SOYBEAN PRODUCTION RESEARCH: A NATIONAL APPROACH

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Abstract

U.S. soybean growers are looking for alternative methods to increase soybean yields and recent increases in commodity prices have given producers more freedom to invest in additional crop inputs or products. Unfortunately, quality data from studies addressing multiple contemporary inputs is scarce. The objective of this work was to evaluate the effectiveness of combined soybean inputs on seed yield. These high input systems were tested in six states to evaluate their value across a broad geography. Evaluated in a drop-out system, a prophylactic application of pyraclostrobin at the R3 growth stage appeared to provide the greatest yield benefit of any additional products used in a combined high input treatment. Although not an input *per se*, narrow row spacing appeared to provide the greatest yield benefit of any treatments imposed.

Introduction

Since 2000, U.S. soybean yields have averaged 2.8 Mg ha^{-1} (USDA-NASS, 2012); however, per annum reports of soybean yields as high as 6.2 Mg ha^{-1} in both production and yield contest fields are common (Penn State Extension, 2011; University of Kentucky, 2013). Interestingly, the highest soybean yield on record was verified in 2010, reaching 10.8 Mg ha^{-1} in the South Central U.S. (Pioneer Hi-Bred, 2010). These reported high yields have caused many U.S. growers to begin looking for alternative management practices in an attempt to reach similar yield levels. One method increasing in popularity is the application of external crop inputs in an attempt to increase soybean yield. The combination of high commodity prices, available capital, and accessible crop inputs has encouraged producers to apply these inputs (fertilizers, pesticides, etc.) beyond label recommendations in an effort to increase yield. However, the current approach often does not use just a single input; instead, several crop inputs are applied throughout the growing season as a high input management system (HIS). The HIS is a relatively new approach in crop management supported by limited scientific evidence. Many of the yield increases attributed to the use of a HIS have been observed in a limited number of replicated strip trials and subjected only to partial statistical analysis. The scientific literature regarding application of specific products is extensive (Shulz and Thelen, 2008; Grau and Gaska, 2002; Garcia and Hanway, 1976; Swoboda and Pedersen, 2009; De Bruin et al., 2010); however, little research has addressed the use of multiple crop inputs applied in a HIS approach.

Currently, some of these alternative management practices include the use of external crop inputs applied as “yield enhancement inputs”. Various products have been developed specifically for yield enhancement, claiming changes in plant growth and physiology (StollerUSA, 2012; Yost et al., 2009; LaBarge, 2012; Holmes and Rueber, 2005). For example, BASF Corporation developed a supplemental label for the fungicide Headline which states that, beyond fungal pathogen control, the fungicide can provide plant health benefits (BASF, 2008; Vincelli, 2009). The label indicates that application of the fungicide at R3 growth stage (Fehr and Caviness,

1977) in soybean increases yield through improved nitrogen utilization and enhanced stress tolerance, in addition to improved seed quality and more uniform seed size. Several of the most popular products used in a HIS include seed treatments (fungicidal/insecticidal), seed-applied inoculant comprised of *Bradyrhizhobium japonicun*, additional soil nutrient amendments (above current recommendations), foliar fertilizers, and foliar fungicides.

Aside from the use of a HIS, row spacing is changing within the soybean production system. With current production practices and increasing farm size, especially in the Corn Belt, growers have been migrating toward wider row spacing compared to the past. The Economic Research Service reported row spacing had increased to 46 cm compared to 32 cm in 1996 (USDA-ERS, 2012). This switch to wider row spacing to adapt to larger equipment and farm size may potentially hurt soybean yields. Though yield response to row spacing has been inconsistent in some studies (Pedersen and Lauer, 2003; Taylor, 1980; Walker et al., 2010), most studies have found consistent yield gains from narrow row spacing in soybean (De Bruin and Pedersen, 2008; Ablett et al., 1991; Bullock et al., 1998; Cox and Cherney, 2011; Etheridge et al., 1989). De Bruin and Pedersen (2008) reported that narrow row spacing increased yield 0.25 Mg ha^{-1} compared to the wide row spacing.

