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Soybean: Evaluation of Inoculation

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Summary

A soybean crop can obtain up to 50 to 75% of its nitrogen (N) requirements from the air when the biological fixation is effectively established (Pedersen, 2007). The overall objective of this project was to quantify the response to inoculation for soybean in a field without previous history of this crop. Following this rationale, a field study was conducted during the 2015 growing season at Ottawa (east central Kansas). The treatments consisted in five different N management approaches: non-inoculated, inoculated × 1, inoculated × 2, inoculated × 3 and non-inoculated but fertilized with 300 lb N per acre as the main N source. The study was planted in an area without soybean history, the grain yield ranged from 26 to 29 bushels per acre. Greater yields were recorded when a double inoculation rate was applied (× 2), while lowest yield was related to the non-inoculated scenario. However, statistically, treatments did not present any significant yield difference. In summary, further research will be performed to be more conclusive as related to the best management approach for N in soybeans when first planted in fields without previous history of this crop.

Introduction

A soybean crop, as a legume species, has the ability to fix nitrogen (N) from the atmosphere when proper symbiosis is established with *Bradyrhizobium japonicum* bacteria. The symbiosis relationship is mutually beneficial: the plant provides carbohydrates (CHOs) and a protective environment and, in turn, the rhizobia fix N from the air and release it to the plant. For an effective symbiotic process to occur, N-fixing bacteria have to be present in the soil. Thus, if the bacteria are absent, the "inoculation" practice can establish the specific rhizobia in the field, providing a successful N fixation. Based on previous information, inoculation is usually effective whenever: 1) soybean was never planted before or in the past 3-5 years; 2) soil pH is below 6.0 units (acidic soil conditions); 3) soil has a high sand content; and 4) in anaerobic conditions, field has been flooded for more than a week when nodulation was supposed to become established. Inoculation has become a standard practice in soybean fields due to the unique importance for establishing the rhizobia in the field so they are available for fixing and providing N to the crop (Christmas, 2008). Additionally, inoculation practice is relatively inexpensive as compared with other input costs. Nonetheless, it is still valid to properly assess both agronomically and economically the yield advantage of the inoculation practice in fields where soybean has never been grown before.

The main objective of this study was to quantify the response to inoculation for soybean in a field without previous history of this crop.

Site characteristics

Soil type at the Ottawa location was a Woodson silt loam (Mollisols). Soil samples were taken before planting to a total depth of 6 inches. Soil chemical parameters analyzed were pH, Melich P, cation exchange capacity (CEC), organic matter (OM), calcium (Ca), magnesium (Mg), and postassium (K) availability (Table 1).

Procedures

The study was arranged in a randomized complete block design with five replications. Plot size was 10-ft wide by 50-ft long. The soybean variety used was soybean P34T43R2 for the Roundup Ready technology (RR-2) (released 2014 yr; MG = 3.4). Five treatment combinations were evaluated for the same genotype by N management approaches: 1) non-inoculated, 2) inoculated × 1 (single-rate), 3) inoculated × 2 (double-rate), 4) inoculated × 3 (triple-rate), and 5) non-inoculated but fertilized with 300 lb/N/a (liquid UAN, 32-0-0 split in three equal applications at planting, flowering, and pod formation) as the main N source. The inoculant used was VAULT® HP plus integral® (BASF company). Herbicides and hand weeding were used to prevent weed interference for the entire season, and soil nutrient concentrations (other than N) were maintained above the recommended critical levels (through inorganic P/K applications).

Stand counts were performed (measuring two 17.5-ft sections per plot) immediately after emergence (VE), in three out of the five replications. Yield information is expressed in bushels per acre adjusted to 13% moisture content. Yield was collected from the central two rows (5 × 50 ft). Vegetative-to-reproductive dry mass partitioning was determined at the onset of the grain-filling period (R5 growth stage). Aboveground plant biomass was collected and soybean plants were fractionated in vegetative (stover = leaf, stem, and petioles) and reproductive (grain plus pods) plant fractions. The reproductive mass to the total plant biomass ratio (herein termed as the "reproductive partitioning index," RPI) was calculated for all treatments evaluated in this study.

Weather information

For temperature, maximum and minimum normal (30 years) variations followed a similar trend as the seasonal temperature for 2015 growing season. At the Ottawa site, the largest deviation was documented for the month of May, minimum temperature was 13°F higher as compared with the historical normal minimum (Figure 2).

Seasonal precipitation distribution, expressed in inches, was documented throughout the entire growing season (Figure 3). For 2015, seasonal precipitation was lower relative to the historical trend, with exception of the month of May, for which 2015 precipitation was almost double the historical record (Figure 3). In agreement with the temperature trend, the month of May was a clear outlier for the 2015 growing season as compared with the historical weather information. Seasonal precipitation for the 2015 growing season was approximately 28 inches (Figure 3).

