Project title: Starter Phosphorous for Wheat
Name of team leader: Dennis Pennington

Project justification: Canadian researchers promote using 50 pounds of starter phosphorus on wheat, claiming it increases fall growth and tillering resulting in higher winter survivability and yields. Research needs to be done in Michigan to verify if this is true for our soils and growing conditions.

Statement of challenge leading to project: Northern Michigan wheat growers are faced with a shorter growing season resulting from later soybean harvest and lower heat unit accumulations after planting which results in less fall tillering. Late planted wheat could benefit from any practice that will help wheat emerge and start tillering as quickly as possible in the fall. Testing the benefit of starter phosphorus could improve yield potential in Michigan under these conditions.

Objectives: The overall objective of this study was to assess the impact of starter phosphorus on wheat yield of various practices. Specific research questions include:

1. Does placement of starter fertilizer matter (broadcast incorporated or in furrow)?
2. Does planting date matter (early vs. late)?

Research was conducted in two phases – on farm and intensive sites. Figure 1 shows the location of each site where plots were planted in the '16-17 and '17-18 wheat growing seasons. The purpose of the on farm sites was to get grower involvement in the research and to add the northern growing conditions to the research. On farm trials were planted in a RCBD with 4 replications. Intensive sites were planted at the Saginaw Valley Research and Extension Center (SVREC) and campus and consisted of a split plot design with planting date as main factor (2 levels) and phosphorus treatment as the sub factor (9 levels) in a RCBD. Soft red winter winter variety "Starburst" was planted at the campus location and soft white winter wheat variety "Jupiter" was planted at the SVREC site. All management factors (herbicide, fungicide, nitrogen rates) were held consistent across all plots following MSUE recommendations. Plots were harvested with an Almaco SPC40 research plot combine equipped with HarvestMaster H2 Classic grain gauge system to obtain grain yield, moisture and test weight.

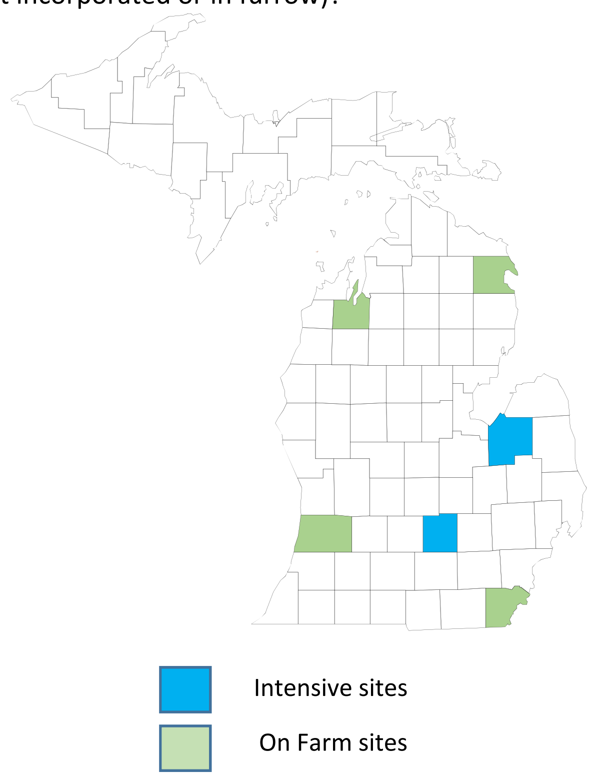

Figure 1. Location of intensive and on farm sites.

Results: Data from the **on farm** trials were analyzed using Proc GLIMMIX, SAS 9.4. Treatment and location were significant and there was no interaction between location*treatment or location*year so data was combined for all locations and all years.

