2014 Results Report
Six Secrets of Soybean Success- Phase 3

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Abstract

Despite a near four-fold increase in soybean yield during the last 90 years, there is a common perception that yields have reached a plateau and are unresponsive to genetic or agronomic innovations. The objective of this research was to evaluate the individual and synergistic contributions from agronomic management for improved soybean yield. Across four Illinois trials during 2014, treatments were arranged in an incomplete factorial design and included the following agronomic factors: phosphate and potassium fertilization, varietal selection, seed treatment use, foliar fungicide and insecticide protection, and row spacing configuration. Yield and yield component responses to agronomic management were dependent upon the factor considered. Narrow rows (i.e., 0.51 m vs 0.76 m), for example, markedly improved grain yield across locations and these yield differences were primarily derived from increased seed number. Unlike observed with broadcasted potassium, banded P consistently improved yield regardless of row spacing, variety used, or location with synergistic improvements in both seed number and seed weight. Full-season varieties were most responsive to the enhanced seed treatment where significant yield improvements occurred as a result of improved final seed weight. Fuller season varieties magnified the yield value associated with agronomic treatments such as P fertilization, foliar protection, and enhanced seed treatments and suggest that opportunities for improved soybean yield are possible from varietal selection. Collectively, the 2014 findings highlight marked seed yield increases from agronomic management, and that full-season varieties may be particularly responsive to this management.

Introduction

Yields have been increasing at a steady rate since soybean's introduction in the United States over 80 years ago. Despite agronomic and genetic progress, there is a common perception that soybean yields have reached a plateau, particularly if soybean yield gains are compared to those of corn. Between 1924 and 2010, for example, average U.S. soybean yields have increased by nearly four-fold but corn yields have risen seven-fold. While the genetic contribution is responsible for as much as 50% to 80% of recent soybean yield improvements (Specht et al., 1999), adoption of agronomic innovations are generally delayed because of significant initial capital investment or uncertainty in yield outcome. Utilization of synergistic agronomic practices in soybean, as recently discovered in corn (Ruffo et al., 2015), may be necessary to ultimately realize the genetic yield potential of modern soybean germplasm.

While most producers overlook the importance of adequate nutrient availability for soybean production, some believe that improved soil fertility management may hold the greatest promise for increasing yields when used with current germplasm (Bender et al., 2015). A common corn-soybean rotation in Illinois, for example, includes an addition of 104 kg P_2O_5 and 119 kg K_2O per hectare prior to the corn production year (USDA-ERS, 2015a; USDA-ERS, 2015b), with over 80% of the subsequent soybean hectares remaining unfertilized (USDA-ERS, 2015c). At a yield level of 12.0 Mg ha^{-1}, the corn crop would remove an estimated 90 kg P_2O_5 and 66 kg K_2O per hectare in the harvested grain (Bender et al., 2013) with a mere 14 kg P_2O_5 ha^{-1} remaining for the following soybean crop. These observations are in general agreement with IPNI (2012) who documented that the current Illinois P use ratios have increased to 1.54 (i.e., 54% more P is removed than supplied), causing the concomitant reduction in soil P test levels (Fixen et al., 2010). The increased fertilizer recovery and removal of mineral elements in high-yielding maize systems, therefore, may necessitate improved agronomic management for nutrients such as P and K that are accumulated during a 50 –70 day period in soybean (Bender et al., 2015).

Soybean cultivars are classified into maturity groups (MGs) based on their estimated time of crop maturity. The earliest maturing genotypes adapted to northern regions of the United States and Canada are also considered indeterminate, a growth habit conducive for continued vegetative growth during initial reproductive development. Producers consider potential varieties by reviewing local yield trial results which frequently vary by as much as 1000 kg ha^{-1} within a similar maturity group (Joos et al., 2014). Furthermore, yield potential may increase as soybean maturity lengthens (Edwards and Purcell, 2005; Joos et al., 2014), suggesting that later maturing indeterminate varieties may be more responsive to supplemental agronomic management that maximizes growth during reproductive development (Edwards and Purcell, 2005).

