



# Using High-Input Systems for Soybean Management Increases Yield but Not Profitability

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## IN A BEAN POD...

- ✓ High-input management systems significantly increased yield on average in the Central (IA, IL, IN) and North (MI, MN, WI) regions, but not in the South (AR, KS, KY) region.
- ✓ Although the high-input management systems increased yield, the probability of breaking-even on the investment was less than 10% for most of the different yield and sale price combinations analyzed.
- ✓ Cultivar selection and high-input system use rarely interacted, suggesting these two management decisions can remain independent.

## INTRODUCTION

Increased soybean commodity prices in the last 10 years have generated interest in developing high-input systems to increase yield. However, little peer-reviewed information exists about the effects of input-intensive, high-yield management on soybean yield and profitability, as well as their interactions with basic agronomic practices.

In 2009, the United Soybean Board funded a study called the “Kitchen Sink Project” to begin examining some of these questions. The research was conducted in six states (Arkansas, Iowa, Kentucky, Louisiana, Michigan, and Minnesota) from 2009 to 2011. While there were several projects within this study, one of the main projects focused on row spacing and a “kitchen sink” approach to input use. The “kitchen sink” treatment included additional soil-applied fertilizer, seed treatment fungicides and insecticide, seed-applied inoculant, foliar fertilizer, and foliar fungicide. Some of the highlights from this particular study included:

- ☑ Narrow row spacing ( $\leq 20$  in) produced the highest yields.
- ☑ Wide row spacing with the “kitchen sink” treatment yielded similar to narrow row spacing without the “kitchen sink” treatment.
- ☑ Foliar fungicide was the input that gave the most consistent positive yield response.

More information regarding the “Kitchen Sink Project” can be found at <http://www.usb-extremebeans.com>.

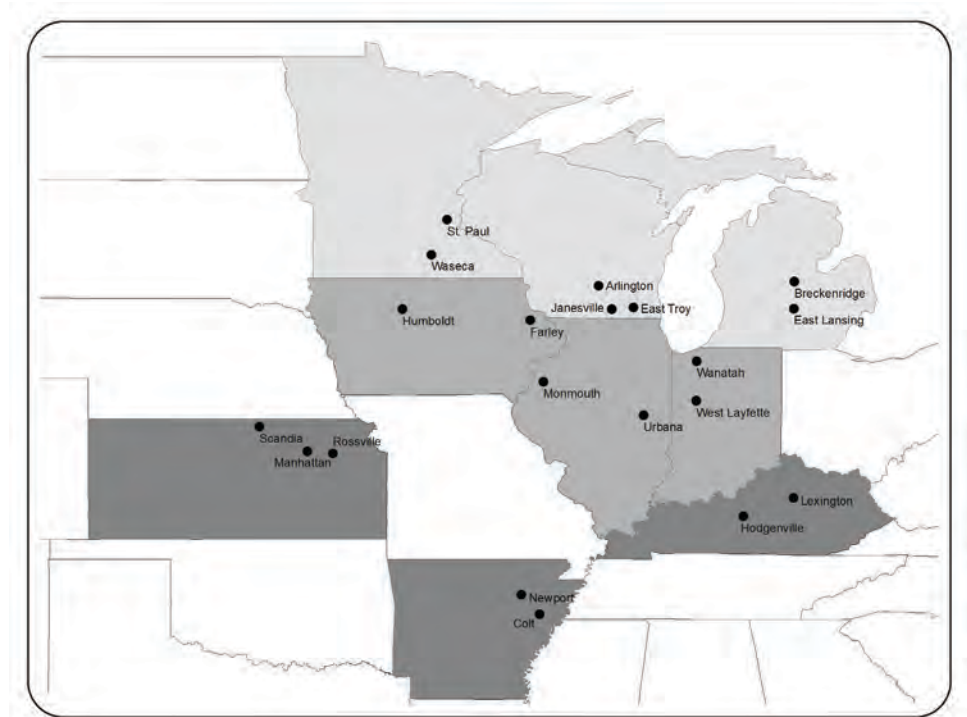
Beginning in 2012, the United Soybean Board funded a follow-up multi-state project, nicknamed “SOYA,” to build off of the research conducted in the “Kitchen Sink Project.” One of the main objectives of this project was to investigate the effects of more inputs and more combinations of these inputs as part of high-input systems on soybean and profitability. Other objectives were to investigate how these high-input systems interact with other agronomic practices. Two of these experiments will be presented in this article.

