UNDERSTANDING COMPONENTS TO HIGH YIELDING SOYBEAN PRODUCTION SYSTEMS

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Abstract

The increasing amount of products and techniques available to producers, coupled with increasing input costs, lends greater importance to the evaluation of management options for optimization of yield and economic return. This study was conducted to determine: 1) soybean yield potential when five additional inputs are combined in a high-intensity production system; 2) soybean yield impact of each additional input when removed from the high-intensity system; 3) soybean yield potential of each additional input when added to a general soybean production program. Generally, the most non-responsive sites were those that had proper soil fertility going into the study and had a low probability of an economic yield response. Conversely, the sites that had the greatest response to added inputs were those sites that would have received nutrient recommendations from the Cooperative Extension Service. Additional inputs did have a tendency to enhance soybean yields, some of the time, at some of the locations, but consistent economic returns are doubtful if soil fertility status is adequate.

Introduction

Soybean commodity prices have increased in the past few years. At the same time, input prices for fertilizer, seed, and crop protection products have also increased. Additionally, new products and techniques not typically associated with soybean production are becoming more common but have not been well evaluated. Field research conducted by C.D. Lee (personal communication) found that greater plant population and the fungicide application growth stage R3 tended to be beneficial when soybean yield potential was greater than 70 bu/A. Testimonial evidence from recent soybean yield contest winners indicated that greater nutrition, from both organic (poultry litter) and inorganic (fertilizer) sources maximized their yield. University recommended seeding rates and fertility additions are sometimes questioned when greater yield potential is coupled with a high input-high management system in soybean production.

Added nitrogen (N) is typically not recommended for soybean production since soybean fixes atmospheric N though a symbiotic relationship with *Bradyrhizobium japonicum* - unless poor nodulation occurs. The use of animal manures to supply essential plant nutrients has been practiced for millennia. The nutrients contained in manure include the macronutrients N, phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), and sulfur (S); and the micronutrients zinc (Zn), copper (Cu), manganese (Mn), and iron (Fe). Other soil quality benefits from manure addition have been promoted over the years and include increased soil organic matter (SOM), improved soil structure, drainage, workability, resistance to compaction, and increased plant available water (PAW) (Eghball et al., 2004; Sistani et al., 2004). When poultry litter (PL) and other manures are used in soybean production, and yield responses are documented, the question regarding the mechanism of the yield response remains (McAndrews et al., 2006). This study was conducted to determine 1) soybean yield potential when five additional inputs are combined in a high-intensity production system; 2) soybean yield impact of each additional input when removed from the high-intensity system; 3) soybean yield potential of each additional input when added to a general soybean production program.

Materials and Methods

In 2011, field research was conducted in cooperation with private producers identified by county extension agents in Graves, Henderson, and Todd counties and on University of Kentucky Agricultural Experiment Station farms located in Fayette (UK-LEX) and Caldwell (UK-REC) counties. All fields were soil sampled to establish baseline soil fertility status prior to applying treatments. All sites were rainfed and planted utilizing no-tillage (NT) technology. All areas were treated with glyphosate prior to planting and received additional herbicide applications, as needed during the growing season, for weed control. The fields were planted to modern soybean varieties with maturity groups (MG) ranging from 3.8 to 4.8. The planting dates ranged from May 30 to June 10. Soybean were planted at three locations in 15 inch rows using corn planter units, and at two locations using a grain drill set for 7.5 or 21 inch rows (Graves and UK-LEX locations, respectively).

The experimental design was split plot, laid out in four randomized complete blocks, with 14 treatment combinations. The main plot consisted of seeding rate targets of 150,000 and 300,000 seeds per acre. Treatment combinations for the split plots consisted of combinations of PL additions at 3 tons per acre, additional potash at 120 lbs K_2O per acre, a Mosaic MES plus micronutrient package (12-40-0-10S plus boron, copper, and zinc at 100 lb product per acre (MES), and a Headline fungicide application at 6 oz per acre at growth stage R3. There were seven treatments at the high seeding rate and seven at the low seeding rate. One group of treatments examined the impact of deletion of certain inputs from an otherwise "intensive" system, while the other group of treatments determined the effect of the addition of certain inputs to an otherwise "conventional" system (Table 1). Standard fertility practices were used by cooperating producers and the remaining treatments were applied just after crop establishment.

Two sources of PL, Beach Grove and Beulah) were used for this study. The reported values are for total N, P_2O_5, and K_20 applied per acre, at the 3 ton litter/acre rate, with the following assumptions for first year nutrient availability: N (50%) P_2O_5 (80%); and K_2O (100%). One source (Beach Grove) was used at the Graves, Todd and UK-LEX locations, and provided the following amount of available nutrition: 111, 192 and 225 lb N, P_2O_5, and K_20/acre, respectively. The other source (Beulah) was used at the UK-REC and Henderson locations and provided the following amount of available nutrients: 112, 156 and 195 lb N, P_2O_5, and K_20/acre, respectively. The moisture content of the PL was approximately 22% at application. Planters and drills were set according to manufacturers specifications to achieve the desired seeding rates and stand counts were made to determine final plant populations. All fields were harvested with a plot combine and adjusted to a constant moisture content (13%) with yield determination.