Table 1. On farm trials showed statistically significant benefit from addition of starter phosphorus compared to the control, but it didn't make any difference whether it was liquid or dry (10-34-0 or MAP) nor was there any difference between the full and half rate of 10-34-0.			
Treatment	Yield (bu/a)		Benefit ($/a)
3.In Furrow Liquid – 12.7 gal/a 10-34-0	75.1	A	$2.56
2.In Furrow Dry – 96 lb/a 11-52-0	74.7	A	$8.00
4.In Furrow Liquid – 6.3 gal/a 10-34-0	72.8	A	$6.90
1.Control – no starter	68.3	B	$0.00

Results from the on farm trials show that addition of starter phosphorus was beneficial and that it didn't matter what form or rate was applied. MAP and 10-34-0 produced statistically the same yield, which was higher than the control. It was expected to see a greater response in more northern locations. When analyzing the data, the standard error was too high in the northern locations to evaluate them separately. When all years and all locations were combined, there was enough degrees of freedom to conduct means separations. Benefit was calculated using partial budget analysis where per acre cost of each treatment was subtracted from the yield benefit in bushels per acre times a wheat price of $5.00 per bushel. A positive benefit indicates the yield gain was more than enough to pay for the additional cost of the fertilizer. MAP in the furrow (treatment 2) provided the greatest economic benefit at $8.00 per acre. This study was not able to confirm that northern sites would have greater benefit from addition of starter phosphorus.

Data from the intensive sites were analyzed using Proc GLIMMIX, SAS 9.4. Treatment, year, year*treatment, location and split fixed effects were significant allowing multiple comparisons to be made. Since treatment*year interaction was significant, data must be reported by year. Tables 2 and 3 show results for '17 and '18 respectively.

Table 2. 2017 Campus and SVREC results indicate that addition of phosphorus significantly increased yield. Placement, product, form and rate produced yields that were not significantly different from each other.						
	Placement	Product	Form	Rate (actual P/a)	Yield (bu/a)	
7	Broadcast	MAP	Dry	96 lb/a (50)	110.5	A
2	Furrow	MAP	Dry	96 lb/a (50)	104.5	AB
3	Furrow	10-34-0	Liquid	12.7 gal/a (50)	101.5	B
8	Broadcast	10-34-0	Liquid	12.7 gal/a (50)	99.9	B
4	Furrow	10-34-0	Liquid	6.3 gal/a (25)	99.8	B
6	Furrow	28% UAN	Liquid	5 gal/a (14.7 lb N)	98.6	B
5	Furrow	Urea	Dry	23 lb/a (10.6 lb N)	89.7	C
1	None	None	None	None	63.4	D

In 2017, treatment 1 (control) received no starter phosphorus as well as no nitrogen. This was corrected in 2018 with the addition of a treatment that received no starter but did receive the full rate of nitrogen. Treatments 5 and 6 received urea and 28% UAN respectively in the furrow. These treatments were included because all of the phosphorus products used in this study contain nitrogen. The results confirm the well-known fact that too much nitrogen placed too close to the seed can have detrimental effects. Urea (Treatment 5) showed signs of injury early and was evident throughout the growing season (see Figure 4). 28% UAN (treatment 6) did not produce the damage and had similar yields to the other treatments. In 2017, MAP had the highest yields with no difference in placement (see Figure 3). For the liquid product, 10-34-0, in furrow and broadcast produced the same response. In addition, the half rate (treatment 4) of 10-34-0 was the same as the full rate (treatment 3). Soft red and white wheat varieties were planted at Campus and SVREC respectively and there were significant differences by location. While yields were higher at the SVREC environment, soft red and white wheats respond the same to addition of phosphorus fertilizer.

Table 3. 2018 Campus and SVREC results indicate that addition of phosphorus significantly increased yield. Placement, product, form and rate produced yields that were not significantly different from each other.

Treatment	Placement	Product	Form	Rate (actual P/a)	Yield (bu/a)		Yield vs. Treat 9	Benefit ($/a)**
2	Furrow	MAP	Dry	96 lb/a (50)	83.4	A	14.0	$46.00
3	Furrow	10-34-0	Liquid	12.7 gal/a (50)	82.1	A	12.7	$32.00
4	Furrow	10-34-0	Liquid	6.3 gal/a (25)	81.3	A	11.9	$43.78
7	Broadcast	MAP	Dry	96 lb/a (50)	79.8	A	10.4	$28.19
8	Broadcast	10-34-0	Liquid	12.7 gal/a (50)	78.7	A	9.3	$15.12
6	Furrow	28% UAN	Liquid	5 gal/a (14.7 lb N)	71.9	B	2.5	$6.10
9	None	None	None	90 lb N/a	69.4	B	0.0	$0.00
5	Furrow	Urea	Dry	23 lb/a (10.6 lb N)	62.9	C	-6.4	-$36.21
1	None	None	None	None	46.7	D	-22.7	-$113.44

