

RE-EVALUATING PHOSPHORUS AND POTASSIUM MANAGEMENT FOR CORN, SOYBEAN, AND WHEAT IN ONTARIO

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ABSTRACT

In Ontario, long term trends show decreasing soil test P and K levels as high crop yields in corn, soybeans, and wheat remove more nutrients than are being replaced through nutrient application. Deficiencies or insufficient available P and K from either the soil, fertilizer applications, or both, could mean that modern yields of these crops are not fully reaching their potential. A long-term project was established between 2010 and 2012 on 4 field sites in Ontario to compare two different fertilizer strategies: the sufficiency approach (current OMAFRA recommendations), and the build-and-maintain approach. This project used various starters on fields varying in background soil test P and K. In Phase I, the “Build Phase” (completed in 2017), the regime of built P+K levels produced the highest yields of all 3 crops: corn, soybean, and wheat yields using starters at approximate replacement rates were 10.0, 3.0, and 11.4 bu/ac higher, respectively, than in the no-build regime using the same starter rates.

Phase II, the “Drawdown Phase”, started in 2018 and was designed to validate the crop responses to both the sufficiency and build-and-maintain fertilization strategies. In the Drawdown Phase, only starter fertilizer treatments were used, the background levels of P and K had been carried on from the Build Phase. Yield responses in the Drawdown Phase were lower compared to those in the Build Phase, identifying that higher crop yield response was due to increased applied P and K fertilizer used to build P and K levels in the soil, instead of the replacement rates of starter fertilizer alone. In the Drawdown Phase, corn, soybean, and wheat yields were 5.9, 0.8, and 6.7 bu/ac higher, respectively, in the built P+K regime using starters at approximate replacement rates compared to the no-build regime using the same starter rates.

INTRODUCTION

Current recommendations from the Ontario Ministry of Agriculture, Food, and Rural Affairs (OMAFRA) for phosphorus and potassium application in corn, soybeans, and wheat are based on research data from the 1960s-1970s. Since these recommendations were developed, crop yields, crop nutrient uptake, and nutrient removal have increased significantly, and P and K soil tests have been decreasing. There is appetite within Ontario’s agriculture industry to identify the best P and K fertility strategy for use with current yield trends: does a build-and-maintain approach provide improved long-term productivity than current recommendations based on the sufficiency approach?

This project is Phase II of a two-part study. Phase I’s primary objective was to initiate trials in 4 locations across southwestern Ontario in a corn-soybean-wheat rotation, and establish plots of various P and K build strategies and P and K starter treatments. The

outcome of Phase I was: in plots that were built to moderate P and K levels, crop yields were significantly higher compared to the strategy where P and K were applied at rates similar to current OMAFRA recommendations (sufficiency approach). However, these responses were generated with a “build” strategy rather than a “build and maintain” strategy, and so Phase II was initiated to identify whether the crop responded to increased rates, or higher P and K background fertility.

Phase II compares the economic yield response of corn, soybean, and wheat in various P and K soil testing scenarios: no P&K build, built P, built K, and built P&K. Maintenance P and K will be applied to the built areas to keep soil test levels adequate. The study will also test various strategies of starter fertilizers within each management approach (build and maintain vs sufficiency), and test whether current OMAFRA P and K recommendations apply to high yield environments.

MATERIALS AND METHODS

Sites were introduced in 2011, 2012, and 2013 that identified as relatively low in soil test P ($P < 12$ ppm Olsen) and K ($K < 80$ ppm Ammonium Acetate). In Phase I, four levels of P and K fertility were established in a randomized strip-plot design, replicated four times, with the same fertility randomizations used each year across the corn-soybean-wheat rotation. The four “build regimes” were established in 4 strips per rep at each site by broadcasting 0-46-0 and/or 0-0-60 plus a no build control: 1. Control, 2. P_2O_5 only, 3. K_2O only, and 4. soil test P+K build. Fertilizer was broadcast and incorporated in the fall of every year at relatively high rates until the end of Phase I. The final crop year of Phase I ended in 2017.

Phase II started in 2018 at all sites. No more P and K fertilizer was broadcast-applied, starter treatments were maintained. The number and rates of starter varied slightly with each field site. Common across all corn and soybean sites were a control, liquid 6-24-6 applied at 3-5 US gal/ac in furrow, MAP applied at 100 lb/ac in a 2x2 band, potash applied at 80 lb/ac in a 2x2 band, and a 6-28-28 blend applied between 90-180 lb/ac (soybean) and 270 lb/ac (corn). Wheat starters were all applied in-furrow, including a control, liquid 6-24-6 applied at 3-5 US gal/ac, MAP at 80-100 lb/ac, potash at 70-80 lb/ac, and a blend of 6-28-28 applied at 90-225 lb/ac.