Expanded adoption of soybean seed treatments has occurred the past 15 years (Munkvold, 2009), where as much as 40 – 50% of current cropland is planted with a fungicide, insecticide, and/or nematicide seed treatment (Yang, 2009; Myers and Hill, 2014). Although not always consistently, seed treatments have demonstrated the potential for improved yield and in some cases grower profit (Bradley, 2007; Munkvold, 2009; Popp et al., 2010). The likelihood of a positive yield response with seed treatment generally increases during cool and wet conditions resulting from early planting, above-average rainfall, and soils with known seedling disease pressure from pathogens such as *Pythium* spp., *Phytopthora sojae, Fusarium* spp., and *Rhizoctonia solani* (Bradley, 2009). It is largely unknown, however, if recent seed treatment innovations (e.g., nematicidal control properties, biological seed treatments) when optimized with supplemental agronomic management have enhanced seed treatment performance.

Application of foliar fungicides and insecticides on soybean serve as a pest management tool that may protect yield, and more recently have been used for their potential beneficial plant physiological effects even in the absence of disease pathogens (Venancio et al., 2003). Variable yield responses associated with nonfungicidal physiological effects (Bradley and Sweets, 2008; Swoboda and Pedersen, 2009), however, have lead researchers to recommend applications only after assessment of the current pathogen level and environmental conditions (Bradley, 2009). Despite low levels of disease pressure in a study by Swoboda and Pedersen (2009), significant increases in seed mass and seed number were reported when fungicidal applications occurred during the R3 growth stage. In a separate study by the Crop Physiology Laboratory at the University of Illinois, it was determined that 50 to 60% of soybean yield (total seeds and pods) is located in the middle region of the soybean canopy (unpublished data from 2012 and 2013). These nodes are accompanied by leaflets with the largest surface area relative to any canopy location during seed-filling (Koller, 1971) on petioles which typically extend to the periphery of the soybean canopy (Willcott, et al., 1984). As a result, it is plausible that foliar treatments at the recommended R3 growth stage may be particularly effective in maintaining leaf activity in this critical canopy region.

The objective of this research was to evaluate the individual and synergistic contributions from agronomic management for improved soybean yield. The research approach included an evaluation of five agronomic factors: phosphate and potassium fertilization, varietal selection, seed treatment, foliar fungicidal and insecticidal protection, and row spacing. These studies were conducted using an supplemented/ withheld plot design (Ruffo et al., 2015) with the hypothesis that agronomic management would be of greater value in environments using more narrow row spacing (e.g., 0.51 m vs 0.76 m rows) with longer relative maturity varieties.

Materials and Methods

A total of six soybean agronomic management trials were evaluated across Illinois during 2014. The trials were located in northern Illinois near the Northern Illinois Agronomy Research Center (DeKalb), central Illinois at the Department of Crop Sciences Research and Education Center (Champaign), and in southern Illinois (Harrisburg). Due to a planter malfunction leading to inconsistencies in plot planting and seed germination and excessive yield outliers, the DeKalb site was dropped from additional analysis. Relevant trial information including planting date, varietal comparisons, and pre-plant soil properties are outlined in Table 1. Fields in conventional tillage following maize as the previous crop were used. An incomplete factorial design was implemented with six replications per trial at each location. Experimental plots were four rows wide (0.76 m or 0.51 m row^{-1}) and 12.2 m in length with the center two rows used for the collection of yield data. Soybean yield components were algebraically derived using the seed mass at harvest to determine seed number (seeds m^{-2}).

Two of these trials were sponsored in part by Syngenta (Syngenta Crop Protection products and NK varieties; Syngenta Seeds, Minnetonka, MN) and the other two trials were co-sponsored by BASF (crop protection products; BASF, Florham Park, New Jersey) and Monsanto (Asgrow varieties; Monsanto Company, St. Louis, MO) (Table 1). Plots were seeded at 440,000 seeds ha^{-1} to target an approximate final stand of 395,000 plants ha^{-1}. The entire trial was evaluated in both 0.76 m and 0.51 m row spacing using a research plot planter (SeedPro 360, ALMACO, Nevada, IA) designed with adjustable row units. Weed control consisted of a pre-emergence application of s-metolachlor {Acetamide, 2-chloro-N-(2-ethyl-6- methylphenyl)-N-(2-methoxy-1- methylethyl]-,(S)}, metribuzin {4-amino-6-(1,1-dimethylethyl)-3- (methylthio)-1,2,4-triazin-5 (4H)-one}, and fomesafen {5-[2-chloro-4-(trifluoromethyl)phenoxy]-N-(methylsulfonyl)-2-nitrobenzamide} and a post-emergence application of glyphosate {*N*-(phosphonomethyl)glycine}.