Results

Statistically, soybean yields did not differ among all evaluated treatments (Figure 4). Still, a yield trend was presented with high grain yields recorded when × 2 the rate of inoculant was added to the soybeans, while lowest yield was found when no inoculant was applied.

Regarding the grain and stover partitioning during the grain-filling period, vegetative and reproductive biomass fractions were separated to characterize a ratio between these plant components. The reproductive partitioning index (RPI) represented about 45% at R5 stage. Across treatments, a trend was documented with low RPI when no inoculant was added (averaging 43%), while both the single inoculation (1×) and the treatment depending solely on fertilizer N presented an overall RPI of 47% (Figure 5). Notwithstanding the previous characterization, any difference documented among all treatments in the RPI was not statistically significant, implying a similar RPI or partitioning process across N management scenarios.

Statistically, all treatments presented equal soybean yields, with maximum yield levels below 30 bushels per acre. Still, a yield trend was observed with maximum agronomical yield when a triple inoculation rate (× 2) was implemented to the soybean crop. On the other side, lowest yield was recorded for the variety that did not receive inoculation.

Reproductive partitioning index (RPI) portrayed comparable biomass partitioning at the onset of the grain-filling period. The RPI did not reflect any benefits on the N management approaches as related to the efficiency in allocating mass to the reproductive organs. In summary, further research will be performed to be more conclusive as related to the best management approach for N in soybeans when first planted in fields without previous history of this crop.

References

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Table 1. Pre-plant soil characterization at 0-6 inch depth at Ottawa during 2015 growing season

Soil Parameters	Location
Units	Ottawa
pH	6.5
Mehlich P (ppm)	7.4
CEC (meq/100g)	25.9
OM (%)	3.3
K (ppm)	191
Ca (ppm)	3273
Mg (ppm)	532

Table 2. Final stand counts per treatment at Ottawa location, 2015 growing season

Field site	Treatments (× 1,000 plants/a)				
	Non-Inoculant	Inoculant x1	Inoculant x2	Inoculant x3	Fertilizer-N
Ottawa	62	65	62	74	72

Table 3. Descriptive statistics (mean, minimum, maximum, and coefficient of variation (CV) on yield parameter, expressed in bushels per acre, for Ottawa site during the 2015 growing season

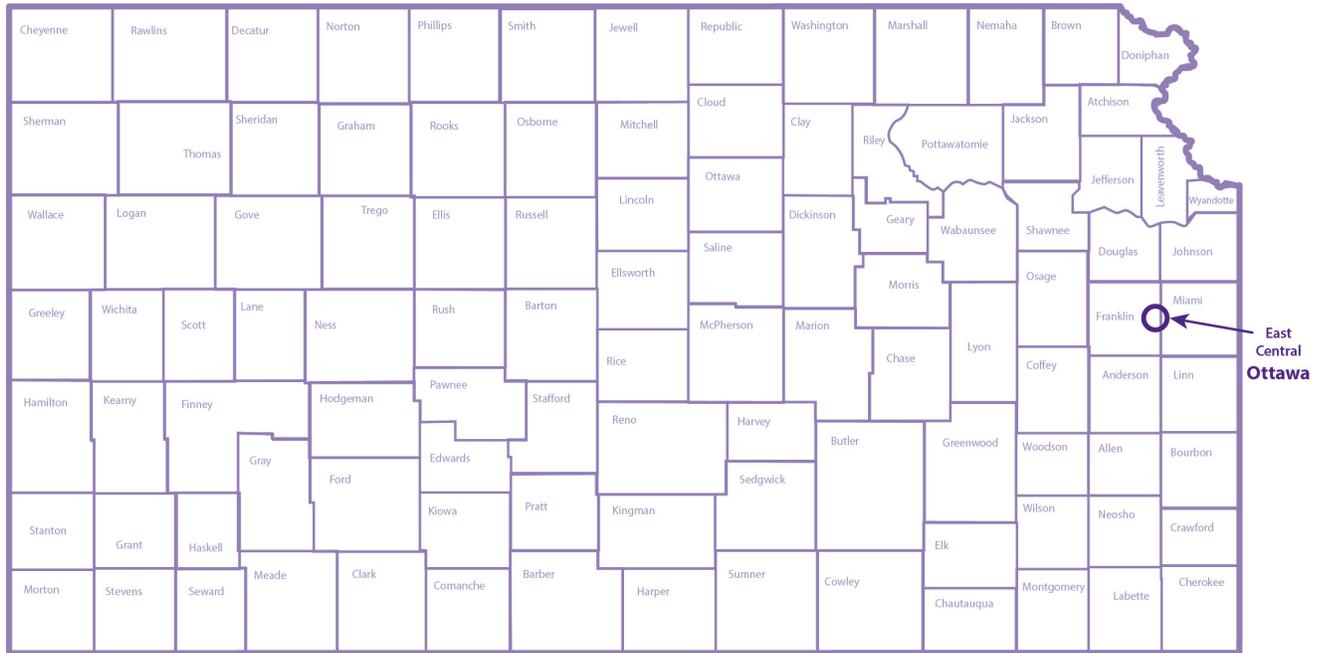| Field site	Mean yield	Minimum yield	Maximum yield	CV
	-------------------- bushels per acre --------------------			%
Ottawa	27.4	26.4	28.5	27