Field experiments were established at 20 locations spanning nine states from 2012 to 2014 (Figure 1). Study locations were managed by cooperating researchers at the eight major land-grant universities who participated in the study.

### EXPERIMENT 1: EVALUATING INPUT-INTENSIVE MANAGEMENT SYSTEMS

The objective of this study was to investigate the effects of individual inputs, including seed treatments, growth promoters, defoliant, soil-applied nitrogen fertilizer, foliar fertilizer, N,N'-diformyl urea, foliar fungicide, and foliar insecticide, as well as combinations of these inputs on soybean seed yield and economic break-even probabilities (Orlowski et al., 2016). The individual inputs, as well as several high-input systems, were evaluated against the standard practice. The standard practice consisted of university recommendations for fertilizer and weed control programs, narrow spacing ( $\leq 20$  in), optimal plant-

**Figure 1.** Field experiment locations from 2012 to 2014. States were grouped into regions which were South (dark gray), Central (gray), and North (light gray).



**Table 1.** Component products, active ingredients, and application rates and timings for the 16 treatments used in Experiment 1 between 2012 and 2014.

Product <sup>†</sup>	Active ingredient	Rate	Timing	SP <sup>‡</sup>	TREATMENTS <sup>§</sup>										COMBINATION			
					SEED TREATMENT					FOLIAR-APPLIED					SOYA+ D	SOYA- N	SOYA- FF	SOYA-FF and FI
					F ST	F + I ST	Max ST	D	N	F	DU	FF	FI	FF + FI	SOYA			
Acceleron F	pyraclostrobin + metal-axyl + fluxapyroxad	1.6 fl oz/100 lb seed	Seed	-	+	+	+	-	-	-	-	-	-	-	+	+	+	+
Acceleron I	imidacloprid	4 fl oz/100 lb seed	Seed	-	-	+	+	-	-	-	-	-	-	-	+	+	+	+
Poncho/Votivo	clothianidin + <i>Bacillus firmus</i>	1 fl oz/100 lb seed	Seed	-	-	+	+	-	-	-	-	-	-	-	+	+	+	+
Optimize	<i>Bradyrhizobium japonicum</i> + LCO <sup>¶</sup>	2.8 fl oz/100 lb seed	Seed	-	-	-	+	-	-	-	-	-	-	-	+	+	+	+
Ratchet	LCO <sup>¶</sup>	4 fl oz/a	V4-V6	-	-	-	+	-	-	-	-	-	-	-	+	+	+	+
Cobra	lactofen	12 fl oz/a + 1% v/v COC	V4	-	-	-	-	+	-	-	-	-	-	-	-	+	-	-
Urea <sup>#</sup>	46-0-0 %N-P <sub>2</sub> O <sub>5</sub> -K <sub>2</sub> O	75 lb/a	V4	-	-	-	-	-	+	-	-	-	-	-	+	+	-	+
ESN	44-0-0 %N-P <sub>2</sub> O <sub>5</sub> -K <sub>2</sub> O	75 lb/a	V4	-	-	-	-	-	+	-	-	-	-	-	+	+	-	+
Task Force II	11-8-5-0.1-0.05-																	
	0.040.02-0.00025-	64 fl oz/a	R1	-	-	-	-	-	-	+	-	-	-	-	+	+	+	+
	0.00025 %N-P <sub>2</sub> O <sub>5</sub> -K <sub>2</sub> O-Fe-Mn-Zn-B-Co-Mo																	
Bio-Forge	N,N'-diformyl urea	16 fl oz/a	R3	-	-	-	-	-	-	-	+	-	-	-	+	+	+	+
Priaxor <sup>††</sup>	pyraclostrobin + fluxapyroxad	8 fl oz/a	R3	-	-	-	-	-	-	-	-	+	-	+	+	+	-	-
Endigo <sup>††</sup>	lambda-cyhalothrin + thiamethoxam	4 fl oz/a	R3	-	-	-	-	-	-	-	-	-	+	+	+	+	+	-

<sup>†</sup> Acceleron® (Monsanto Co.); Poncho®/Votivo® (Bayer Crop Science); Optimize® (Novozymes); ESN [environmentally smart nitrogen (polymer-coated urea)] (Agrium); Ratchet™ (Novozymes); Cobra® (Valent USA Corp.); Task Force® 2 (Loveland Products, Inc.); Bio-Forge® (Stoller USA, Inc.); Priaxor™ (BASF Corp.); Endigo® (Syngenta Crop Protection).

