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Soybean Evaluation of Inoculation: A Three-Year Summary

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Abstract

The relationships between soybean (*Glycine max*) seed yield and response to nitrogen (N) fertilization have received considerable coverage in scientific literature. This project aims to quantify the response to inoculation for soybean in a field without previous history of this crop (20 years). To address this objective, field studies were conducted during the 2015, 2016, and 2017 growing seasons at the East Central Experiment Field, Ottawa, KS. The treatments consisted of five different N-management approaches: non-inoculated (NI), inoculation at the recommended commercial rate (I1), a double rate of inoculation (I2), a triple rate of inoculation (I3), and non-inoculated but fertilized with 300 lb of N/a (NF). In the 2015 growing season, yields did not statistically differ from one another. In the 2016 growing season, treatment differences were observed and seed yield ranged from 36 to 59 bu/a. In the 2017 growing season, treatments showed significant yield difference, with yields ranging from 23 to 52 bu/a, from the NI to the NF treatment, respectively. Further research should be carried out to understand the impact of the inoculation practice and better understand the best management for N in soybean in newly-planted areas.

Keywords

Inoculation, soybean, nitrogen management

Authors

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Summary

The relationships between soybean (*Glycine max*) seed yield and response to nitrogen (N) fertilization have received considerable coverage in the scientific literature. This project aims to quantify the response to inoculation for soybean in a field without previous history of this crop (20 years). To address this objective, field studies were conducted during the 2015, 2016, and 2017 growing seasons at the East Central Experiment Field, Ottawa, KS. The treatments consisted of five different N-management approaches: non-inoculated (NI), inoculation at the recommended commercial rate (I1), a double rate of inoculation (I2), a triple rate of inoculation (I3), and non-inoculated but fertilized with 300 lb of N/a (NF). In the 2015 growing season, yields did not statistically differ from one another. In the 2016 growing season, treatment differences were observed and seed yield ranged from 36 to 59 bu/a. In the 2017 growing season, treatments showed significant yield difference, with yields ranging from 23 to 52 bu/a, from the NI to the NF treatment, respectively. Further research should be carried out to understand the impact of the inoculation practice and better understand the best management for N in soybean in newly-planted areas.

Introduction

Soybean seed has a high content of oil and protein in the seeds. The main countries growing soybean are the United States (33%), Brazil (32%) and Argentina (16%) of the estimated global soybean production. Soybean crop, as a legume specie, has the characteristic of fixing N from the atmosphere (biological N fixation, BNF) when a proper symbiosis relationship with specific bacteria has been established. Most of the N required by a soybean plant is supplied via the BNF process. When BNF is adequately established in the host plant, soybean can obtain 50 to 60% of its N from the atmosphere. For high-yielding soybean, the gap between plant N demand and BNF supply becomes larger, and thus, more N might need to be potentially available from the soil to satisfy this demand.

Based on previous studies, inoculation is usually effective when: 1) soybean was never planted before or in the past 3 to 5 years; 2) soil pH is below 6.0 units; 3) soil has a high sand content; 4) in anaerobic conditions, field has been flooded for more than one week when nodulation was supposed to become established; and 5) early-season stress conditions (e.g. heat) affects plant-bacteria establishment.

The inoculation has become a standard practice in soybean fields due to its low cost (as compared to N fertilizer applications) and the critical N need of the plant to successfully achieve seed yields.

The objective of this project was to study the yield response, if any, to variable inoculation rates and the addition of N to a soybean field without history of this crop in the last 20 years.

Procedures

Site Characteristics

The field where the experiment was conducted is an area without history of soybean (20 years). For three years, the experiment was conducted at the East Central Experiment Field, Ottawa, KS, (38.54 N, 95.24 W) (Figure 1). The soil at this location is characterized to be a Woodson silt loam soil series (or Mollisols). Soil samples were collected before planting at a depth of 6 and 24 inches. Soil chemical parameters analyzed with the 6-in. samples were: soil pH, phosphorus (P) levels (Mehlich P), cation exchange capacity (CEC), organic matter (OM), calcium (Ca), magnesium (Mg), and potassium (K). Nitrate analysis (or analyses) were conducted with 24-in. samples (Table 1).