Figure 1. Map of the state of Kansas where the project was conducted in the 2015 season.
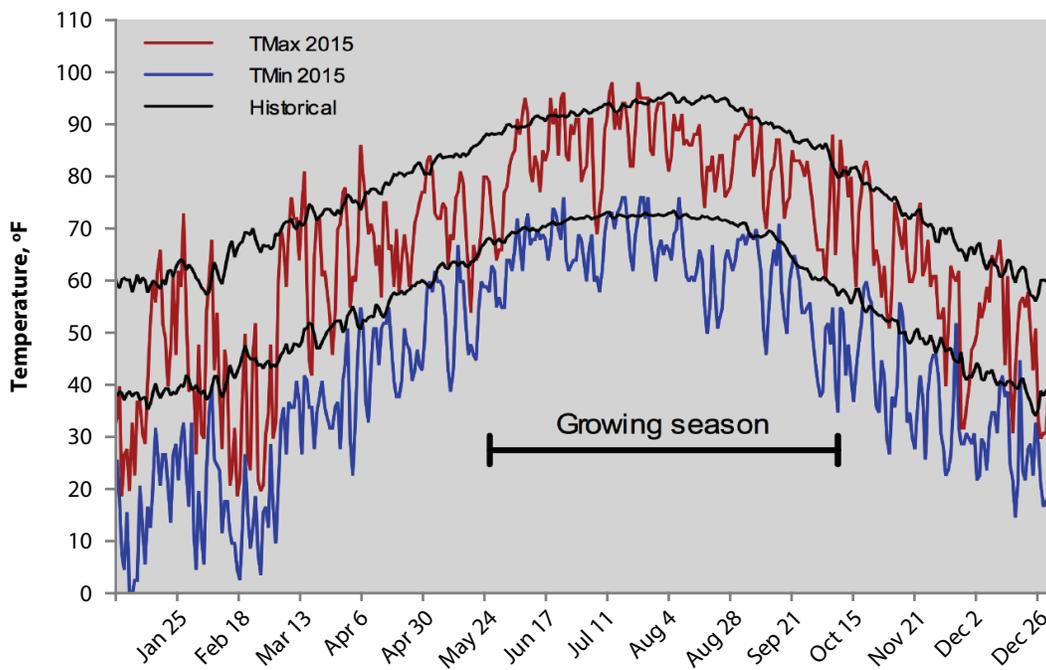