<sup>‡</sup> SP, standard practice. This consisted of following university guidelines for fertilizer and herbicide applications. No other inputs were used.

<sup>§</sup> F ST, fungicide seed treatment; F + I ST, fungicide + insecticide seed treatment; D, defoliant; N, soil-applied nitrogen fertilizer; F, foliar fertilizer; DU, N,N'-diformyl urea; FF, foliar fungicide; FI, foliar insecticide; FF + FI, foliar fungicide + foliar insecticide.

<sup>¶</sup> LCO; lipo-chitoooligosaccharide.

<sup>#</sup> Treated with Agrotain® [N-(n-butyl) thiophosphoric triamide] (Koch Agronomic Services, LLC) at a rate of 95 fl oz/ton.

<sup>††</sup> Headline® fungicide (BASF Corp.) was used in 2012. Warrior II® insecticide (Syngenta Crop Protection, LLC) was used in 2012.

ing dates, and a seeding rate of 175,000 seeds/a. No other inputs were used in the standard practice. Products and rates for the 16 different treatments evaluated in this study are listed in Table 1.

Sixty site-years of data were collected. Analyzing the yields within each individual site-year revealed significant differences among the treatments were observed in 26 of 60 site-years (43%), and the majority of the responsive site-years were found in the northern Midwest.

When the site-years were grouped by region (see Figure 1), the analysis for the South region showed no differences in yield among any of the input treatments. Economic break-even probabilities in the South region were  $\leq 2\%$  for all high-input systems (i.e., the SOYA treatments) across all yield levels and sale prices (Table 2). The only input which demonstrated a break-even probability  $>50\%$  for any of the yield and sale price combinations was the defoliant.

In the Central region, the defoliant significantly decreased yield by 4.7% compared to the standard practice. The only treatment which increased yield compared to the standard practice was the SOYA treatment. However, break-even probabilities for all five high-input systems were 0% for all yield and sale price combinations (Table 3). Foliar insecticide was the only input that achieved break-even probabilities over 50%.

**Table 2.** Percent relative yield change and break-even probabilities for input treatments compared to the standard practice at multiple yield levels and soybean sale prices for studies across the South region (Arkansas, Kansas, and Kentucky) between 2012 and 2014. Average yield for the standard practice in the South region across all three years of the experiment was 61.1 bu/a.

			Yield level								
			45 bu/a			60 bu/a			75 bu/a		
			Soybean sale price								
Input	Cost (\$/a)	RYC (%) <sup>†</sup>	\$9	\$12	\$15	\$9	\$12	\$15	\$9	\$12	\$15
----- % probability of break-even -----											
Fungicide ST	\$8.75	-1.5	13	18	21	18	22	25	21	25	27
Fungicide + Insecticide ST	\$21.25	-1.0	2	7	11	7	13	18	11	18	23
Max ST	\$24.25	1.2	7	17	27	17	30	39	27	39	47
Foliar Fertilizer	\$19.00	0.2	9	19	27	19	29	36	27	36	42
Defoliant (D)	\$18.11	1.2	31	47	57	47	60	67	57	67	72
Nitrogen fertilizer(N)	\$44.22	0.0	0	0	2	0	2	6	2	6	12
N,N'-diformyl urea	\$20.80	-0.5	4	9	15	9	17	23	15	23	28
Foliar Fungicide (FF)	\$38.90	0.5	0	0	2	0	3	6	2	6	11
Foliar Insecticide (FI)	\$13.79	-1.5	8	13	18	13	19	23	18	23	27
Foliar Fungicide + Insecticide	\$44.69	0.0	0	0	1	0	1	4	1	4	8
SOYA <sup>‡</sup>	\$152.96	4.4	0	0	0	0	0	0	0	0	0
SOYA + D	\$171.07	3.7	0	0	0	0	0	0	0	0	0
SOYA - N	\$108.74	2.9	0	0	0	0	0	0	0	0	1
SOYA - FF	\$114.06	3.4	0	0	0	0	0	0	0	0	2
SOYA - FF and FI	\$108.27	1.5	0	0	0	0	0	0	0	0	0

<sup>†</sup> RYC, percent relative yield change compared to the standard practice. Average yield for the standard practice in the South region was 61.1 bu/a.