Results

The yield data was statistically analyzed in two different ways. The first method was to compare individual treatments, as listed below. The second approach was to separate main and interaction effects, regardless of treatment. One of the five locations exhibited significant differences between individual treatments. This lack of response was largely due to high yield variance between plots with the same treatment, but was also due, in part, to the small yield differences attributable to individual treatments.

Caldwell County (UK-REC): A very productive Huntington soil was planted June 7th and the overall test yield was 62.8 bu/A. Soil fertility was in the high and high-medium range for P and K, respectively. The yield difference, from the highest (70.2 bu/A) to lowest (55.0 bu/A) yielding treatment, was 15 bu/A but this was not statistically significant (90% level of confidence). The highest yielding treatment received all of the extra inputs, minus the high seeding rate. Surprisingly, the second highest yielding treatment was also at the 150,000 seeding rate and only with added PL - no additional inputs. Most of the higher yielding treatments did have additional inputs, but no one input appeared to be substantially better than another. At this location, the fungicide and PL influenced yield more than other input, particularly seeding rate. Based on scouting, there was no disease pressure and fungicide applications would not have been warranted. Similarly, the addition of PL would not have been warranted due to soil nutrient levels and crop responses would not be expected. Most of the lowest yielding treatments received few additional inputs. The lowest yielding treatment received no additional inputs other than the high seeding rate. If a high seeding rate was used, additional inputs were needed to increase yield, otherwise a yield penalty occurred. Few differences were noted when examining the UK-REC location for main and interaction effects (Table 2). Two main effects significantly influenced soybean yield: use of PL and fungicide. One of the two most noticeable aspects of this analysis is that all additional inputs numerically increased yield, but few would have been economically justifiable.

Graves County: A Collins silt loam was drilled June 9th. The average test yield was 62.3 bu/A. Soil test P and K were in the very high and low-medium range, respectively. A yield response to added K was not unexpected at this location. This location resulted in the tallest soybean crop of the five sites used in this study, and plants were well over five feet tall prior to lodging before harvest. This field did have some late season disease and weed escapes that did influence some individual plot yields. However, this was considered at harvest and these areas were not included in plot yield calculations. Yields ranged from 68.5 to 50.5 bu/A, but no significant treatment differences were observed. No main effects or interactions were significant, at the 90% level of confidence, for this location (Table 3).

Henderson County: Soybean was planted on June 8th on a Dekoven silt loam soil. The overall test yield was 72.6 bu/A. Soil fertility for P and K was in the high and medium-high range, respectively. According to University of Kentucky Cooperative Extension recommendations in AGR-1 (Murdock and Ritchey, 2012), a crop response to additional inputs would not be expected at this location. Soybean yields ranged from 76.8 bu/A to 68.3 bu/A. However, no individual treatments were statistically better than another. Numerically higher yields were associated with the PL and fungicide treatments. The high seeding rate resulted in significantly lower yield at this location, but no other input was a statistically significant yield determinant (Table 4). High yields were achieved with minimal input use at this location.

Todd County: Soybeans were planted June 10th on a Newark silt loam. The average yield at this location was 64.1 bu/A. Soil fertility for P and K were in the medium and low range, respectively. Expected yield response to P addition would be low. A yield response to K addition would be likely. Additional fertilizer was not added to the plot area prior to planting, despite university recommendations. The producer utilized current management practices. Early season rainfall was low at this site and resulted in limited vegetative growth. Soybeans at this site were the shortest of all five locations, throughout the growing season. This Newark silt loam was considered to be the least productivel of the five soils/sites. Timely rain events during reproductive growth were extremely beneficial to crop yield. Soybean yield ranged from 78.2 to 52.9 bu/A, causing this to be the most responsive location of the five in this experiment.

Significant treatment effects occurred at this location (Table 5). A trend for greater inputs resulting in greater yields was evident. Although PL additions were included in all of the highest yielding treatments, all additional treatments appeared to benefit yield. The treatments with the least additional inputs resulted in the lowest yields. This was the only location in the study that maximized yields with a higher seeding rate. One possible explanation is that plant populations were less than desired for both seeding rate treatments. The 150,000 seed/A gave 117,000 plants/A and 300,000 seed/A resulted in 253,000 seed/A. It is plausible that the seeding rate treatment was significant due to the lower than intended plant stands.