Figure 2. Seasonal minimum (blue line) and maximum (red line) temperatures for the historical trend (1985-2015 period) and 2015 growing season at Ottawa, KS.
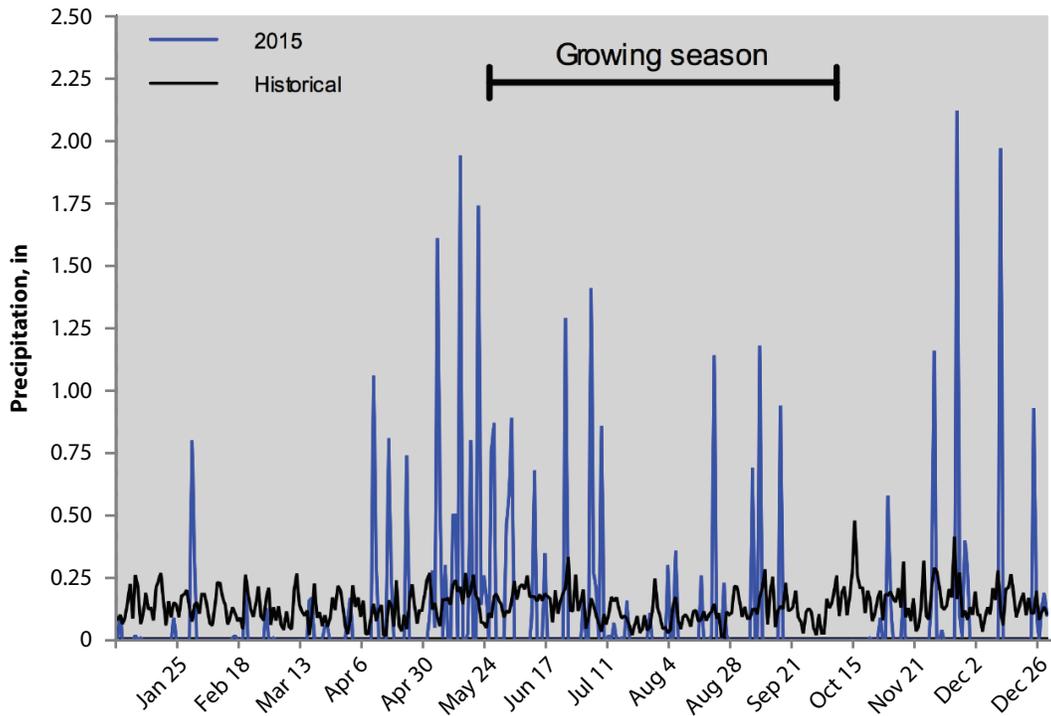
Figure 3. Monthly precipitation (black line) for the historical evolution (1985-2015 period) and daily precipitation for the 2015 growing season (blue line) at Ottawa, KS.
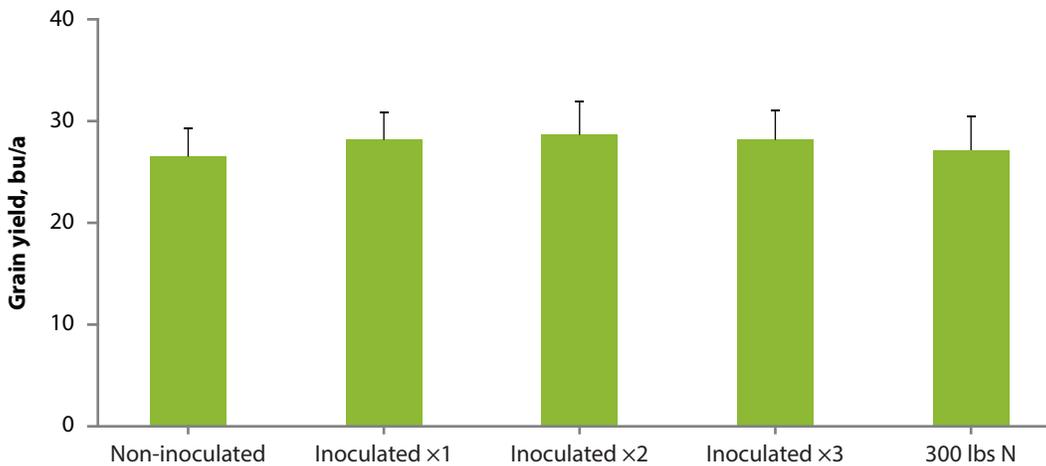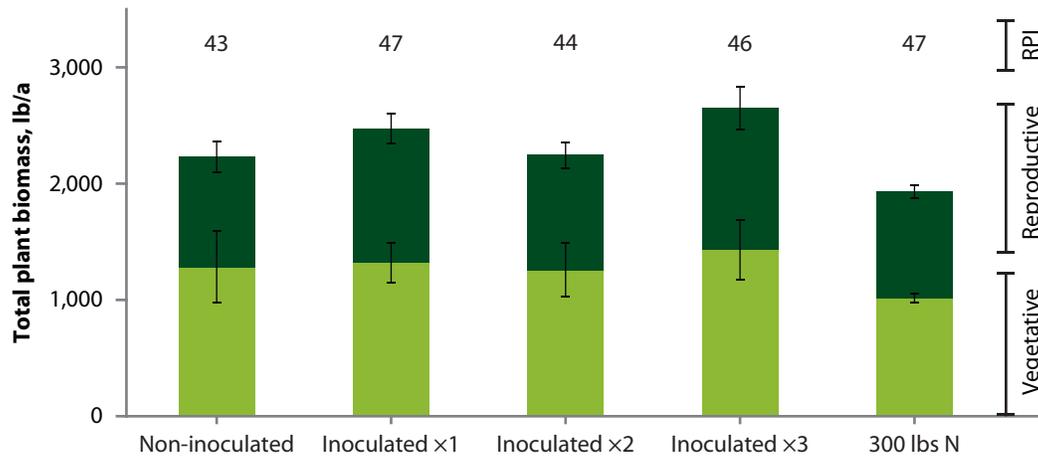

Figure 4. Grain yield (13.5% moisture) under diverse nitrogen (N) management approaches at Ottawa site (KS, U.S.) during the 2015 season. Error bars represent the standard error for each treatment.

Figure 5. Total plant biomass, dry mass for the vegetative (stem, leaf, and petioles) and reproductive (pods and grain) plant fractions, and reproductive partitioning index (RPI) were all determined during mid-grain filling period on soybean crop at Ottawa site (KS, U.S.) during the 2015 season. Error bars represent the standard error for each treatment.