<sup>‡</sup> SOYA, high-input treatment consisting of the max ST, nitrogen fertilizer, foliar fertilizer, N,N'-diformyl urea, foliar fungicide, and foliar insecticide.



Field trial in East Troy, WI in June 2014 depicting the 16 input treatments evaluated in Experiment 1.



**Table 3.** Percent relative yield change and break-even probabilities for input treatments compared to the standard practice at multiple yield levels and soybean sale prices for studies across the Central region (Illinois, Indiana, and Iowa) between 2012 and 2014. Average yield for the standard practice in the Central region across all three years of the experiment was 60.1 bu/a.

			Yield level								
			45 bu/a			60 bu/a			75 bu/a		
			Soybean sale price								
Input	Cost (\$/a)	RYC (%) <sup>†</sup>	\$9	\$12	\$15	\$9	\$12	\$15	\$9	\$12	\$15
----- % probability of break-even -----											
Fungicide ST	\$8.75	-0.5	9	16	21	16	23	28	21	28	32
Fungicide + Insecticide ST	\$21.25	0.5	0	1	2	1	3	6	2	6	10
Max ST	\$24.25	-0.5	0	0	1	0	1	2	1	2	5
Foliar Fertilizer	\$19.00	-0.7	0	1	2	1	3	5	2	5	9
Defoliant (D)	\$18.11	-4.7	0	0	0	0	0	0	0	0	0
Nitrogen fertilizer(N)	\$44.22	1.2	0	0	0	0	0	2	0	2	6
N,N'-diformyl urea	\$20.80	-0.2	0	1	2	1	3	7	2	7	11
Foliar Fungicide (FF)	\$38.90	2.5	0	0	2	0	4	13	2	13	28
Foliar Insecticide (FI)	\$13.79	1.5	19	37	49	37	53	62	49	62	69
Foliar Fungicide + Insecticide	\$44.69	3.5	0	0	3	0	6	22	3	22	43
SOYA <sup>‡</sup>	\$152.96	5.2	0	0	0	0	0	0	0	0	0
SOYA + D	\$171.07	3.2	0	0	0	0	0	0	0	0	0
SOYA - N	\$108.74	3.5	0	0	0	0	0	0	0	0	0
SOYA - FF	\$114.06	2.7	0	0	0	0	0	0	0	0	0
SOYA - FF and FI	\$108.27	2.7	0	0	0	0	0	0	0	0	0

<sup>†</sup> RYC, percent relative yield change compared to the standard practice. Average yield for the standard practice in the Central region was 60.1 bu/a.

<sup>‡</sup> SOYA, high-input treatment consisting of the max ST, nitrogen fertilizer, foliar fertilizer, N,N'-diformyl urea, foliar fungicide, and foliar insecticide.

As demonstrated from the individual site-year analysis, more yield responses to the input treatments were observed in the North region. Similar to results in the Central region, using the defoliant led to decreased yield (by 4.1%) compared to the standard practice. On the other hand, the treatments that yielded significantly greater than the standard practice were: max seed treatment, nitrogen fertilizer, foliar fungicide, foliar insecticide, foliar fungicide + foliar insecticide, and all five SOYA treatments.

For the high-input systems, break-even probabilities were <40% at all yield and sale prices for SOYA, SOYA + D, and SOYA – FF and FI (Table 4). However, two of the high-input systems (SOYA – N and SOYA – FF) achieved a break-even probability >50%, but only at the highest yield and grain sale price. For the other input treatments that significantly increased yield compared to the standard practice, the max seed treatment had ≥50% break-even probabilities at all but the lowest yield level and soybean sale price. The nitrogen fertilizer and foliar fungicide treatments only achieved a break-even probability at, or above, 50% at the highest yield level and grain sale price. In contrast, break-even probabilities (≥98%) were observed for the foliar insecticide and foliar fungicide + foliar insecticide treatments at nearly all yield and sale price scenarios.