Agronomic Practices

Fertility

Fertilizer containing N, P, S, and Zn was applied in a subsurface band 10 to 15 cm deep immediately prior to planting using a research-scale fertilizer toolbar. This toolbar was constructed by the University of Illinois Crop Physiology Laboratory using DAWN 6000 Universal Fertilizer Applicator row units (Dawn Equipment, Sycamore, IL), and a Gandy Orbit-Air Applicator (Gandy Company, Owatonna, MN) to meter dry fertilizer sources. The P fertilizer source used was MicroEssentials SZ (12-40-0-10S-1Zn; The Mosaic Company, Plymouth, MN) applied at 84 kg P_2O_5 ha^{-1} to supply the P, S, and Zn nutrition required to produce approximately 5000 kg ha^{-1} grain yield in soybean. A second nutrient source contained K and B and was broadcast applied before planting using a research-scale spinner-spreader attached to a Kubota RTV1100 (Kubota Tractor Corporation, Torrance, CA). The potassium source was Aspire (0-0-58-0.5B; The Mosaic Company, Plymouth, MN) applied at a rate of 84 kg K_2O ha^{-1}.

Variety

Adapted soybean varieties for each location were used as per the recommendation of seed company partners. At each site, a variety of typical or early maturity for the region (labeled as 'early-season') and a variety of longer maturity for the region (labeled as 'full-season') were evaluated across all management treatments (Table 1). The rationale for also using a full-season variety was that a longer period of vegetative growth may potentially allow for greater responsiveness to agronomic inputs such as fertility and foliar protection.

Foliar Protection

The value of a foliar fungicide and insecticide were jointly used prophylactically. The Syngenta sponsored trials evaluated Quilt Xcel (azoxystrobin + propiconazole) and Endigo ZC (lambda-cyhalothrin + thiamethoxam) as the fungicide and insecticide, respectively. Products were applied at the recommended label rate (i.e., Quilt Xcel at 1023 ml ha^{-1} and Endigo ZC at 292 ml ha^{-1}). The Monsanto/BASF sponsored trials included the fungicide Priaxor (fluxapyroxad + pyraclostrobin) and insecticide Fastac (alpha-cypermethrin), each applied at 292 ml ha^{-1}. Applications were made at the beginning of pod development (R3) using a pressurized CO_2 back-pack sprayer. The center two rows of each plot were treated with a spray volume of 140 liters ha^{-1}.