Experimental Design

The study was arranged in a complete randomized block design with six replications. Plot size was 10-ft wide × 60-ft long. The soybean variety was P34T43R2 (Dupont Pioneer), with the RR-2 event; maturity group 3.4.

Treatments

Five treatment combinations were evaluated:

1) non-inoculated (NI),
2) inoculated single-rate (I1),
3) inoculated double-rate (I2),
4) inoculated triple-rate (I3), and
5) non-inoculated but fertilized with 300 lb of N/a (NF).

Nitrogen source utilized was liquid urea ammonium nitrate (UAN), N-P-K, 32-0-0, and was equally split into three applications: at planting, flowering (R1), and pod formation (R3) following the plant N uptake curve for this crop. The inoculant used was VAULT HP plus integral (BASF). Herbicides and hand weeding were used to maintain no weed interference during the entire growing season, and soil nutrient concentrations (other than N) were maintained above the recommended critical levels (through inorganic P and K applications). Seeding rate target was 140,000 seeds per acre.

Measurements

Stand counts were performed measuring 5-ft sections per row, 4 rows in each plot, at the V4 stage (4 full developed trifoliates) in all replications (Table 2). Aboveground biomass samples were collected at the R8 stage, before harvest. Seed harvest index was estimated as the ratio between the grain yield and the aboveground biomass collected at the R8 stage. Yield was collected from the central two rows (5 × 60 ft) and is expressed in bu/a adjusted to 13% of moisture content. Seed number was estimated with the seed weight and yield information.

Weather Information

Maximum and minimum temperatures were recorded and compared to the 30 years of historical information for the region. Seasonal variations in temperature followed a similar trend as the historical. Seasonal precipitation distribution was also recorded and expressed in inches. On average, the amount of precipitation during the growing season was five inches greater than the historical (Figure 2).

Results

Overall seed yield for 2017 averaged 36 bu/a (ranging from 23 to 52 bu/a). Statistically, soybean yields were different for treatment 5 (NF), reaching the maximum yields, although they did not differ from treatment 2 (I1). Final soybean yields averages presented the following trend from high to low: 300 lb of N/a > inoculated 1× > inoculated 2× = inoculated 3× > non-inoculated treatments (Figure 3).

Plant biomass presented an overall value of 4500 lb/a (dry basis). Values greater than 5780 lb of biomass per acre were observed for the single inoculation treatment (I1) (Figure 4). On the other hand, the lowest biomass result was recorded in the non-inoculated (NI) treatment. Seed harvest index (HI) was expressed in relative terms (as percentage) and was similar across all treatments averaging 46%. The treatment with lowest HI was treatment 5 (NF) with 43% (this was the treatment with greatest seed yield); while treatment 4 (I3) achieved the maximum seed HI, with 48% (Figure 4). Overall, maximum yields were attained with biomass playing a major role despite the changes in HI.

Soybean seeds per unit of area did not show statistical differences, but overall followed the same trend as portrayed by final yields with a greater number of seeds per unit of area for the NF treatment, 162 seeds/sq. ft, while the lowest number was found in the NI treatment (control) with 127 seeds/sq. ft (Figure 5).

Yields 2015, 2016, and 2017

Yield response to inoculation and N fertilizer addition in the system were studied for 2015, 2016, and 2017 growing seasons in Ottawa, KS. A summary is presented in Figure 6.

- In 2015, soybean yield treatments were not statistically different.
- In 2016, soybean yields were different for treatment 5 (NF), reaching the maximum yields, while treatments 1 (NI), 2 (I1), and 3 (I2) resulted in the lowest yields levels.
- In 2017, soybean yields were significantly different for treatment 5 (NF) although without differing from treatment 2 (I1). Final soybean yields averages presented the following trend from high to low: 300 lb of N/a > inoculated 1× > inoculated 2× = inoculated 3× > non-inoculated treatments (Figure 6).