It is important to remember that the break-even probabilities calculated in this study were based off the costs we were able to obtain for each input (Tables

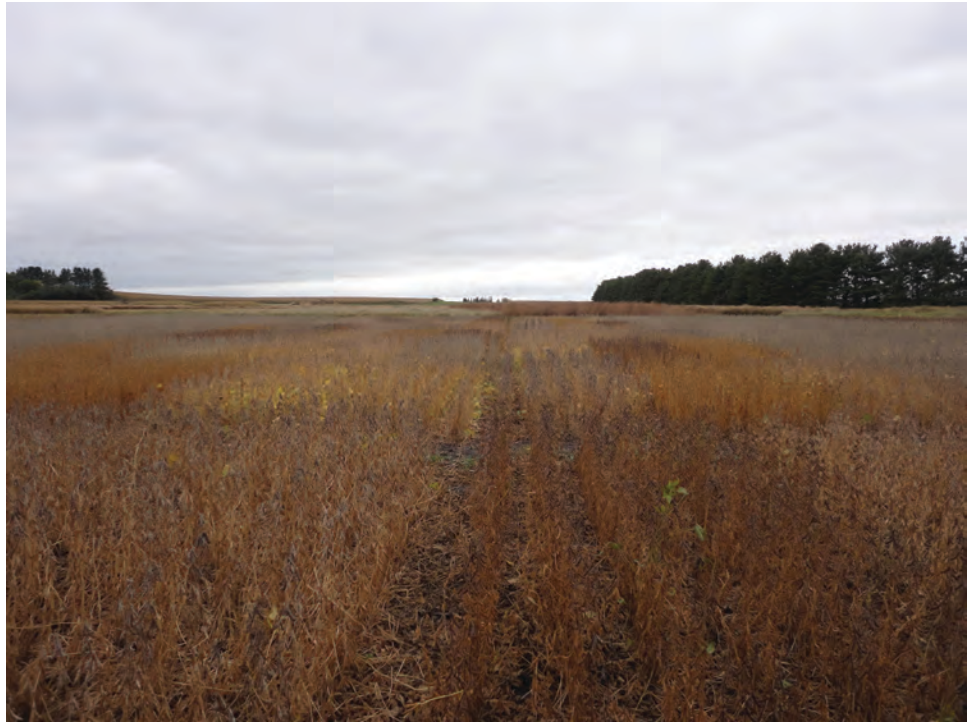
**Table 4.** Percent relative yield change and break-even probabilities for input treatments compared to the standard practice at multiple yield levels and soybean sale prices for studies across the North region (Michigan, Minnesota, and Wisconsin) between 2012 and 2014. Average yield for the standard practice in the North region across all three years of the experiment was 61.1 bu/a.

			Yield level								
			45 bu/a			60 bu/a			75 bu/a		
			Soybean sale price								
Input	Cost (\$/a)	RYC (%) <sup>†</sup>	\$9	\$12	\$15	\$9	\$12	\$15	\$9	\$12	\$15
----- % probability of break-even -----											
Fungicide ST	\$8.75	1.0	27	39	46	39	48	54	46	54	59
Fungicide + Insecticide ST	\$21.25	1.7	1	5	13	5	15	25	13	25	36
Max ST	\$24.25	3.9	18	50	71	50	76	87	71	87	93
Foliar Fertilizer	\$19.00	2.4	5	17	30	17	34	47	30	47	57
Defoliant (D)	\$18.11	-4.1	0	0	0	0	0	0	0	0	0
Nitrogen fertilizer(N)	\$44.22	3.9	0	0	5	0	9	27	5	27	50
N,N'-diformyl urea	\$20.80	1.0	1	7	15	7	18	29	15	29	39
Foliar Fungicide (FF)	\$38.90	4.6	0	3	16	3	23	47	16	47	67
Foliar Insecticide (FI)	\$13.79	7.1	99	99	99	99	99	99	99	99	99
Foliar Fungicide + Insecticide	\$44.69	11.2	64	98	99	98	99	99	99	99	99
SOYA <sup>‡</sup>	\$152.96	11.9	0	0	0	0	0	1	0	1	36
SOYA + D	\$171.07	7.5	0	0	0	0	0	0	0	0	0
SOYA - N	\$108.74	9.0	0	0	0	0	0	12	0	12	63
SOYA - FF	\$114.06	10.7	0	0	0	0	1	31	0	31	86
SOYA - FF and FI	\$108.27	6.3	0	0	0	0	0	0	0	0	2

<sup>†</sup> RYC, percent relative yield change compared to the standard practice. Average yield for the standard practice in the South region was 61.1 bu/a.

<sup>‡</sup> SOYA, high-input treatment consisting of the max ST, nitrogen fertilizer, foliar fertilizer, N,N'-diformyl urea, foliar fungicide, and foliar insecticide.