Seed Treatment

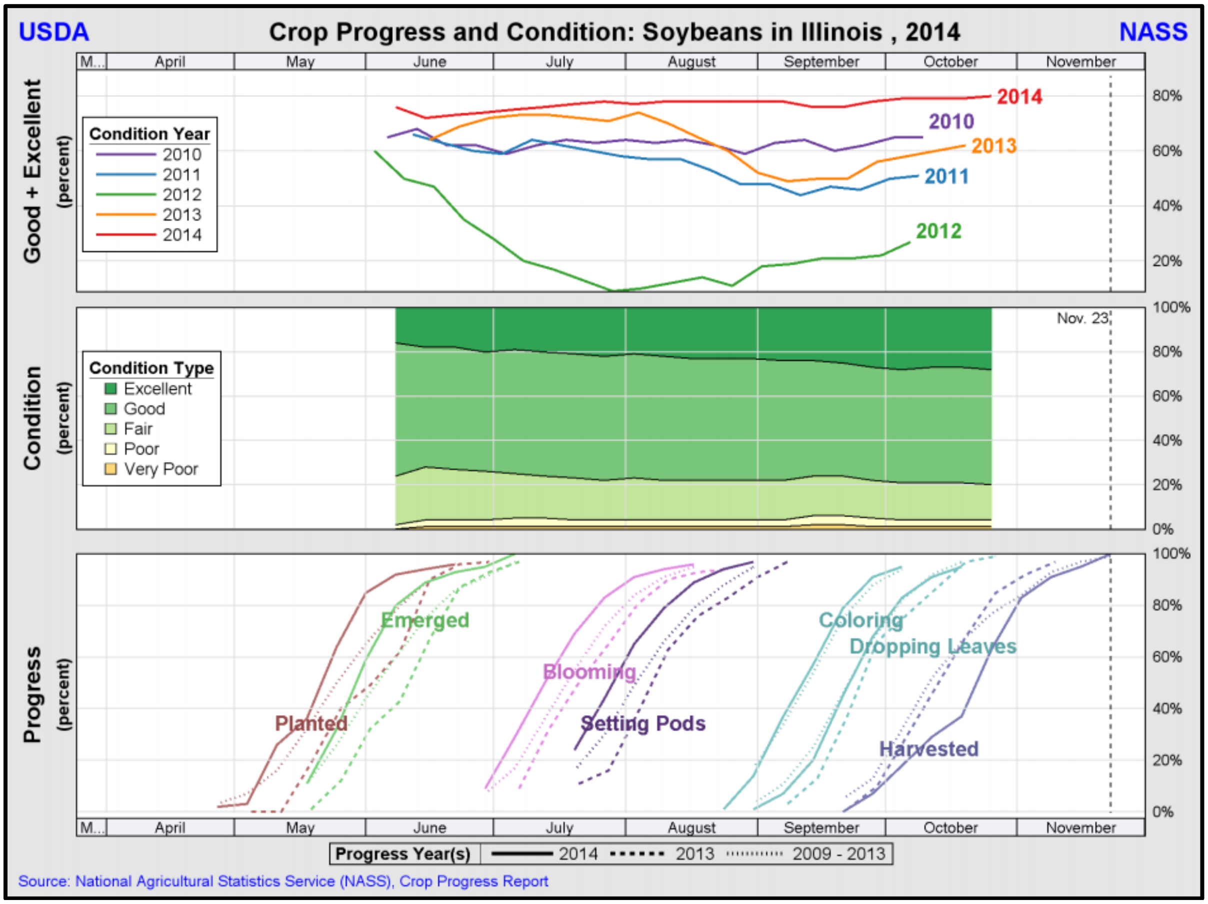
The seed treatment comparison varied according to the trial's industry sponsored partner. Base and advanced seed treatment packages were compared in the Syngenta trials. The high tech treatment included the Clariva Complete Beans treatment package (CruiserMaxx + Vibrance + Nematicide) (fungicide + insecticide + nematicide: mefenoxam + fludioxonil + thiamethoxam + sedaxane + Pasteuria nishizawaue), while the base seed treatment included the ApronMaxx (fungicide only: mefenoxam + fludioxonil) seed treatment. Seed of the same lot was treated and provided by Syngenta Seed Care. The Monsanto/BASF trials focused on untreated seed compared to a full seed treatment package. This seed treatment included the Acceleron with Poncho VOTiVO seed treatment (fungicide + insecticide + nematicide: metalaxyl + pyraclostrobin + fluxapyroxad + clothianidin + *Bacillus firmus*), while the base seed treatment included untreated seed. Seed was sourced from commercial seed lots.

Statistical Analysis

Grain yield and yield components were analyzed using PROC MIXED in SAS (SAS Institute, 2009). All yield and seed weight units are expressed on a dry weight basis (i.e., 0% moisture concentration). Location (n=2), row spacing (n=2), and agronomic management treatment (n=12) and their interactions were included in the model as fixed effects. Location, replication, and research collaborator (i.e., Monsanto/BASF or Syngenta) were included as random effects.

Results and Discussion

The 2014 production year experienced near ideal conditions with crop planting, emergence, and season-long soybean development progress reports ahead of the five-year average (Figure 1; USDA-NASS, 2014). Furthermore, the limited little weather-induced heat or moisture stress resulted in ‘Good’ to ‘Excellent’ conditions throughout much of the growing season (Figure 1). Maturity, row spacing, and agronomic management treatments were significant sources of variation for grain yield and yield components (Table 2). Across four trials in Illinois during 2014, the average grain yield measured 4326 kg ha^{-1} (0% moisture concentration, 74.0 bu Ac^{-1}).



Source: National Agricultural Statistics Service (NASS), Crop Progress Report

Figure 1. Effect of growing season on soybean growth and development in Illinois during 2014. Information was summarized from USDA-NASS (2014) and adapted for this report.

Effect of Row Spacing

Row spacing (i.e., 0.76m vs 0.51m) markedly influenced grain yield and yield components during 2014 (Table 2). The main effect of narrow rows improved yield by nearly 9% at Champaign and Harrisburg (Table 3). Seed yield differences were primarily due to increased seed number (+10%) which offset the more moderate reduction in seed weight (-1%; Table 3). The apparent inverse relationship between these yield components clearly illustrates the complex and compensatory nature of yield establishment in soybean. The significant yield improvement suggests a potential photoassimilate source limitation in which narrow rows were able to successfully increase light interception and net carbon fixation. It should be noted that aside from the initial capital equipment investment, narrow row spacing generally requires no additional expense at seeding. Consistent with the previous 16 site-years of yield data measured using this trial approach (data not shown), narrow row spacing never decreased yield, yet offered the potential upside of significantly greater yields in certain environments.

