to 10) than the low fertility (1 to 5). As in 2019, yield was highest with treatment 6 (Gly + 50 P, 20 K, 10 S treatment), 16 bu/ac higher than the lowest yielding treatment, treatment 1 (Gly + 20 P).

The two highest yielding treatments in Melfort, treatment 3 (Gly + Tri + 20 P + VM) and treatment 9 (Gly + 50 P, 20 K, 10 S + VM + I), both yielded 55 bu/ac and only had seed treatment in common. The lowest yielding treatments, treatment 4 (Gly + Tri + 20 P + VM + I) and 5 (Gly + Tri + 20 P + VM + I + Fn), yielded 52 bu/ac and had in common trifluralin, low fertility, and the Vibrance® Maxx and Intego™ seed treatments.

At Swift Current, treatment 1 (Gly + 20 P) had the highest yield, 6 bu/ac higher than the lowest yielding treatment, treatment 10 (Tri + 50 P, 20 K, 10 S + VM + I + Fn). At Swift Current, yields were largely affected by drought conditions.

Table 7. Field pea yield (bu/ac) by treatment at Scott, Outlook, Swift Current, and Melfort SK in 2019 and 2021

Treatments	2019				2021				Combined 2019	Combined 2021	Combined 2019+2021
	Scott	Outlook	Swift Current	Melfort	Scott	Outlook	Swift Current	Melfort			
1. Gly + 20 P	17	64	34	40	33	33	31	54	40	36	38
2. Gly + 20 P+ VM + I	7	64	38	53	35	34	28	53	43	37	40
3. Tri + 20P + VM	19	69	34	47	36	42	28	55	42	40	41
4. Tri + 20P + VM + I	17	65	36	45	34	42	27	52	41	39	40
5. Tri + 20P + VM + I + FN	20	67	38	48	34	35	27	52	43	36	40
6. Gly + 50 P, 20 K, 10 S	27	71	33	55	37	49	26	53	47	41	44
7. Gly + 50 P, 20 K, 10 S + VM + I	26	66	36	47	34	44	26	55	44	40	42
8. Tri+ 50 P, 20 K, 10 S + VM	30	65	38	49	34	42	25	54	46	39	42
9. Tri+ 50 P, 20 K, 10 S + VM + I	25	67	35	47	38	42	25	52	44	41	42
10. Tri+ 50 P, 20 K, 10 S + VM + I + FN	27	68	37	49	36	38	25	53	45	38	42
LSD (0.05)	S	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Gly=glyphosate, Tri=trifluralin, ST=Seed Treatment, VM=Vibrance® Maxx, I=Intego™, Fn=Foliar Nutrient, NS = not significant

Economic Analysis

Profitability of the treatment combinations differed by location (Table 8). In 3 of 8 site-years and the average of all site-years, the most profitable treatment was treatment 6 (Gly + 50 P, 20 K, 10 S). This treatment, however, did not show promise for reducing the impact of

A. euteiches based on the root rot ratings. Interestingly, at Scott in 2019, where yield results were statistically significant, the treatment with the highest yield, treatment 8 (Gly + Tri + 50 P, 20 K, 10 S + VM), was as profitable as treatment 6 (Gly + 50 P, 20 K, 10 S).

Table 8. Economic analysis (net profit) of field pea yield by treatment at Scott, Outlook, Swift Current, and Melfort SK, 2019 and 2021

Treatments	Scott	Outlook	Swift Current	Melfort	Scott	Outlook	Swift Current	Melfort	All Sites Combined
	2019				2021				
Net Profit (\$/ac)									
Gly + 20 P	178.24	742.24	382.24	454.24	366.64	371.44	341.44	616.24	431.44
Gly + 20 P+ VM + I	144.24	708.24	396.24	576.24	355.44	345.84	281.04	576.24	420.24
Tri + 20P + VM	175.17	775.17	355.17	511.17	377.97	454.77	277.17	601.17	439.17
Tri + 20P + VM + I	135.17	711.17	363.17	471.17	337.97	436.37	255.17	551.57	408.77
Tri + 20P + VM + I + FN	155.52	719.52	371.52	491.52	328.32	337.92	235.92	533.52	393.12
Gly + 50 P, 20 K, 10 S	273.34	801.34	345.34	609.34	388.54	536.14	266.14	587.74	474.94
Gly + 50 P, 20 K, 10 S + VM + I	227.34	707.34	347.34	479.34	320.94	440.94	226.14	569.34	419.34
Tri+ 50 P, 20 K, 10 S + VM	282.27	702.27	378.27	510.27	326.67	426.27	224.67	566.67	429.87
Tri+ 50 P, 20 K, 10 S + VM + I	206.27	710.27	326.27	470.27	361.07	412.67	202.67	533.87	413.87
Tri+ 50 P, 20 K, 10 S + VM + I + FN	214.62	706.62	334.62	478.62	325.02	347.82	184.62	526.62	392.22

Green value indicates highest net profit in column.