All individual input main effects significantly influenced yield at this location (Table 6). The addition of PL resulted in the greatest increase in yield (17.2 bu/A), followed by MES (7.6 bu/A), fungicide at R3 (6.6 bu/A), additional potash (6.0 bu/A), and a higher seeding rate (5.7 bu/A). The large response to PL additions was likely a combination of several factors. Soil test K was in the low range and the response to additional K was expected. According to the PL nutrient analysis there was approximately 225 lbs K_2O/A supplied with PL addition. The PL also contained considerable amounts of N, P, and other secondary and micronutrients. The large yield response to PL was unexpected. Responses to potash (6.0 bu/A) and MES that contained P, S, B, Cu, and Zn (7.6 bu/A) would be expected to contain provide similar levels of nutrition, but an additional 3.6 bu/A of response to PL was not accounted for in that comparison. It is possible that the additional N contained in the PL contributed to the additional yield increase. Although PL additions are known to improve soil structure, tilth, and plant available water (PAW), it is unlikely that improvements in physical properties would occur in such a short time frame.

The response to the R3 fungicide application was also surprising since no disease pressure was noticed at any point during the growing season. It could be possible that the often mentioned “plant health” response occurred at this location. Regardless of the mechanism responsible for the yield increase, this R3 application more than paid for itself at this location.

Fayette County (UK-LEX): Soybeans were planted on May 30th on a Huntington silt loam soil. The average yield for this location was 58.9 bu/A. Soybean yield ranged from 66.1 bu/A to 51.6 bu/A. No significant treatment effects were observed at this location. Soil fertility for P and K were in the high and medium-high range, respectively, and no yield response to additional inputs was expected. The two highest yielding treatments at this location were the 150,000 and 300,000 seeding rates that received only the R3 fungicide treatment. The next highest yielding treatments received all additional inputs, at both seeding rates. Only 3 bu/A separated the four highest yielding treatments. No main effects due to the treatments were found to be significant at this location (Table 7).

Overall Summary

When evaluating the top three yielding treatments, across all locations, seven were from the low seeding rate and eight from the high seeding rate (Table 8). For the lowest three yielding treatments, eight were from the low seeding rate and seven from the high seeding rate. As such, there is no evidence that supports use of the higher seeding rate. Treatment 1, the high intensity production system (all inputs added), was in the top three highest yielding treatments at two locations. However, the conventional treatment (Treatment 8) was among the lowest yielding treatments at only one location. Treatments that received MES appeared in the top three yielding treatments 11 times, followed by the R3 fungicide 10 times, PL additions 9 times, and additional K 7 times. Conversely, MES was in the lowest three yielding treatments 6 times, R3 fungicide 6 times, additional K 5 times and PL 3 times. No one treatment appeared to be substantially better or worse than the others across the experimental locations. All additions were numerically (though not statistically) beneficial to some degree or another across the experiment, with some inputs being slightly more beneficial than others (e.g. PL over seeding rate). As would be expected, most of the positive responses to additional inputs appeared to be in the locations that lacked adequate fertility (e.g. Todd County). Poultry litter influenced yield as much or more than any additional input across the experimental locations. This response can be attributed to increased soil fertility (P, K, and micronutrients) as well as other unidentified mechanisms (additional N, Mg, improved water holding capacity, etc.). Generally, the most non-responsive sites were those that had proper soil fertility going into the study and had a low probability of an economic yield response to additional nutrition. Conversely, the sites that had the greatest response to added inputs were those sites that would have received recommendations for nutrient addition from the Cooperative Extension Service. Additional inputs do have a tendency to enhance soybean yield, some of the time, at some of locations, but consistent economic returns are doubtful if soil fertility status is adequate.

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Table 1. Treatment descriptions for the high yield soybean studies.

Treatment Number	Seed Rate	Poultry Litter	Extra Potash*	MESZ + B + Cu	Fungicide
1	300K	yes	B+120	yes	yes
2	300K	no	B+120	yes	yes
3	300K	yes	B	yes	yes
4	300K	no	B	no	no
5	300K	no	B	no	yes
6	300K	yes	B+120	no	yes
7	300K	yes	B+120	yes	no
8	150K	no	B	no	no
9	150K	yes	B	no	no
10	150K	no	B+120	no	no
11	150K	no	B	yes	no
12	150K	yes	B+120	yes	yes
13	150K	no	B+120	yes	no
14	150K	no	B	no	yes

*B=Basal potash recommendation.

Table 2. Soybean yield main effects for Caldwell County (UK-REC)†.

Significance Level*	Main Effect	Yield (bu/A)
	Seed Rate	
0.3825	150K	61.7
	300K	62.8
	Poultry Litter	
0.0176	No	60.9
	Yes	65.4
	Potash (K_2O)	
0.1036	Base (B)	61.4
	B+120 lbs/A	64.3
	MES	
0.1692	No	61.6
	Yes	64.1
	Fungicide	
0.0780	No	61.3
	Yes	64.4

*Values with a significance level > 0.10 are considered non-significant.
†No significant interactions were present, therefore not reported.