Effect of Variety Relative Maturity

A more typical or early-season variety was compared to a fuller season variety within each trial and location. The marginal yield increase (+1%) associated with a fuller season variety was obtained through greater seed number (+8%) with a concomitant reduction in final seed mass (-6%; Table 4). The phenomenon known as yield component compensation (Egli, 1998) illustrates how the generation of different yield levels may be achieved despite an inverse relationship between seed number and seed weight. Differences in the physiological determination of yield between varieties (e.g., high seed number vs high seed mass) may necessitate contrasting agronomic management considerations for maximum seed yield.

The value of additional agronomic management was evaluated in the so-called 'Standard' and 'High Tech' management systems. The 'High Tech' management system included the individual and synergistic effects of added P and K fertility, foliar protection, and a full seed treatment package in contrast to the standard system, which included no fertility or foliar protection with the most basic seed treatment (e.g., no seed treatment or a fungicide only). The interaction of variety maturity with agronomic management (Table 2) suggested that variety selection may be more critical for optimal yields in intensively managed soybean environments. 'Standard' and 'High Tech' treatments were selected to represent this comparison among varieties. Although the average response to this management across all varieties was +419 kg ha^{-1}, full-season varieties measured a 51% greater response (+504 kg ha^{-1} vs +333 kg ha^{-1}; Table 5) compared to varieties of more typical maturity for a region. Unlike that observed with standard management, the full-season variety outperformed the early-season variety when provided a full suite of intensive management practices (Table 5).

Significant yield improvements were observed with P fertilization, foliar protection, and the comprehensive seed treatment package across varieties (Table 6 and Table 7). Selection of a fuller season variety magnified the yield value associated with nearly each of these management decisions. Relative to the early-season variety, the enhanced yield response due to management in fuller season varieties was primarily associated with increased seed weight as opposed to seed number (Table 6 and Table 7). Although pre-plant or early season management practices are thought to increase seed number in soybean (Egli, 1998), greater source availability may promote differential yield component responses depending on variety selected (e.g., increased seed number for early season varieties or increased seed weight with full season varieties). Collectively, these findings suggest that opportunities for improved soybean yield derived from variety selection are possible, and this decision may be especially important under intensively managed soybean environments.

Effect of Fertility

Averaged across all varieties and row spacing configurations, fertilization of banded P improved yield in 'Standard' management by nearly 6% (Table 8). A similar response was measured in the 'High Tech' treatments, where omitting banded P significantly reduced yield by 5% (Table 9). The yield increase due to banded P, either alone or in combination with K, primarily resulted from greater seed number (+3 to 5%) with a synergistic improvements in seed weight (+1 to 2%; Tables 8 and 9).

The broadcasted potassium treatment alone did not consistently improve yield regardless of row configuration or management level (Tables 8 and 9). Each of the soil test values for potassium measured between 103 and 135 ppm Mehlich III and were considered 'Medium' for these environments. These values, along with the more confined period of K accumulation and unique remobilization tendencies of K in soybean (Bender et al., 2015), may have contributed to the less consistent yield enhancements with this treatment.

Interestingly, the most recent USDA-ERS survey suggest that nearly twice as many Illinois acres receive potash (31%; USDA-ERS, 2015d) as opposed to phosphate (16%; USDA-ERS, 2015c) directly before the soybean production year. Given the consistency of yield responses to fertilized P observed in the current study, additional research may be necessary to further improve the predictability of yield responses associated with potassium when applied to soybean. The season-long demand of P (Bender et al., 2015) and 'Low' preplant soil test levels which ranged from 14 to 29 ppm P (Table 1), may at least partially explain the marked yield improvements associated with P fertilization.

The banded P treatment was applied at 84 kg P_2O_5 ha^{-1} and is near the estimated quantity removed with a 5000 kg ha^{-1} seed yield (Bender et al., 2015). This rate does not serve as a recommendation for producers or researchers and should be adjusted for differences in soil test values and yield goals in other environments. The Champaign location nearly achieved the 5000 kg ha^{-1} yield level and the average yield increase associated with banded P across all treatments was approximately 427 kg ha^{-1} (data not shown). Using the 5-year Olympic average soybean price (\$12.27 bushel^{-1}, Schnitkey et al., 2015), this represents a \$221 ha^{-1} increase in producer revenue at an estimated expense of approximately \$176 ha^{-1} (*Assuming \$600/ton of MESZ or \$1.65 kg* $P_2O_5^{-1}$ *(\$0.75 lb* $P_2O_5^{-1}$*) + \$37.07 ha*$^{-1}$ *(\$15.00 Ac*$^{-1}$*) application cost*).

