Corn and Soybean Response to Phosphorus and Potassium Fertilization in Ohio

By A.M. Fulford, S.W. Culman, R.W. Mullen, C.E. Dygert, G.A. LaBarge, E.M. Lentz, and H.D. Watters

The most recent fertilizer P and K rate recommendations for corn and soybeans grown in Ohio were last updated in the mid-90s.

Research is needed to verify the appropriateness of these recommendations after 20 years.

This study found that corn and soybean yield response frequencies to P and K fertilization did not differ much from expectations based on initial soil test levels, but greater than expected soil test declines call for further research.

Maintaining or building soil fertility can be influenced by soil test trends that become apparent only after years of crop production. Results from nearly 30 years of corn and soybean production have been used to document the buildup, maintenance, or decline of soil P as influenced by initial soil test P (McCollum, 1991; Dodd and Mallarino, 2005). Long-term nutrient budgets have also been developed from over 30 years of corn and soybean production to assess the soil balance of P and K in the U.S. (Fixen and Murrell, 2002; Bruulsema et al., 2011).

In Ohio, P and K fertilizer recommendations for corn and soybeans follow the buildup, maintenance, and drawdown approach outlined in the, "Tri-State Fertilizer Recommendations for Corn, Soybeans, Wheat and Alfalfa" (Vitosh et al., 1995). This publication has served as a cornerstone for field crop soil fertility in the region, but after 20 years, a re-examination of these fertility recommendations is necessary, as a number of factors have changed in field crop production. In this study, fertilizer P and K application rates estimated to equal or exceed crop removal were applied and resulting corn and soybean grain yield and soil test P and K trends were observed throughout nine years of production at three sites in Ohio.

The study was initiated in 2006 in Clark, Wayne, and Wood counties in Ohio and continued until 2014. At all sites, corn-soybean (CS) and corn-corn-soybean (CCS) rotations were established and subsequently managed according to the phase of each cropping sequence. The total fertilizer N rate applied to corn was 180 lb N/A following soybean and 210 lb N/A following corn.

Abbreviations and notes: N = nitrogen; P = phosphorus; K = potassium. IPNI Project USA-OH16.