The highest starter treatment rates were approximately 50 lbs P_2O_5 /ac and 50 lbs K_2O /ac per cropping season. These rates were chosen at the onset of the experiment in 2011 to approximate rates (or exceed) the recommended P and K fertilizer rates under the “sufficiency approach” across a 3-crop rotation, assuming crop yields of corn, soybean and wheat were 180, 50 and 80 bu/ac.

Every plot was tested at startup for soil test P and K, as well as 4-5 times depending on the site during the study.

RESULTS AND DISCUSSION

Phase I of the study had an objective to build soil test P, K, or both to medium testing levels from the starting levels of the individual sites. This was called the “Build Phase”. Phase II of the study was called the “Drawdown Phase” because rates of P and K application across all sites were at or below crop removal rates. The Drawdown Phase

will give the best comparison of the “sufficiency” approach to the “build and maintain” approach of fertilization.

Corn

Table 1. Grain corn yield responses to starters by P and K build regimes during the build and drawdown phases at 4 Ontario locations (2012-2021).

Build or drawdown phase Starter regime	Build regime								Average across all regimes	
	No build	P build only	K build only	P+K build						
<i>Build phase (to 2017)</i>										
-----bu/ac-----										
No starter	156.9	d ¹	163.9	c	173.9	bc	188.9	c	170.9	d
6-24-6 @ 3-5 gal IF	167.0	c	176.8	b	177.8	b	191.7	bc	178.3	c
MAP @ 100 lb (2x2)	171.3	bc	175.0	b	187.3	a	195.3	ab	182.2	b
0-0-60 @ 80 lb (2x2)	174.7	b	190.5	a	172.6	c	193.0	bc	182.7	b
6-28-28@ 90-270 lb (2x2)	185.1	a	192.4	a	188.7	a	198.0	a	191.0	a
<i>Drawdown phase (2018-2021)</i>										
No starter	142.4	d	142.9	c	170.6	c	183.3	b	159.8	d
6-24-6 @ 3-5 gal IF	153.5	c	159.4	b	174.5	bc	185.2	ab	168.2	c
MAP @ 100 lb (2x2)	150.8	c	148.1	c	183.0	b	188.7	ab	167.7	c
0-0-60 @ 80 lb (2x2)	173.0	b	185.7	a	172.6	c	185.5	b	179.2	b
6-28-28@ 90-270 lb (2x2)	184.3	a	185.6	a	190.6	a	193.0	a	188.4	a

¹Means within column of each build and drawdown phase followed by the same letter are not statistically different at P=0.05.

Table 2. Grain corn yield responses to P and K build regimes with and without high-rate starter during the build and drawdown phases across 4 Ontario locations (2012-2021).

Build or drawdown phase ³ Starter regime	Build regime ²								P>F across regime
	No build	P build only	K build only	P+K build					
<i>Build phase (to 2017)</i>									
-----bu/ac-----									
No starter	156.9	d ¹	163.9	c	173.9	b	188.9	a	<0.0001
P+K starter only	187.5	c	195.0	b	189.7	bc	197.5	a	0.0014
<i>Drawdown phase (2018-2021)</i>									
No starter	142.4	c	143.0	c	170.6	b	183.3	a	<0.0001
P+K starter only	188.0	a	189.3	a	191.6	a	193.9	a	0.5377

¹Means within row followed by the same letter are not statistically different at P=0.05.

²No build=starter only; P+K build=broadcast 0-46-0 and/or 0-0-60 during the fall up to and including 2016.

³P+K starter only=highest rate of 6-28-28 applied as a starter at each location (up to 270 lb/ac).

During the Build Phase, the highest corn yields were produced where soil test values were built up in both P and K. Corn yields responded to a starter blend of P and K in the “no build” plots by 28 bu/ac across 21 site-years of this study. As expected, corn response to starter fertilizers was lower in the higher soil test P and/or K built strips. None of the starter rates applied in the non-built plots could produce yields as high as those in P+K built plots with the starter. The high corn yields in the P+K built soils may be partially due to responses to P and K fertilizers broadcast to build the soil test levels in this treatment, hence the need to assess corn responses when soils are not being built (i.e., just maintained) in the Drawdown Phase (2018-2021).