Effect of Seed Treatment

Untreated or fungicide only seed treatments were compared to a comprehensive seed treatment package (i.e., fungicide + insecticide + nematicide) for each variety (Table 1). Unexpectedly, the yield improvement over 'Standard' management was a result of increased seed weight (Table 8). The yield penalty associated with omitting the comprehensive seed treatment in the 'High Tech' management system was not significant. Compared to early-season varieties, the full-season varieties were more responsive to the seed treatment where yield increases by as much as 5% occurred (Tables 6 and 7).

Although no quantitative soybean cyst nematode tests were conducted, a separate root evaluation study identified nematode damage to soybean roots at each of these locations. As a result, final plant stand was measured at harvest and comprehensive seed treatments were found to significantly improve this parameter regardless of management system or variety used (Table 10). Increased plant stand is well-correlated with increased nodes m^{-2}, pods m^{-2}, and ultimately seed number m^{-2} (Egli, 2013). Egli (2013) also suggested that increasing node or pod number per unit area with no corresponding increase in photoassimilate supply will not likely increase final seed yield, instead, simply increase the rate of reproductive failure. The yield improvements in this study associated with the seed treatment were predominately related to seed weight as opposed to seed number (Tables 6 to 9) and, among other possibilities, suggest that: 1) seed treatments may increase yield through greater seed number, seed weight, or both, 2) increased seed number may be realized with a seed treatment in environments limited by node or pod number per unit area through increased plant stand, and 3) conditions which promote a high seed number per unit area (e.g., high planting population, narrow row spacing, early planting date, full-season variety, etc.) may still realize yield benefits from a seed treatment via greater biomass production and photosynthetic capacity leading to increased final seed weight.

Effect of Foliar Protection

Although no qualitative or quantitative evaluation of pest pressure was evaluated in season, the low levels of insect feeding and disease pressure observed were not expected to reduce yield. The addition of fungicide and insecticide did, however, significantly improve yield by 134 kg ha^{-1} (+3%) when applied to the 'Standard' management treatment (Table 8). The value of this agronomic management practice was magnified in the 'High Tech' treatment, where omitting the foliar fungicide and insecticide treatment resulted in a near 4% yield reduction (Table 9). The yield improvements associated with this practice was largely derived from increased seed weight in full-season varieties (+2%) compared to the early-season varieties, which was more equally derived from increased seed number (+3%) and weight (+1%; Tables 6 and 7). We suspect that the increased pressures of Japanese beetles, bean leaf beetles, and stink bugs at Harrisburg contributed to the 176 to 205 kg ha^{-1} yield response to foliar protection (data not shown).

Conclusions

The objective of this research was to evaluate the use of agronomic management for improved soybean yield. The research approach included an individual and synergistic evaluation of five agronomic factors: phosphate and potassium fertilization, varietal selection, seed treatment, foliar fungicidal and insecticidal protection, and row spacing. Narrow rows (i.e., 0.51 m vs 0.76 m) markedly improved grain yield across locations and these yield differences were primarily derived from increased seed number. The yield advantage of full-season varieties was especially apparent with 'High Tech' management. Fuller season varieties magnified the yield value associated with agronomic treatments such as P fertilization, foliar protection, and enhanced seed treatments and suggest that opportunities for improved soybean yield are possible from varietal selection. Unlike observed with broadcasted potassium, banded P consistently improved yield regardless of row spacing, variety used, or location with synergistic improvements in both seed number and seed weight. Full-season varieties were most responsive to the enhanced seed treatment where significant yield improvements occurred as a result of improved final seed weight. Collectively, the 2014 findings suggest marked seed yield increases are possible with agronomic management, and that full-season varieties may be particularly responsive to this management.

Progress Report Update

This dataset represents a compilation of data from only 2014. A more comprehensive analysis of yield components and grain quality (i.e., protein and oil), will be conducted and combined with results from 2012 and 2013. The completed manuscript will thoroughly evaluate the individual and synergistic contributions of seed treatment, foliar protection, variety selection, fertility management, and row spacing as five categorical factors across 18 site-years that can be used to influence yield of soybean. We anticipate that the initial version of this peer-reviewed publication will be submitted by the summer of 2015.