Conclusions

- In 2017 (third consecutive year after the first soybean study was planted), the difference between the non-inoculated treatment or control (NI) and the inoculated with recommend rate (I1) was on average 4.7 bu/a, favoring the inoculated condition.
- Across years, treatments with different inoculation rates did not differ in the final yields.
- For 2017, maximum agronomical yield was observed when 300 lb of N/a were applied, even though yields did not differ from the single rate of inoculant treatment. However, the lowest yield was recorded for the control treatment (NI).
- Inoculation is a key piece for enhancing good nodulation in the system, improving N fixation, and helping to ensure stable yields; inoculation practice is relatively inexpensive as compared with other input costs.

In summary, further evaluation and research is needed in order to properly inform our farmers about the best N management approach in soybean grown in a newly-planted area.

Table 1. Pre-plant soil characterization at 0- 6-inch depth, Ottawa, KS

Soil parameters, units	Ottawa
pH	5.8
Mehlich P (ppm)	19
Cation exchange capacity (meq/100 g)	29.7
Organic matter (%)	4.4
Potassium (ppm)	139.5
Calcium (ppm)	3008
Magnesium (ppm)	440
Nitrates (ppm) *	10.24

*Soil samples for nitrate analysis were taken at 24 inches depth.

Table 2. Final stand counts per treatment in the 2017 growing season, Ottawa, KS

Treatments (× 1,000 plants/a)				
Non-inoculation	Inoculation 1	Inoculation 2	Inoculation 3	Fertilizer nitrogen
91	101	97	96	99

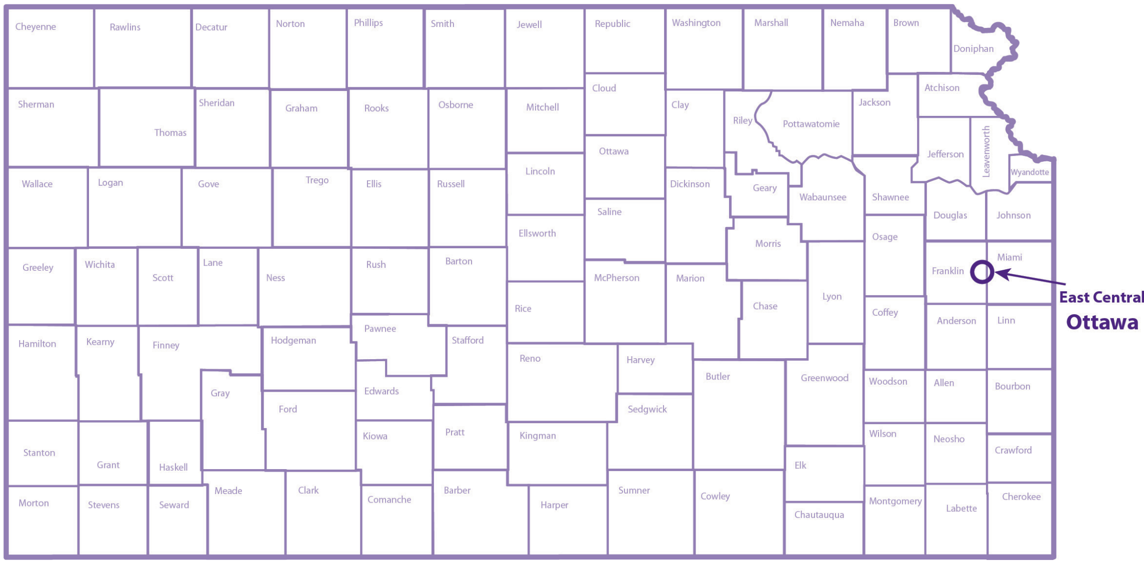

Figure 1. Field location for the soybean inoculation project during the 2015, 2016, and 2017 growing seasons (Ottawa, KS).