**Wheat=$5.00/bu. Fertilizer prices per ton: MAP=$500, 10-34-0=$425, Urea=$350, 28%UAN=$240

Yields in '18 were lower compared to '17. In '18, all starter phosphorus treatments were statistically the same – placement, product or form did not matter. Urea in the furrow (treatment 5) injured the crop and was statistically lower in both years. Treatment 9 was the control with full nitrogen rate applied. Means separations were conducted and treatments were compared to treatment 9, creating the yield and economic benefit columns in Table 3. In '18, MAP placed in the furrow produced the highest yield and economic benefit numerically although not statistically. The average economic benefit of all the phosphorus treatments was $33.02 per acre.

The intensive sites were split into early and late planting dates. Early planting dates were the last week of September with late planting dates 4 weeks later. It was anticipated that the benefit from phosphorus fertilizer would be greater for late planted wheat compared to early planted wheat. Table 4 shows that this was in fact opposite. The highest yield of the late planting was treatment#7 which was 23.2 bushels higher than the control. The highest yield of the early planting was also treatment #7 which was 28.3 bushels higher than the control. In both planting dates, starter phosphorus did increase yields but we didn't see a bigger response with the late planting as expected. The economic benefit of early planting date was also calculated as (Early yield – Late yield) x $5.00 per bushel. Early planting had higher economic benefit in every treatment comparison with an overall average benefit of $52.64 per acre simply due to planting early compared to late.

Table 4. Effect of planting date on starter phosphorus application 17-18.						
Late Planting Date			Early Planting Date			
Treatment	Yield (bu/a)		Treatment	Yield (bu/a)		Benefit***
7	89.0	A	7	101.3	A	$61.83
2	86.9	AB	2	100.2	AB	$66.36
3	84.3	AB	3	99.1	AB	$73.94
8	84.2	AB	8	94.4	AB	$51.15
4	84.1	AB	4	97.0	AB	$64.54
6	79.4	ABC	6	91.1	B	$58.64
5	75.9	BC	5	76.7	C	$4.38
9	65.8	C	9	73.0	C	$36.25
1	49.4	D	1	60.7	D	$56.66
***Benefit is calculated as (Early yield - Late yield) x $5.00 per bushel.						

An additional outcome of this project was the effect of planting date overall. There was a significant year*planting date interaction so data is reported by year. In '17 and '18 there was a 6.6 and 16.1 bushel per acre increase respectively, confirming many other studies showing that planting date is an important factor affecting yield potential of wheat.

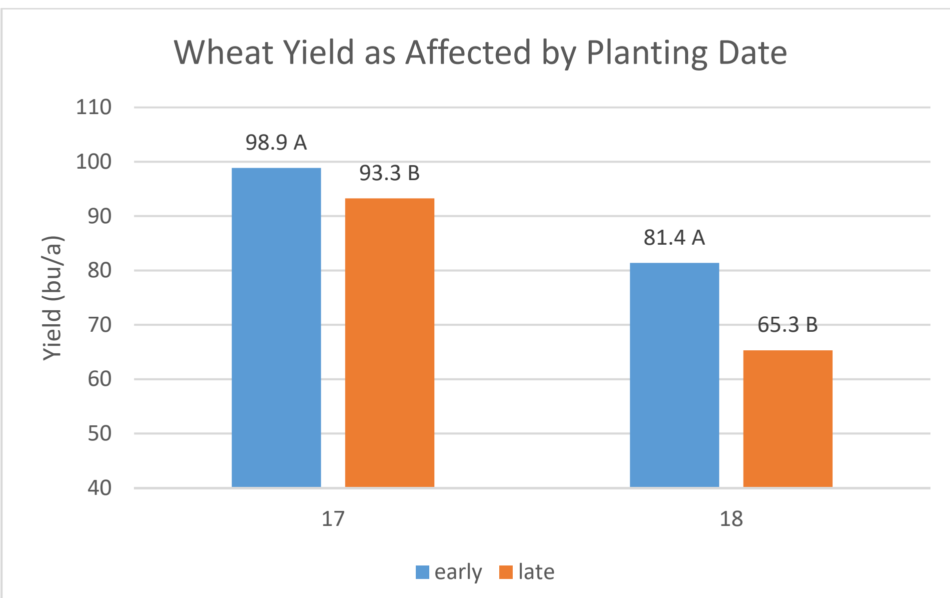

Figure 2. Planting date had a significant effect on yield in both years. Early planting produced higher yields that the late planting time in both years.