Table 1. Trial information and initial soil properties for four soybean management trials evaluated at two Illinois locations during 2014. Trials were planted in Champaign (7 May) and Harrisburg (25 May) to varieties shown below (RM in parentheses).

Location, Collaborators	**Variety Comparison**	**Organic Matter**	**pH**	**CEC**	**P**	**K**	**Ca**	**Mg**	**S**	**Zn**	**B**
Champaign		*%*		*meq* $100g^{-1}$	ppm†						
Syngenta	S32-L8 (3.2),	3.5	6.0	22.8	17	135	2852	552	10	1.5	0.5
	S39-U2 (3.9)				L	M	M	H	M	L	L
Monsanto,	AG3634 (3.6),	3.7	5.7	23.0	20	106	2740	510	10	1.4	0.5
BASF	AG3832 (3.8)				L	M	M	H	M	L	L
Harrisburg											
Syngenta	S46-L2 (4.6),	2.4	6.4	14.2	17	116	2196	205	8	1.0	0.3
	S48-P4 (4.8)				L	M	M	M	L	L	VL
Monsanto,	AG4933 (4.9),	2.5	6.5	13.3	14	103	2026	204	7	0.8	0.2
BASF	AG5233 (5.2)				VL	M	M	M	L	L	VL

† Minerals P, K, Ca, Mg, S, Zn, and B were extracted using Mehlich III solution and are reported as raw means along with their designation: 'Very Low' (VL), 'Low' (L), 'Medium' (M), 'High' (H), and 'Very High' (VH).

Table 2. Analysis of variance for yield and yield components for four soybean management trials at two Illinois locations during 2014. 'Maturity' represents an early vs full-season variety comparison, 'Row spacing' compares 0.51 and 0.76m and 'Treatment' represents the remaining 12 fertility, leaf, or seed treatments.

Source of Variation	**Grain Yield**	**Seed Number**	**Seed Mass**
Maturity (M)	0.035	<0.001	<0.001
Row Spacing (S)	<0.001	<0.001	0.004
M x S	0.657	0.368	0.241
Treatment (T)	<0.001	<0.001	<0.001
M x T	0.055	0.630	0.741
S x T	0.779	0.934	0.616
M x S x T	0.788	0.719	0.699

Table 3. Grain yield and yield components for row spacing configurations across four Illinois soybean management trials during 2014. Both yield (kg ha^{-1}) and seed mass (mg $seed^{-1}$) are presented on a dry weight basis (i.e., 0% moisture concentration).

Row Spacing	**Grain Yield**	**Seed Number**	**Seed Mass**
	kg ha^{-1}	number m^{-2}	mg $seed^{-1}$
0.51m	4502	3428	131.3
0.76m	4149	3125	133.1
Difference	-353***	-303***	+1.8***

Significantly different than zero at 0.10 (*), 0.05 (**), and 0.01 (***).

Table 4. Grain yield and yield components for the soybean variety comparison across four Illinois soybean management trials during 2014. Both yield (kg ha^{-1}) and seed mass (mg seed^{-1}) are presented on a dry weight basis (i.e., 0% moisture concentration).

Maturity	Grain Yield	Seed Number	Seed Mass
	kg ha^{-1}	number m^{-2}	mg seed^{-1}
Early-Season	4306	3153	136.3
Full-Season	4345	3400	128.2
Difference	+39**	+247***	-8.1***

Significantly different than zero at 0.10 (*), 0.05 (**), and 0.01 (***).

Table 5. Effect of agronomic management (Standard vs High Tech treatments) and variety selection on grain yield at two Illinois locations during 2014.

Maturity	Standard	High Tech	Δ
		kg ha^{-1}	
Early-Season	4128	4461	+333***
Full-Season	4070	4574	+504***
Difference	-58	113*	

Significantly different than zero at 0.10 (*), 0.05 (**), and 0.01 (***)

Table 6. Effect of ‘Standard’ agronomic management and variety selection on soybean yield and yield components across four trials in Illinois during 2014. Both yield (kg ha^{-1}) and seed mass (mg seed^{-1}) are provided on a dry weight basis (i.e., 0% moisture concentration). Values within a column represent the difference relative to the ‘Standard’ treatment.