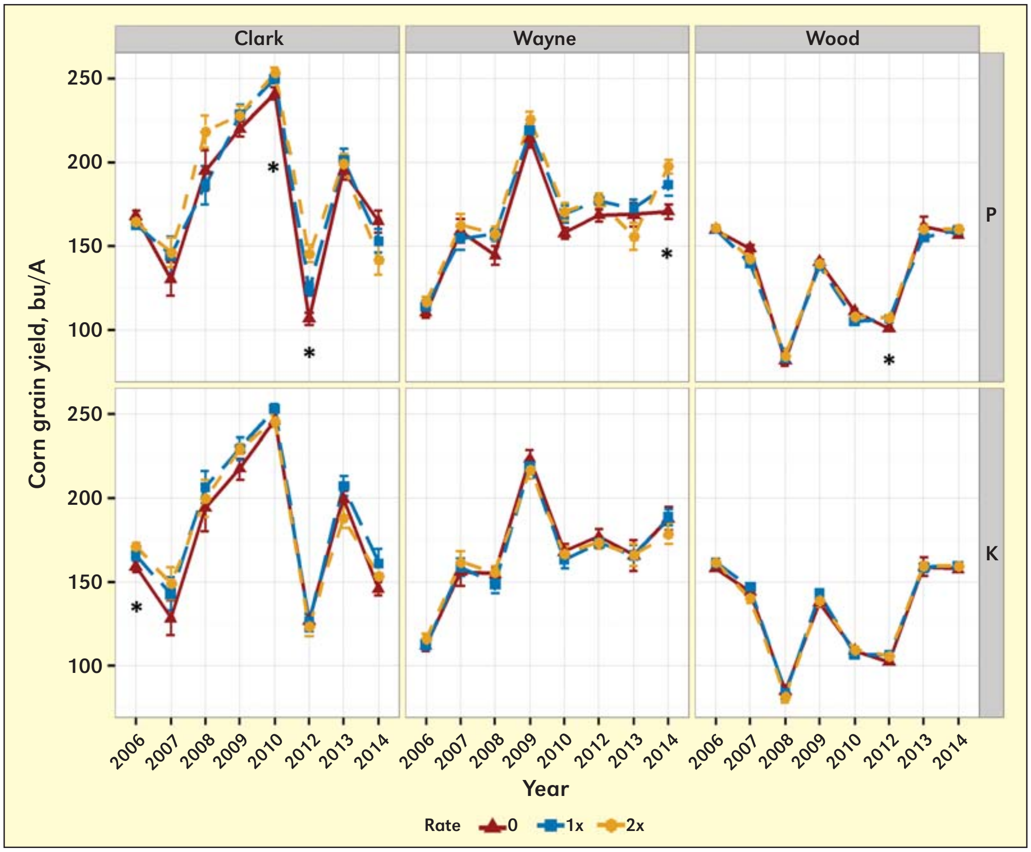

Figure 1. Corn grain yield response to P or K fertilizer applied at 0, 1x, and 2x the estimated crop removal rate for Clark, Wayne, and Wood county sites in Ohio. Asterisk denotes a significant ($p < 0.05$) grain yield increase compared to unfertilized (0 lb/A P_2O_5 or 0 lb/A K_2O) corn. All error bars denote standard error of the mean.

Fertilizer P and K was applied based on the estimated nutrient removal of each crop rotation. The 2005 Ohio statewide average corn (145 bu/A) and soybean (40 bu/A) yields were multiplied by the Tri-State Fertilizer Recommendations estimated crop removal, in pounds of nutrient per bushel (0.37 and 0.27 for P_2O_5 and K_2O for corn; 0.80 and 1.4 for P_2O_5 and K_2O for soybeans, respectively; Vitosh et al., 1995). Therefore, the respective 1x and 2x fertilizer rates for CS were 85 and 170 lb P_2O_5/A, and 95 and 190 lb K_2O/A, while the respective 1x and 2x fertilizer rates for CCS were 140 and 280 lb/A for both P_2O_5 and K_2O. Phosphorus was supplied as triple superphosphate or diammonium phosphate and K was supplied as potassium chloride. Initial P and K fertilization occurred in fall 2005 (Wood County) or spring 2006 (Clark and Wayne counties) and subsequent P and K fertilization followed soybean harvest for both rotations.

Soil samples were collected from each site in the fall prior to broadcast and surface incorporation of P and K fertilizer. Grain yield was measured for each crop in the rotation and soil test P (i.e., Bray P1) and K (i.e., ammonium acetate extractable-K) were measured for each site. Soil test levels were interpreted with respect to the maintenance range for plant-available P and K for corn and soybeans grown in Ohio (Vitosh et al., 1995). For each rotation, only one crop within that rotation (i.e., one entry point) was present for any given year. In other words, 2006, 2010, and 2012 were corn years for CS and CCS; 2011 was a soybean year for CS and CCS. The influence of crop rotation on grain yield was evaluated in these four (out of nine) years but was not significantly different between rotations. Accordingly, grain yields were averaged across crop rotations for these years.