Red value indicates lowest net profit in column.

Discussion

Scott in 2019 had the highest root rot disease ratings of all site-years and was the only site with a significant yield difference between treatments, with high fertility rates producing the yield response. There was no significant difference between root ratings at Scott in 2019, indicating that the high fertility treatments may not have reduced visual symptoms of root disease. Higher fertilizer rates, however, may have helped maintain yields better than the low fertility treatments when infection was high.

Outlook had the highest yields of all sites in 2019, at 67 bu/ac on average, even though the disease ratings were second highest in 2019. Root disease was also high at Outlook in 2021; however, yield (40 bu/ac on average) was still adequate considering the extreme heat conditions. Irrigation may explain why root disease had less influence on yield at Outlook than Scott, and why there was no significant difference in yield between fertility treatments. Readily available water supplied through irrigation may have helped the plants take up enough water despite root damage from *A. euteiches* infection.

Of the four root health management strategies, higher fertility (50 P, 20 K, 10 S) had the greatest influence on disease severity and yield. The only statistically significant treatment effect on recorded parameters in this research was yield at Scott in 2019, where higher fertility rates increased yield by 9 bu/ac over the low fertility treatments. Although disease and yield results were not significant at other site-years, there was a trend of 3 to 16 bu/ac higher yield with higher fertilizer rates at five of the seven remaining site years. These results align with past studies that determined reduced root disease development with increased plant P concentration.

Use of seed treatments, trifluralin herbicide, or foliar nutrition alone or in combination with the other treatment factors did not have influence on root disease or yield. Both seed treatments (Vibrance® Maxx and Intego™ Solo) provided varying results in this study. The possible explanation for the inconsistent effect of seed treatments can be due to the dry soil conditions at all site-years. Seed treatments provide the best disease protection and crop benefits under wet conditions conducive to disease development.

Trifluralin herbicide did not have any significant effect on ARR or yield. The irregularities in herbicide results may be due to variance in incorporation timing, soil moisture and temperature, seeding depth, and surface crop residue, which ultimately will impact trifluralin efficacy. Although there was no advantage of trifluralin herbicide in 2021 due to dry growing conditions, in 2019 the use of trifluralin in combination with high fertility rates did have the two highest yields at Scott, the highest yield at Swift Current, and the third and fourth highest yields at Outlook. The possible reason for the yield advantage in 2019 could be that trifluralin treatment did help in delaying *A. euteiches* infection. The foliar nutrient application did not show any trends of reduced root disease or increased yield.

Conclusions and Recommendations

The aim of this field pea research was to identify combinations of soil fertility, herbicide, seed treatment, and foliar nutrients to manage root health, reduce *A. euteiches* infection, and improve yield and profitability. Assessments of plant stand density and root health showed no significant differences between any treatments in any site-years. Cool and dry conditions early in the season in 2019 and hot and dry conditions throughout 2021 led to low levels of root disease development in the early season in 2019 and throughout the season in 2021. The only significant result was yield at Scott in 2019, in which treatments with the high rates of fertilizer (50 P, 20 K, 10 S) yielded 9 bu/ac higher than the low fertility treatments (20 P). Although other yield results were not significant, the most evident trend was increased yield with higher fertility rates. Use of trifluralin herbicide and seed treatment did not consistently improve yield. The use of foliar nutrients showed no evidence of yield increase. Profitability varied between sites and years; however, the most profitable treatment at three of eight sites and the combined average, was the treatment involving glyphosate and the high fertility rate.

Based on this demonstration, recommendations to maintain yield and profitability when growing peas in *A. euteiches*-infected soil include: 1) use of fertilizer rates above 20 lb actual P per acre, such as the 50 lb P, 20 lb K, and 10 lb S per acre rate used in this research; 2) pre-seed application of herbicides such as glyphosate and trifluralin to manage weed pressure; and 3) application of seed treatments in cold, wet springs.

This demonstration project took place in two drier years; thus, the ability of these treatments to reduce root infection of *A. euteiches* and maintain yield, both alone and in combination, may be better in wetter years. Further research is required to determine the most effective and profitable input combinations for growing peas in *A. euteiches*-infected soils in different growing conditions.

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