In the Drawdown Phase, no P or K fertilizer was broadcast. Only the high-rate starter fertilizer treatments approximated a “P+K maintain” scenario; other stater treatments resulted in higher P and K removals in the grain than was applied. The highest corn yields were produced in the P+K built soils, but the yield response between the no-build regime and the P+K built regime was slightly less than the Build Phase. Based on a trend that occurred at all 4 site-years, it may be argued that the average +5.9 bu/ac response to built P+K levels (compared to not built) is real despite the lack of statistical significance across 4 sites.

Soybean

Table 3. Soybean yield responses to starters by P and K build regimes during the build phase and drawdown phases at 4 Ontario locations (2012-2021).

Build or drawdown phase	Build regime								Average across all regimes	
	No build		P build only		K build only		P+K build			
<i>Build phase (to 2017)</i>										
-----bu/ac-----										
No starter	51.9	c ¹	53.5	c	54.5	b	58.6	b	54.6	c
6-24-6 @ 3-5 gal IF	53.5	b	54.9	b	55.1	b	58.8	ab	55.5	b
MAP @ 100 lb (2x2)	54.6	b	55.3	b	57.5	a	59.8	a	56.8	a
0-0-60 @ 80 lb (2x2)	53.5	b	56.7	a	52.4	c	58.4	b	55.2	bc
6-28-28@ 90-270 lb (2x2)	56.0	a	57.3	a	57.3	a	59.4	ab	57.5	a
<i>Drawdown phase (2018-2021)</i>										
No starter	53.6	c	55.7	c	58.4	b	61.9	ab	57.4	c
6-24-6 @ 3-5 gal IF	55.4	bc	56.9	bc	59.1	b	60.6	bc	58.0	c
MAP @ 100 lb (2x2)	57.2	b	57.3	bc	62.5	a	62.9	a	60.0	b
0-0-60 @ 80 lb (2x2)	55.6	b	59.1	b	55.9	c	59.7	c	57.6	c
6-28-28@ 90-270 lb (2x2)	61.0	a	61.9	a	61.4	a	62.2	ab	61.6	a

¹Means within column of each build and drawdown phase followed by the same letter are not statistically different at P=0.05.

Table 4. Soybean yield responses to P and K build regimes with and without high-rate starter during the build and drawdown phases across 4 Ontario locations (2012-2021).

Build or drawdown phase ³	Build regime ²								P>F across regime
	No build		P build only		K build only		P+K build		
<i>Build phase (to 2017)</i>									
-----bu/ac-----									
No starter	51.9	c ¹	53.5	b	54.5	b	58.6	a	<0.0001
P+K starter only	56.7	b	58.1	ab	57.8	b	59.7	a	0.0043
<i>Drawdown phase (2018-2021)</i>									
No starter	54.2	c	55.7	c	58.4	ab	61.9	a	<0.0001
P+K starter only	62.0	a	62.7	a	61.4	a	62.7	a	0.6472

¹Means within row followed by the same letter are not statistically different at P=0.05.

²No build=starter only; P+K build=broadcast 0-46-0 and/or 0-0-60 during the fall up to and including 2016.

³P+K starter only=highest rate of 6-28-28 applied as a starter at each location (up to 270 lb/ac).

During the Build Phase, soybeans responded to a starter blend of P and K in the no-build regime by 4.1 bu/ac across 21 site-years of the study, compared to a response of less than 1 bu/ac in the P+K built plots. This study supports existing work that soybeans

respond to starter fertilizers when soil test levels are low; response to starter fertilizer becomes less as soil test values increase. This study has shown P nutrition is critical for the highest soybean yield; potash by itself was not sufficient to maximize soybean yield.

In the Drawdown Phase, soybean yields were similar in both the no-build and P+K built regimes where a high-rate starter was applied; the lack of response contrasts with the Build Phase, which showed 3 bu/ac higher soybean yields in the P+K built regime compared to the no-build regime. Based on this outcome, it may be argued that soybean yields did not respond to built P+K where starter was applied at removal rates.

Wheat

Table 5. Wheat yield responses to starters by P and K build regimes during the build phase and drawdown phases at 4 Ontario locations (2012-2021).