Little has been published addressing the use of the HIS in soybean production. Information does exist regarding the use of crop inputs individually; however, the information is limited to specific regions and is difficult to apply to a wide geographical region. Our hypothesis is that the application of a HIS in wide and narrow row spacing will increase soybean yield. The objectives of this study were to assess the influence a HIS has on soybean seed yield in 18 locations in six states across U.S. soybean producing regions, and to evaluate the potential influence individual products may have on yield under a HIS.

Materials and Methods

This experiment was a six-state (Arkansas, Iowa, Kentucky, Louisiana, Michigan, and Minnesota) collaborative project conducted from 2009 to 2011. Participating Universities each selected three locations within their state representing common soybean production regions. All states used a randomized complete block design with six replications. A total of 12 individual treatments were used. Plots were a minimum of 1.5 m wide and 6.1 m long. Each state used its University recommended best management practices and soybean cultivars adapted for the region. Soil fertility was maintained for optimum crop growth based on a composite soil test taken at each location. Weed and insect management were performed by individual cooperators to ensure neither was yield limiting. Grain yield was measured at harvest with a small plot research combine.

The 12 treatments were a combination of seven individual management practices; seed treatment (fungicide/insecticide), seed-applied inoculant, additional soil fertility, row spacing, seeding density, foliar fungicide, and foliar fertility. All treatments were planted at a seeding density of 346,800 live seeds ha^{-1}. Nine of the twelve treatments were planted in a narrow row (≤51 cm) configuration, including a control (no inputs applied) (Table 1). A HIS treatment was created by using all five of the selected crop inputs. An omission treatment structure was then used for five of the subsequent treatments, in which a single crop input was removed from the HIS system

(Table 1). Two of the narrow row treatments assessed early and late season crop management, wherein the early season management treatment received only seed and soil applied products, and the late season management system focused on late season foliar nutrition and foliar pathogen control (Table 1). The three remaining treatments were planted in a wide row configuration (76 cm) and included a control, HIS, and HIS minus the foliar fungicide (Table 1). Treatment combinations were designed to reflect the most probable inputs and management systems a grower might implement.

The seed treatment used in 2009 was Trilex 6000 (Bayer Crop Science LP, Research Park, NC). The seed treatment consisted of fungicides, trifloxystrobin (methyl (E)-methoxyimino-{(E)-α-[1-(α,α,α-trifluoro-m-tolyl)ethylideneaminooxy]-o-tolyl}acetate), at 2.47 g ai 50 kg^{-1} of seed; and metalaxyl (methyl-N-(2,6-dimethylphenyl)-N-(2-methoxyacetyl)-DL-alaninate), at 1.98 g ai 50 kg^{-1}; the insecticide imidacloprid (1-[(6-Chloro-3-pyridinyl) methyl]-N-nitro-2-imidazolidinimine) at 31.5 g ai 50 kg^{-1} of seed; and a biological fungicide, *Bacillus pumilus* at 3.12 x 1010 colony forming units 50 kg^{-1} of seed. In 2010 and 2011 the seed treatment was changed to Cruiser Maxx (Syngenta Crop Protection, Greensboro, NC) due to availability. This seed treatment was a combination of the insecticide thiamethoxam (3-[(2-Chloro-1,3-thiazol-5-yl)methyl]-5-methyl-N-nitro-1,3,5-oxadiazinan-4-imine) at 25 g ai 50 kg^{-1} of seed; and fungicides mefenoxam ((R)-2-[(2,6-dimethylphenyl) methoxyacetylamino] (R)-2-[(2,6-dimethylphenyl) methoxyacetylamino]) at 1.88 g ai 50 kg^{-1} of seed, and fludioxonil (4-(2,2-difluoro-1,3-benzodioxol-4-yl)-1H-pyrrole-3-carbonitrile) at 1.25 g ai 50 kg^{-1} seed.