Field trial in Arlington, WI in early October 2014 depicting the six soybean cultivars near maturity (R8) which were grown under the three different input systems in Experiment 2.



2-4). Our input costs were derived from publicly available sources and industry representatives. Application costs were included for some inputs, but not for others. For example, it was assumed that the defoliant treatment could be applied to the soybean crop in a tank mix with a standard post-emergence herbicide application at V4, and therefore, no additional application costs would be incurred by the soybean producer. We understand these input costs will vary. Using your own input costs, you can determine whether or not input costs were covered based on the relative yield changes (RYC) listed for your region (Tables 2-4), your average yield, and your grain sale price.

## **EXPERIMENT 2: EVALUATING CULTIVAR AND HIGH-INPUT SYSTEM INTERACTIONS**

The objective of this study was to evaluate cultivar  $\times$  input system interactions on soybean yield and yield components (Marburger et al., 2016). Six soybean cultivars, representing high-yield potential cultivars suitable for each specific location, were chosen by the collaborating university agronomist from each state. The six chosen cultivars were evaluated under three input systems: the standard practice, SOYA, and SOYA – FF. See Table 1 product rates and inputs for each input system.

Fifty-three site-years of data were used for analysis. Analyzing the yields within each individual site-year found only 3 of 53 (5.7%) site-years had a significant cultivar  $\times$  input system interaction. Because of this low percentage, this suggests that cultivar selection and the high-input systems used as part of this study can most often remain as separate management decisions. When the data were analyzed by each region, both high-input systems (SOYA and SOYA-FF) increased yield compared to the standard practice within all three regions, but a yield increase from fungicide use (i.e., part of the SOYA treatment) was only observed in the North region. Across all site-years, the SOYA and SOYA-FF treatments yielded 3.4 (5.5%) and 2.2 bu/a (3.5%) more than the standard prac-





tice, respectively. Furthermore, the yield component measurements (seeds  $\text{m}^{-2}$ , seed mass, early-season and final plant stand, pods  $\text{plant}^{-1}$ , and seeds  $\text{pod}^{-1}$ ) indicated the positive yield responses for the high-input systems were due to increased seeds  $\text{m}^{-2}$  and seed mass.

## CONCLUSIONS AND RECOMMENDATIONS

Following established soybean management recommendations developed by university research and Extension programs will allow soybean producers to maximize soybean yield and profitability under most circumstances. Growers in the Mid-South and lower Midwest are unlikely to see positive economic returns from prophylactic use of inputs and combinations of inputs (i.e., high-input systems) in their soybean management, especially in the absence of pest pressure.

Meanwhile, growers in the upper Midwest may see responses to certain additional inputs, especially at higher yield levels and soybean prices. However, lower soybean prices will significantly decrease break-even probabilities for individual and combinations of inputs. The yield responses and subsequent break-even probabilities associated with the foliar insecticide and foliar fungicide and insecticide combination were found even though disease and insect pressure were low at most locations each year. Because this particular experiment was based on applying inputs prophylactically, it is not quite 'real world' from this aspect, as things like fungicide and insecticide resistance management were not taken into consideration. Therefore, we still recommend applying foliar fungicides and insecticides based on integrated pest management principles (IPM) and at established thresholds.

Soybean producers should continue focusing on ensuring that basic agronomic practices, such as adequate seeding rates, adapted cultivars, proper soil fertility, and IPM principles are optimized and should not expect dramatic increases in yield and profitability solely from the inclusion of additional inputs into their management systems.

### Data from:

Marburger, D.A., B.J. Haverkamp, R.G. Laurenz, J.M. Orlowski, E.W. Wilson, S.N. Casteel, C.D. Lee, S.L. Naeve, E.D. Nafziger, K.L. Roozeboom, W.J. Ross, K.D. Thelen, and S.P. Conley. 2015. *Characterizing genotype  $\times$  management interactions on soybean seed yield*. Crop Science 56:786-796.

Orlowski, J.M., B.J. Haverkamp, R.G. Laurenz, D.A. Marburger, E.W. Wilson, S.N. Casteel, S.P. Conley, S.L. Naeve, E.D. Nafziger, K.L. Roozeboom, W.J. Ross, K.D. Thelen, and C.D. Lee. 2015. *High-input management systems effect on soybean seed yield, yield components, and economic break-even probabilities*. 2016. Crop Science in press.