<i>Build or drawdown phase</i>	Build regime								Average across all regimes	
	No build		P build only		K build only		P+K build			
<i>Build phase (to 2017)</i>	-----bu/ac-----									
No starter	66.7	c ¹	85.7	c	68.7	c	91.6	ab	78.2	c
6-24-6 @ 3-5 gal IF	73.8	b	87.5	bc	76.3	b	91.3	b	82.2	b
MAP @ 100 lb IF	82.1	a	89.2	ab	87.2	a	94.2	a	88.2	a
0-0-60 @ 80 lb IF	68.6	c	90.1	ab	69.9	c	88.5	c	79.3	c
6-28-28@ 90-270 lb IF	82.2	a	91.6	a	85.6	a	93.2	ab	88.1	a
<i>Drawdown phase (2018-2021)</i>										
No starter	70.7	c	86.4	c	76.5	c	93.2	ab	81.7	c
6-24-6 @ 3-5 gal IF	81.1	b	89.1	bc	84.7	b	93.8	ab	87.2	b
MAP @ 100 lb IF	88.9	a	90.4	b	93.1	a	95.8	a	92.0	a
0-0-60 @ 80 lb IF	71.3	c	91.2	b	74.6	c	91.5	b	82.1	c
6-28-28@ 90-270 lb IF	88.8	a	94.9	a	92.0	a	95.9	a	92.9	a

¹Means within column of each build and drawdown phase followed by the same letter are not statistically different at P=0.05.

Table 6. Wheat yield responses to P and K build regimes with and without high-rate starter during the build and drawdown phases across 4 Ontario locations (2012-2021).

<i>Build or drawdown phase³</i>	Build regime ²								P>F across regime	
	No build		P build only		K build only		P+K build			
<i>Build phase (to 2017)</i>	-----bu/ac-----									
No starter	66.7	c ¹	85.7	b	68.7	c	91.5	a	<0.0001	
P+K starter only	82.3	c	92.5	a	86.7	b	93.7	a	<0.0001	
<i>Drawdown phase (2018-2021)</i>										
No starter	70.6	d	86.3	b	76.4	c	93.1	a	<0.0001	
P+K starter only	90.7	c	94.9	ab	92.9	bc	97.4	a	0.0094	

¹Means within row followed by the same letter are not statistically different at P=0.05.

²No build=starter only; P+K build=broadcast 0-46-0 and/or 0-0-60 during the fall up to and including 2016.

³P+K starter only=highest rate of 6-28-28 applied as a starter at each location (up to 270 lb/ac).

Winter wheat yields responded to MAP placed in-furrow in the no-build regime by 15.4 bu/ac; the addition of potash to the MAP did not increase yield in the Build Phase. On soils with built P+K, wheat showed less than 3 bu/ac response to any starter fertilizer

compared to no starter. This study found that wheat is responsive to starter fertilizers especially when soil test levels are low, and that winter wheat is highly responsive to starter P. Results from the Build Phase of this study demonstrate that the sufficiency approach yielded significantly less (11.4 bu/ac) than soils that have been built with higher P and K; however, Phase II is necessary to identify whether the response was due to higher amounts of P and K that were broadcast to build soil test levels.

In the Drawdown Phase, 6.7 bu/ac higher wheat yields were produced in the P+K built regime using a high-rate starter compared to the no-build regime. Again, significant response was shown to starters including higher rates of P in-furrow in when soil test P was low, whereas starters low in P performed adequately when soil test P was built.

SUMMARY

This long-term project was established to compare various starters on various background P and K levels to compare two fertilizer strategies: the sufficiency approach (current OMAFRA) vs. a build-and-maintain approach. The highest grain yields of all 3 crops were produced with moderate soil test levels of P and K.

Soils low in both P and K did not respond to P fertilizer unless potash was applied. This was particularly evident at the Elora site.

During the Build Phase, it was determined that corn, soybean, and wheat yields using high-rate starter (at approx. replacement rates) were 10, 3, and 11 bu/ac higher, respectively, in the P+K build regime, compared to the no-build regime. The Drawdown Phase was initiated to determine whether these yield increases were the result of increased fertilization rates for the built regimes, compared to maintenance levels once soil test P and K are built. Corn, soybean, and wheat yields were 5.9, 0.8, and 6.7 bu/ac higher, respectively, in the P+K built regime with replacement rate starter compared to the same rate starter that was applied in the no-build regime during the Drawdown Phase.

In addition to this study, an M.Sc. thesis was produced by Mr. Harpreet Hanza at the University of Guelph, which analyzes the effects of the various build regimes in both phases of this study on P+K concentration in the grain, nutrient removal from the soil, and changes in soil test P+K.

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