The seed inoculant was Vault (Becker Underwood, Inc., Ames, IA) with the active ingredient *Bradyrhizobium japonicum*. The product was applied at the manufacturer's recommended rate of 102 mL 50 kg^{-1} of seed within one week of planting.

The soil fertility treatment was comprised of 84.03 kg ha^{-1} P, 56.02 kg ha^{-1} K, 2.25 kg ha^{-1} Mn, 0.568 kg ha^{-1} S and Zn. These soil amendments were added to soils that had previously tested at or above optimum fertility levels within each state. Products were hand-applied prior to planting.

The foliar fertilizer treatment consisted of Task Force 2 at the R1 growth stage, providing 0.77 kg N ha^{-1}, 0.56 kg P ha^{-1}, 0.35 kg K ha^{-1}, 0.001 kg B ha^{-1}, 3.5 x 10^{-5} kg Co ha^{-1}, 0.004 kg Cu ha^{-1}, 0.007 kg Fe ha^{-1}, 0.004 kg Mn ha^{-1}, 3.5 x 10-5 kg Mo ha^{-1}, and 0.004 kg Zn ha^{-1}. Foliar fungicide applications were performed at the R3 and R5 growth stages. The fungicide pyraclostrobin (methyl N-{2-[1-(4-chlorophenyl)-1H-pyrazol-3-yloxymethyl]phenyl}(N-methoxy)carbamate) was applied at R3 (0.22 g ai ha^{-1}). An application of the fungicide azoxystrobin (Methyl (2E)-2-(2-{[6-(2-cyanophenoxy)pyrimidin-4-yl]oxy}phenyl)-3-methoxyacrylate) at 0.11 g ai ha^{-1} and propiconazole (1-[[2-(2,4-dichlorophenyl)-4-propyl-1,3-dioxolan-2-yl]methyl]-1,2,4-triazole) at 0.19 g ai ha^{-1} was made at the R5 growth stage.

Prior to the R3 and R5 applications of fungicides, visual disease ratings on a scale of 0 to 5, where 0 = no disease and 5 = completely diseased, were performed at all locations. One week after R3 and R5 fungicide applications, a second disease rating was performed.

Results and Discussion

The wide row spacing system was used in three treatments (trt 1, 3, 11) and all produced grain yields similar to or less than the narrow row control (trt 12) (Table 2). Grain yield increased 185.9 kg ha^{-1} in the HIS in the wide row spacing (trt 3) compared to its respective control (trt 1). We found no significant decrease in grain yield when fungicide was removed in the HIS (trt 11) in the wide row spacing. These results are similar to Dorrance et al. (2010) who reported that grain yield increased at only 6 of 28 locations following the application of a fungicide.

The remaining discussion will focus on the narrow-row treatments. Grain yield increased 302.3 kg ha^{-1} in the HIS narrow treatment compared to its control (trt 2). Grain yield was not influenced by the removal of foliar fertility, soil fertility, seed inoculants, or seed treatment compared to the HIS. Our results are similar to those in other studies that have looked at analogous products on an individual basis; foliar fertility (Mallarino et al., 2001); soil fertility (Ross et al., 2006; Rehm et al., 2001); and seed inoculant (De Bruin et al., 2010; Furseth et al., 2012). Both Esker and Conley (2012) and Shulz and Thelen (2008) reported limited yield response to seed treatment at several locations and stated that response is highly dependent on growing environment.

The removal of the foliar fungicide from the HIS decreased grain yield by 196 kg ha^{-1}, producing yields similar to the control treatment in the narrow row spacing. The observed yield response indicates that this product may contribute the greatest fraction of any product to the observed yield increase in the HIS. However, foliar fungicide studies have reported mixed results related to their influence on grain yield. Swoboda and Pedersen (2009) reported no yield increase when fungicides were applied at R1, R3, or R5. Industry published studies have reported increases in grain yield following the application of foliar fungicide, but several of these studies appear to be limited in statistical power and, in some instances, replication (BASF, 2009). The yield increase observed with the HIS was likely due in part to an interaction of the products and management practices employed within that system. Due to the design of the experiment we were unable to test products individually to determine their contribution to any observed yield gain. No yield differences between the seasonal management strategies, treatments 9 and 10, were observed. An analysis of regional testing locations indicated that the late season management strategy was effective at maximizing grain yield in the northern U.S. (Iowa, Michigan, Minnesota; data not shown). This was likely due in part to the use of fungicide within the system controlling disease below economic threshold (data not shown).