The soil test phosphorus critical level is 25 ppm; crop removal values ranges from 25-40, and 50% crop removal runs from 40-50ppm. Soil tests for all locations evaluated in this study ranged from 25 -76 ppm. The Bray-P1 test was used for all locations, although the SVREC site had a pH above 7.4 indicating the Olsen test would be better. At these levels, you would not expect to see a response.

Summary:

Research Questions:	Results
1. Does placement of the fertilizer matter (broadcast incorporated or in furrow)?	No
2. Does planting date matter (early vs. late)?	Yes

This study shows that there is yield and economic benefit from adding phosphorus to starter fertilizer. Form, product and placement are equivalent. In this study, we used 50 pounds per acre. It is recommended that additional research be conducted to determine the proper rate of phosphorus to maximize wheat yields. Care should always be taken to properly manage phosphorus. Environmental consequences of over application of phosphorus should be considered and fertilizer rates should be made on a field by field basis. Planting early should certainly be the goal of all farmers.

Impacts: The economic benefit of adding phosphorus to starter fertilizer on wheat in trial ranged from $15.12 to $46.00 per acre in higher income (from Table 3). The average benefit from phosphorus treatments 2, 3, 4, 7 and 8 is $33.02 per acre. In 2018, Michigan farmers planted 470,00 acres of wheat (USDA NASS, 2018). If this practice was adopted on all acres, wheat farmers could increase income by $15.5 million ($33.02 per acre x 470,000 acres = $15,519,400).

Leveraged Funding: The Michigan Wheat Program provided $23,305 in funding for the first year of this project.

Summary statement: Starter phosphorus showed yield and economic benefit in ’17 and ’18. Wheat growers should consider adding phosphorus in starter fertilizer while being mindful of environmental consequences of over application of phosphorus.

Visuals:

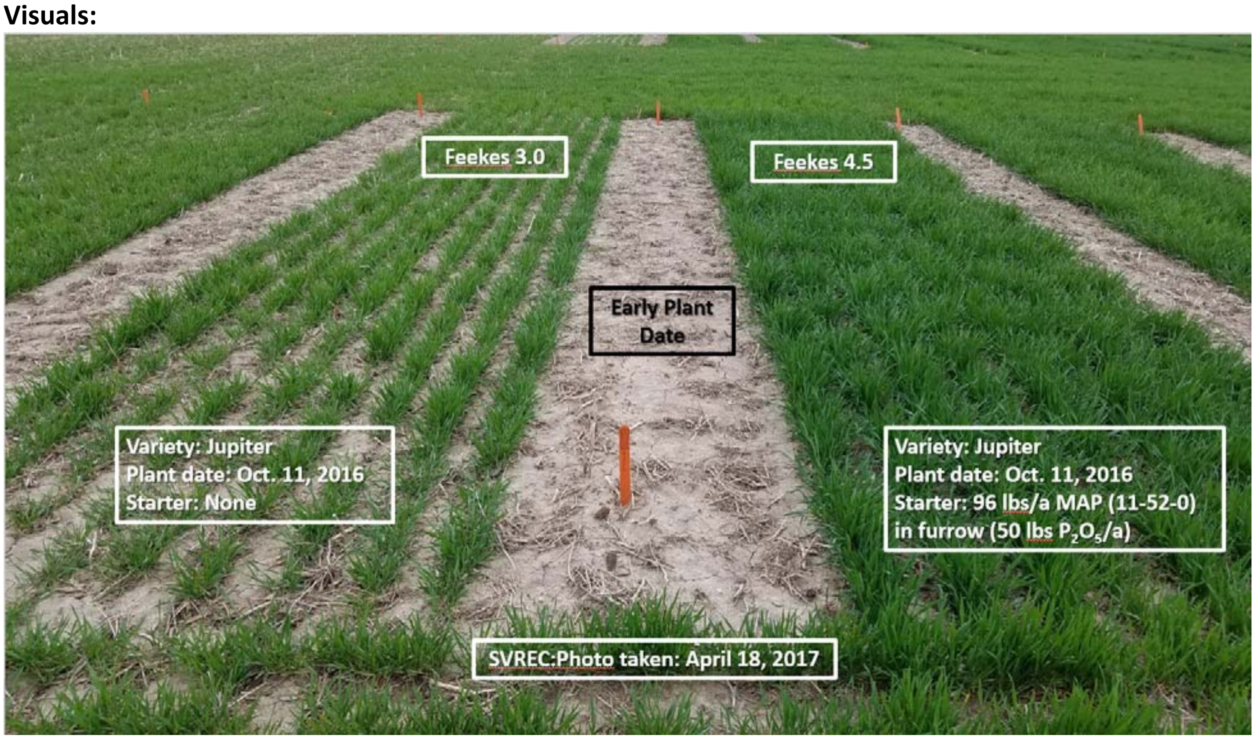

Figure 3. Photo taken on April 18, 2017 showing adjacent plots with Treatment 1 (control) and Treatment 2 (MAP in furrow).

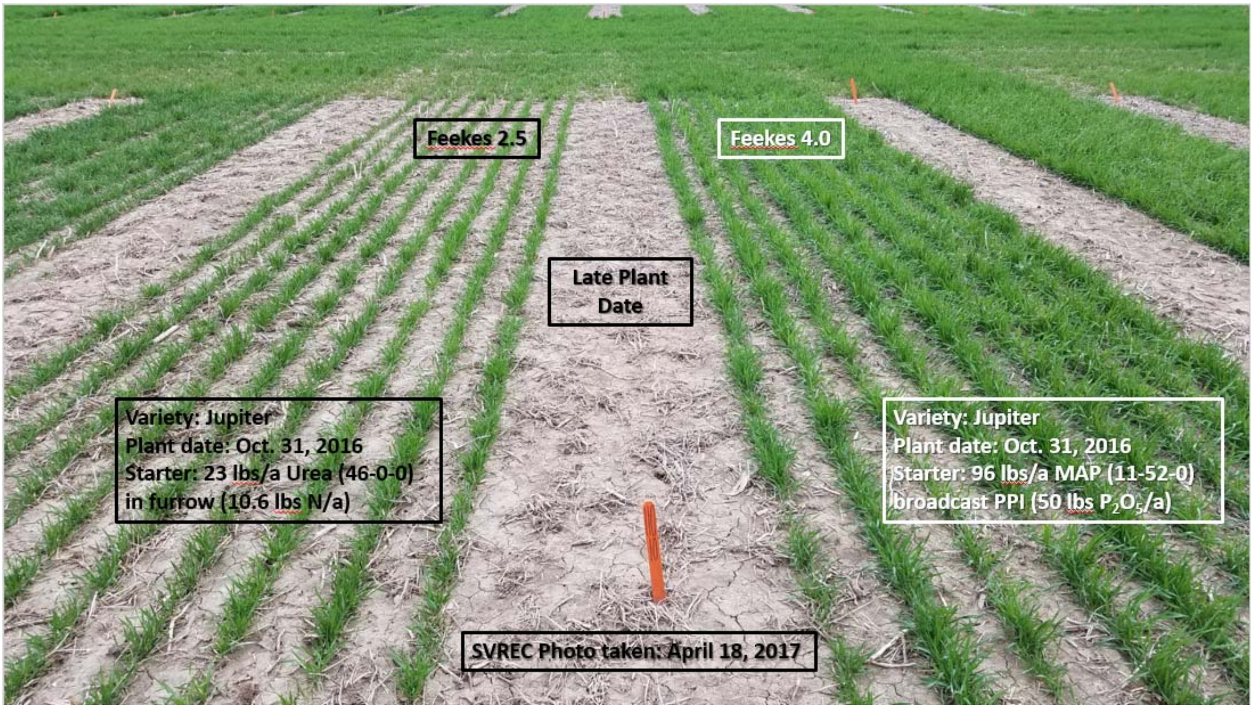

Figure 4. Photo taken on April 18, 2017 showing adjacent plots with Treatment 5 (urea in furrow) and Treatment 2 (MAP in furrow).