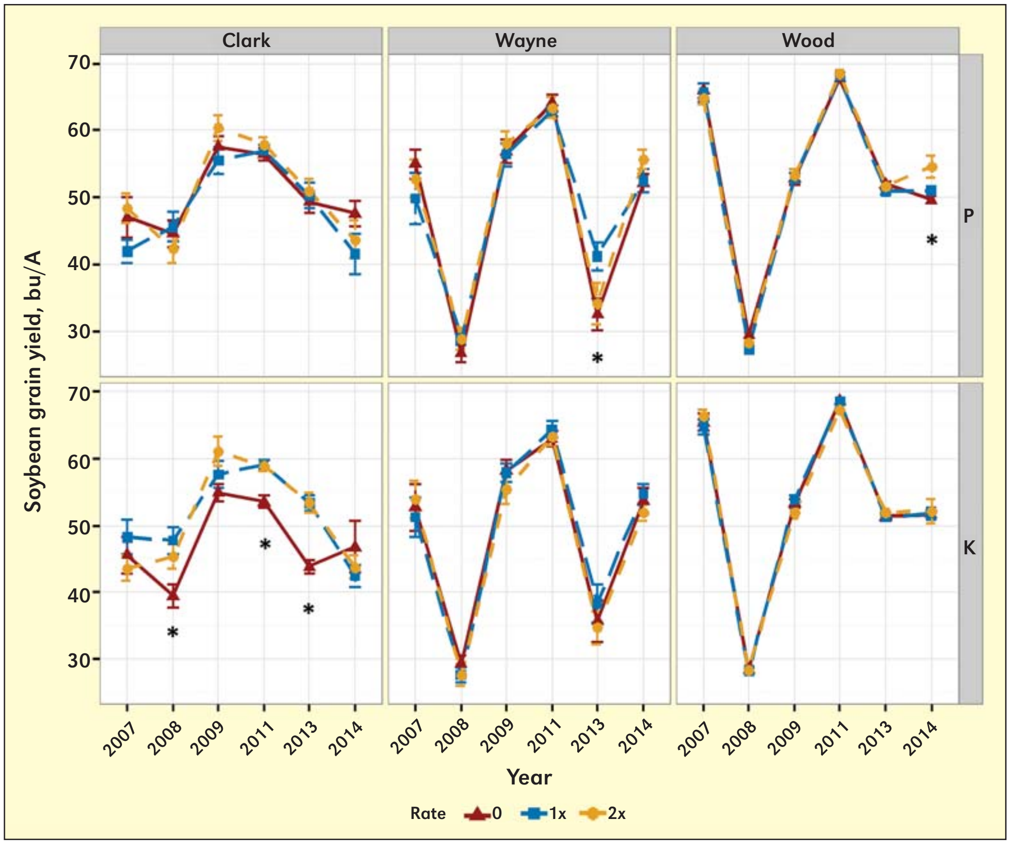

Figure 2. Soybean grain yield response to P or K fertilizer applied at 0, 1x, and 2x the estimated crop removal rate for Clark, Wayne, and Wood county sites in Ohio. Asterisk denotes a significant ($p < 0.05$) grain yield increase compared to unfertilized (0 lb/A P_2O_5 or 0 lb/A K_2O) soybeans. All error bars denote standard error of the mean.

Corn and Soybean Yield

Corn grain yield exhibited a significant positive response to P fertilization in four of 24 site-years, while corn yield increased significantly with K fertilization in one of 24 site-years (**Figure 1**). A positive response to P fertilization occurred in 2010 (Clark County), 2012 (Clark and Wood counties), and 2014 (Wayne County) as corn yield increased by as much as 13, 39, and 27 bu/A, respectively. Phosphorus fertilization significantly increased soybean yield in two of 18 site-years and grain yield increased by as much as 9 bu/A at Wayne in 2013 and by up to 5 bu/A at Wood in 2014 (**Figure 2**). Soybean grain yield was significantly increased by K fertilization in three of 18 site-years as yield increased by as much as 9, 5, and 9 bu/A at Clark in 2008, 2011, and 2013, respectively. (Respective corn and soybean yields averaged across nine years were: Clark, 182 and 51 bu/A; Wayne, 163 and 51 bu/A; Wood, 130 and 55 bu/A). Across years, fertilizer P and K rates applied in combination did not significantly influence the grain yield of corn ($p = 0.72$) or soybeans ($p = 0.58$).

Table 1. Nine-year nutrient balance (nutrient applied - nutrient removed, lb/A) of corn-corn-soybean (CCS) and corn-soybean (CS) rotations at Clark, Wayne, and Wood county sites.

Nutrient	Fertilizer Rate	- - Clark - - CCS	CS	- - Wayne - - CCS	CS	- - Wood - - CCS	CS
		- - - - - - - - lb/A					- - - - - - - -
Phosphorus	1x	-90	-38	-57	-37	8	8
	2x	339	340	350	384	418	439
Potassium	1x	-82	-97	-42	6	4	-14
	2x	356	439	393	447	413	449

Cumulative nutrient applied for the respective 1x and 2x fertilizer rates for CCS were: 420 and 840 lb/A for both P_2O_5 and K_2O; while the respective 1x and 2x rates for CS were: 425 and 850 lb P_2O_5/A, and 475 and 950 lb K_2O/A. Grain yields of CCS and CS rotations were used to estimate cumulative nutrient removal.

Soil Test Phosphorus and Potassium Levels

Nine-year soil test P levels appeared to decline more rapidly for CCS at Clark and Wayne compared to Wood (**Figure 3**). Soil test P decreased from initial levels in 2006 for CCS, despite P fertilization at a 1x rate, by as much as 9 ppm for Wood and by as much as 21 and 18 ppm for Clark and Wayne counties, respectively. This trend is consistent with yields averaged across years at these sites, as Clark and Wayne yielded more than 145 bu corn/A and 40 bu soybean/A, while Wood yielded less corn. The nine-year trend of soil test K appeared to decline at each site for both rotations regardless of fertilizer K rate (**Figure 4**). Soil test K decreased from initial levels in 2006 for the respective 1x and 2x fertilizer K rates by an average of 30 and 19 ppm for CS and by 32 and 25 ppm for CCS.