Grain yield was influenced by the use of a HIS, especially when the HIS was used in a narrow row configuration. To the best of our knowledge, this is the first work to consider a HIS in U.S. soybean production. The observed yield results indicate that soybean yield can be increased when produced using a HIS, but growers should consider the potential economic and environmental implications of utilizing such a system.

Row spacing

Row spacing influenced grain yield across all environments. A comparison of the control treatments indicated an increase in grain yield of 177 kg ha^{-1} under the narrow row spacing configuration. Various studies have reported similar yield increases when soybean was grown in narrow rows (Ablett et al., 1991; Bullock et al., 1998; Cox and Cherney, 2011; Etheridge et al., 1989). Grain yield improved by an average of 293 kg ha^{-1} in the narrow row HIS treatment compared to the analogous 76 cm row spacing treatment. De Bruin and Pedersen (2008) reported a similar yield advantage for narrow row soybean production of 248 kg ha^{-1}.

The data indicate that soybean grown in a wide row spacing (≥76 cm) under intensive management produce yields similar to a low input management system grown in narrow row spacing. These results were consistent across all environments, and provide further support for improved grain yield through the use of narrow row spacing. Currently, U.S. soybean production is trending toward wider row spacing due to increased corn production (ERS, 2012). Given the observed yield advantage from narrow row spacing we found in this research, as well as that found in other studies, soybean producers should consider narrow rows as an integral part of an intensive soybean management system.

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Table 1. Crop inputs, row spacing, and seeding rates imposed within the individual treatments.

Treatment #	Treatment	Seed treatment	Foliar fungicide	Seed inoculant	Soil fertility	Foliar fertility	Row spacing (cm)
1	Control (W[†])	-	-	-	-	-	76
2	HIS[‡] (N[§])	+	+	+	+	+	51
3	HIS (W)	+	+	+	+	+	76
4	HIS - Foliar fertility	+	+	+	+	-	51
5	HIS - Soil fertility	+	+	+	-	+	51
6	HIS - Seed inoculant	+	+	-	+	+	51
7	HIS - Foliar fungicide	+	-	+	+	+	51
8	HIS - Seed treatment	-	+	+	+	+	51
9	Late season mgmt[¶]	-	+	-	-	+	51
10	Early season mgmt	+	-	+	+	-	51
11	HIS - Foliar fungicide (W)	+	-	+	+	+	76
12	Control (N)	-	-	-	-	-	51

[†] W = wide row spacing (76 cm; Baton Rouge, LA 96 cm; Crowley, LA 81 cm; St. Joseph, LA 102 cm)
[‡] HIS = high input system
[§] N = narrow row spacing (≤ 51 cm)
[¶] mgmt. = management

Table 2. Treatment influence on soybean grain yield, 2009-2011.

Treatment #	Treatments	Yield (kg ha^{-1})	
1	Control (W[†])	3630.7	f[¶]
2	HIS[‡] (N[§])	4110.1	a
3	HIS (W)	3816.6	de
4	HIS - Foliar fertility	4068.9	ab
5	HIS - Soil fertility	4031.6	abc
6	HIS - Seed inoculant	4062.8	ab
7	HIS - Foliar fungicide	3914.1	cd
8	HIS - Seed treatment	4016.1	abc
9	Late season management	3988.9	bc
10	Early season management	3959.1	bc
11	HIS - Foliar fungicide (W)	3739.5	ef
12	Control (N)	3807.9	de

[†] W = wide row spacing
[‡] HIS = high input system
[§] N = narrow row spacing
[¶] Means with the same letter within a column are not significantly different at the 5% significance level

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