Variety	Early-Season			Full-Season		
Add One Enhanced Factor	Yield	Seed Number	Seed Weight	Yield	Seed Number	Seed Weight
	kg ha^{-1}	number m^{-2}	mg seed^{-1}	kg ha^{-1}	number m^{-2}	mg seed^{-1}
Standard	4128	3032	134.4	4070	3303	125.1
+Phosphorus	+169	+150	+1.2	+296	+141	+2.6
+Potassium	-76	-8	-0.3	+90	+35	+0.3
+P and K	+297	+200	+2.6	+330	+130	+3.4
+Fung. + Insect.	+152	+94	+2.3	+117	-7	+2.8
+Seed Treatment	-27	-9	+1.0	+223	+33	+3.2
LSD (α=0.10)	106	86	2.0	105	86	2.0

Table 7. Effect of ‘High Tech’ agronomic management and variety selection on soybean yield and yield components across four trials in Illinois during 2014. Both yield (kg ha^{-1}) and seed mass (mg seed^{-1}) are provided on a dry weight basis (i.e., 0% moisture concentration). Values within a column represent the difference relative to the ‘High Tech’ treatment.

Variety	Early-Season			Full-Season		
Withhold One Enhanced Factor	Yield	Seed Number	Seed Weight	Yield	Seed Number	Seed Weight
	kg ha^{-1}	number m^{-2}	mg seed^{-1}	kg ha^{-1}	number m^{-2}	mg seed^{-1}
High Tech	4461	3245	137.4	4574	3510	130.8
-Phosphorus	-124	-77	-0.7	-302	-149	-2.3
-Potassium	+34	+22	+0.9	+7	+4	+0.0
-P and K	-177	-152	+0.1	-237	-144	-3.2
-Fung. + Insect.	-142	-72	-1.6	-182	-83	-2.9
-Seed Treatment	+7	+24	-1.2	-88	-43	-1.3
LSD (α=0.10)	106	86	2.0	105	86	2.0

Table 8. Effect of agronomic management added to the 'Standard' treatment averaged across all varieties and row spacing configurations in Illinois during 2014. Both yield (kg ha^{-1}) and seed mass (mg seed^{-1}) are presented on a dry weight basis (i.e., 0% moisture concentration).

Add One Enhanced Factor	**Yield**	**Δ**	**Seed Number**	**Δ**	**Seed Weight**	**Δ**
	kg ha^{-1}		number m^{-2}		mg seed^{-1}	
Standard	4095		3167		129.8	
+Phosphorus	4328	+232***	3313	+146***	131.6	+1.8**
+Potassium	4102	+7	3181	+14	129.7	-0.1
+P and K	4409	+313***	3332	+165***	132.7	+2.9***
+Fung. + Insect.	4230	+134***	3211	+43	132.3	+2.6***
+Seed Treatment	4193	+98**	3180	+13	131.9	+2.1**

Significantly different than mean of 'Standard' treatment at 0.10 (*), 0.05 (**), and 0.01 (***).

Table 9. Effect of agronomic management omitted from the 'High Tech' treatment averaged across all varieties and row spacing configurations in Illinois during 2014. Both yield (kg ha^{-1}) and seed mass (mg seed^{-1}) are presented on a dry weight basis (i.e., 0% moisture concentration).

Withhold One Enhanced Factor	**Yield**	**Δ**	**Seed Number**	**Δ**	**Seed Weight**	**Δ**
	kg ha^{-1}		number m^{-2}		mg seed^{-1}	
High Tech	4517		3378		134.1	
-Phosphorus	4304	-213***	3264	-113***	132.6	-1.5*
-Potassium	4538	+21	3391	+13	134.6	+0.5
-P and K	4311	-207***	3229	-148***	132.6	-1.5*
-Fung. + Insect.	4355	-162***	3300	-77**	131.9	-2.2***
-Seed Treatment	4477	-40	3368	-9	132.8	-1.3

Significantly different than mean of 'High Tech' treatment at 0.10 (*), 0.05 (**), and 0.01 (***).

Table 10. Increase in final plant stand due to seed treatment in 'Standard' and 'High Tech' treatments. Plant stand was estimated at physiological maturity (R8) for plots with and without a seed treatment (e.g., Standard vs. Standard + Seed Treatment; High Tech vs High Tech – Seed Treatment).

Maturity	**Standard**	**High Tech**	**Average**
	plants ha^{-1}		
Early-Season	+14,696**	+22,543***	+18,620***
Full-Season	+25,271***	+38,244***	+31,757***
Average	+19,984***	+30,393***	

Significantly different from zero at 0.10 (*), 0.05 (**), and 0.01 (***)

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