Declining trends of soil test P and K regardless of fertilization calls into question estimated crop removal rates and the soil test level response. The nine-year nutrient balance of the 1x fertilizer rate indicated a deficit of 97 lb/A or less, while the 2x fertilizer rate resulted in a nutrient surplus ranging from 339 to 449 lb/A across sites and rotations (**Table 1**). This raises two (or more) questions which should be addressed in future research: 1) *Do current estimated nutrient concentrations in*

Figure 3. Soil test P (Bray P1) trends for two corn and soybean rotations (CS or CCS) in response to P fertilizer applied at 0, 1x, and 2x the estimated crop removal rate for Clark, Wayne, and Wood county sites in Ohio. Dotted lines represent the maintenance range for each site.Fertilizer was initially applied in fall 2005 (Wood) or spring 2006 (Clark and Wayne) and then following soybean harvest in 2008 and 2011 for CCS or 2007, 2009, 2011, and 2013 for cs. All error bars denote standard error of the mean.

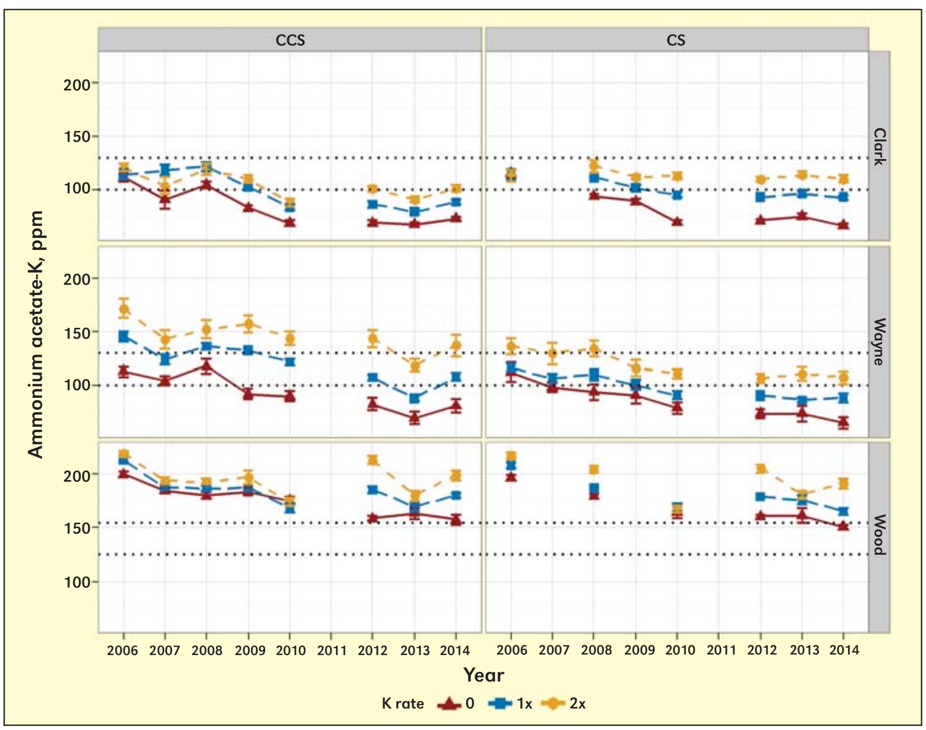

Figure 4. Soil test K (ammonium acetate extractable-K) trends for two corn and soybean rotations (CS or CCS) in response to K fertilizer applied at 0, 1x, and 2x the estimated crop removal rate for Clark, Wayne, and Wood county sites. The dotted lines represent the upper and lower limits of the maintenance range for each site. Fertilizer was initially applied in fall 2005 (Wood) or spring 2006 (Clark and Wayne) and then following soybean harvest in 2008 and 2011 for CCS or 2007, 2009, 2011, and 2013 for CS. All error bars denote standard error of the mean.

corn and soybean grain accurately reflect what is removed? and 2) *Are soil test P and K levels relatively stable from year to year if the amount of nutrient applied approximates the quantity of nutrient removed?*

Summary

In Ohio, soils with P and K initially testing within recommended maintenance ranges exhibited positive corn and soybean yield responses to P and K fertilization in 10 of 42 site-years. Results from 24 site-years of corn production indicated 17% and 4% of site-years responded positively to P and K fertilization, respectively. Results from 18 site-years of soybean production revealed a positive response to P and K fertilizer application in 11% and 17% of site-years, respectively. The response frequencies to P and K fertilization suggest the current maintenance ranges for soil test P and K are not too low and reflect the expected odds of a yield response to P and K for corn and soybeans grown in rotation. However, questions remain about observed soil test P and K downward trends, despite application of P and K fertilizer at two times the estimated crop removal rate. BC

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