Table 3. Soybean yield main effects for Graves County†.

Significance Level*	Main Effect	Yield (bu/A)
	Seed Rate	
0.5518	150K	61.7
	300K	62.8
	Poultry Litter	
0.4096	No	61.4
	Yes	63.4
	Potash (K_2O)	
0.3597	Base (B)	61.4
	B+120 lbs/A	63.1
	MES	
0.6566	No	61.8
	Yes	62.8
	Fungicide	
0.2790	No	63.5
	Yes	61.0

*Values with a significance level > 0.10 are considered non-significant.
†No significant interactions were present, therefore not reported.

Table 4. Soybean yield main effects for Henderson County[†].

Significance Level[*]	Main Effect	Yield (bu/A)
	Seed Rate	
0.0761	150K	73.9
	300K	71.4
	Poultry Litter	
0.3346	No	72.0
	Yes	73.4
	Potash (K_2O)	
0.7256	Base (B)	72.8
	B+120 lbs/A	72.5
	MES	
0.4856	No	73.1
	Yes	72.1
	Fungicide	
0.4098	No	72.0
	Yes	73.2

[*]Values with a significance level > 0.10 are considered non-significant.
[†]No significant interactions were reported.

Table 5. Soybean yield for Todd County, ordered from highest to lowest yield. (Pr>F = 0.0001)

Treatment Number	Seed Rate	Poultry Litter	Potash	MES	Fungicide	Yield (bu/A)[†]
3	300K	yes	B	yes	yes	78.2a
6	300K	yes	B+120	no	yes	74.1a
1	300K	yes	B+120	yes	yes	74.1a
12	150K	yes	B+120	yes	yes	74.0a
7	300K	yes	B+120	yes	no	72.5a
9	150K	yes	B	no	no	70.8a
13	150K	no	B+120	yes	no	61.4b
2	300K	no	B+120	yes	yes	59.5bc
8	150K	no	B	no	no	58.2bc
5	300K	no	B	no	yes	57.4bc
11	150K	no	B	yes	no	55.6bc
10	150K	no	B+120	no	no	54.5bc
14	150K	no	B	no	yes	54.3bc
4	300K	no	B	no	no	52.9c

[*]B=Base potash, no additional potash added.
[†]Yields followed by the same letter are not significantly different at a 5% level of confidence.

Table 6. Soybean yield main effects for Todd County[†].

Significance Level[*]	Main Effect	Yield (bu/A)
	Seed Rate	
0.0463	150K	61.2
	300K	66.9
	Poultry Litter	
<0.0001	No	56.7
	Yes	73.9
	Potash (K_2O)	
0.0575	Base (B)	61.1
	B+120 lbs/A	67.1
	MES	
0.0070	No	60.3
	Yes	67.9
	Fungicide	
0.0211	No	60.8
	Yes	67.4

[*]Values with a significance level > 0.10 are considered non-significant.
[†]No significant interactions were present, therefore not reported.

Table 7. Soybean yield main effects for Fayette County (UK-LEX)[†].

Significance Level[*]	Main Effect	Yield (bu/A)
	Seed Rate	
0.9826	150K	58.9
	300K	58.9
	Poultry Litter	
0.7144	No	58.4
	Yes	59.5
	Potash (K_2O)	
0.2639	Base (B)	60.2
	B+120 lbs/A	57.6
	MES	
0.2933	No	60.4
	Yes	57.4
	Fungicide	
0.1108	No	56.5
	Yes	61.2

[*]Values with a significance level > 0.10 are considered non-significant.
[†]No significant interactions were present, therefore not reported.

Table 8. Treatments that resulted in the three highest and lowest soybean yields, across all locations, in 2011. Refer to Table 1 for treatment descriptions.

Yield Ranking	UK-REC*	Graves	Henderson	Todd	UK-LEX
1st Highest	12 (70.2)	6 (68.5)	12 (76.8)	3 (78.2)	14 (76.8)
2nd Highest	9 (66.8)	11 (66.4)	14 (76.0)	6 (74.1)	5 (64.3)
3rd Highest	6 (65.4)	2 (65.8)	9 (75.7)	1 (74.1)	1 (64.1)
3rd Lowest	11 (60.0)	3 (60.1)	7 (69.1)	10 (54.5)	11 (54.5)
2nd Lowest	8 (59.6)	5 (59.4)	13 (68.8)	14 (54.3)	7 (53.1)
1st Lowest	5 (59.5)	14 (50.5)	5 (68.3)	4 (52.9)	10 (51.6)

*Treatment number (yield, bu/A).

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