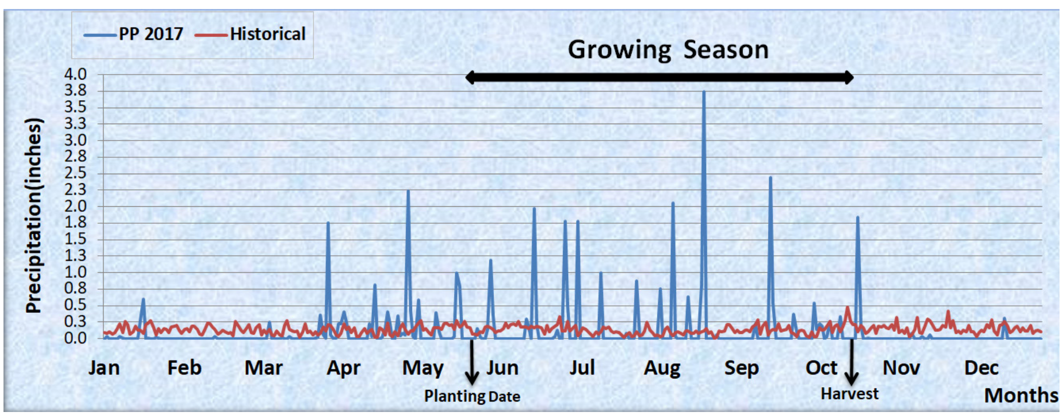

Figure 2. Daily precipitation of 2017 growing season at Ottawa, KS (blue line) and historical means for 30 years (red line). Data from Kansas Mesonet (Historical Weather, http://mesonet.k-state.edu/).

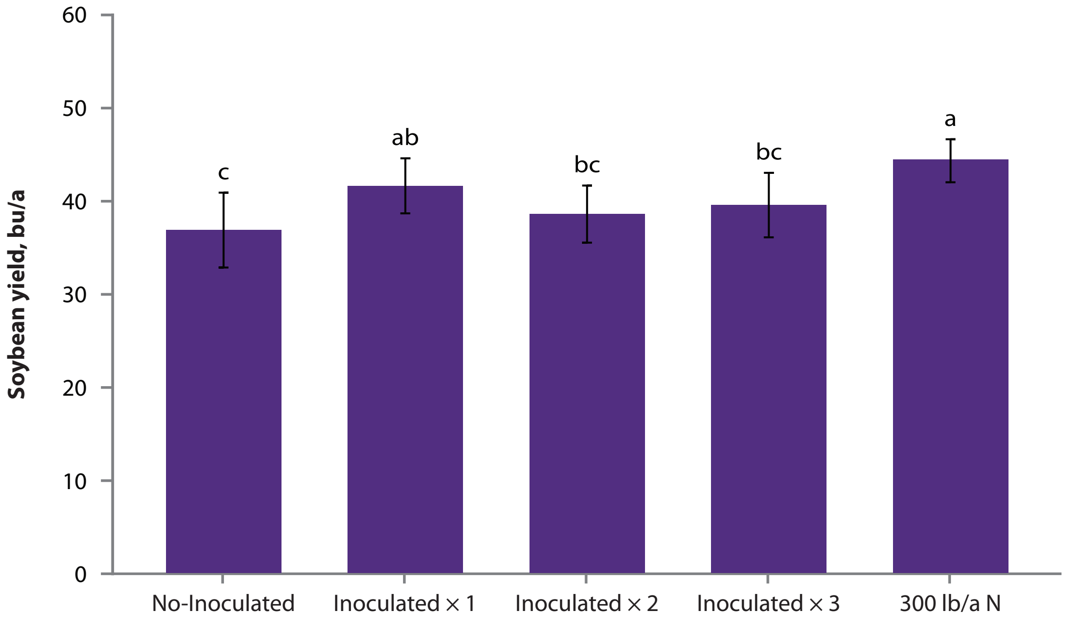

Figure 3. Soybean yield (13% moisture) at Ottawa, KS, for five different treatments during the 2017 season. Whiskers represent standard error of the mean and different letters indicate significant differences at ($P < 0.05$).

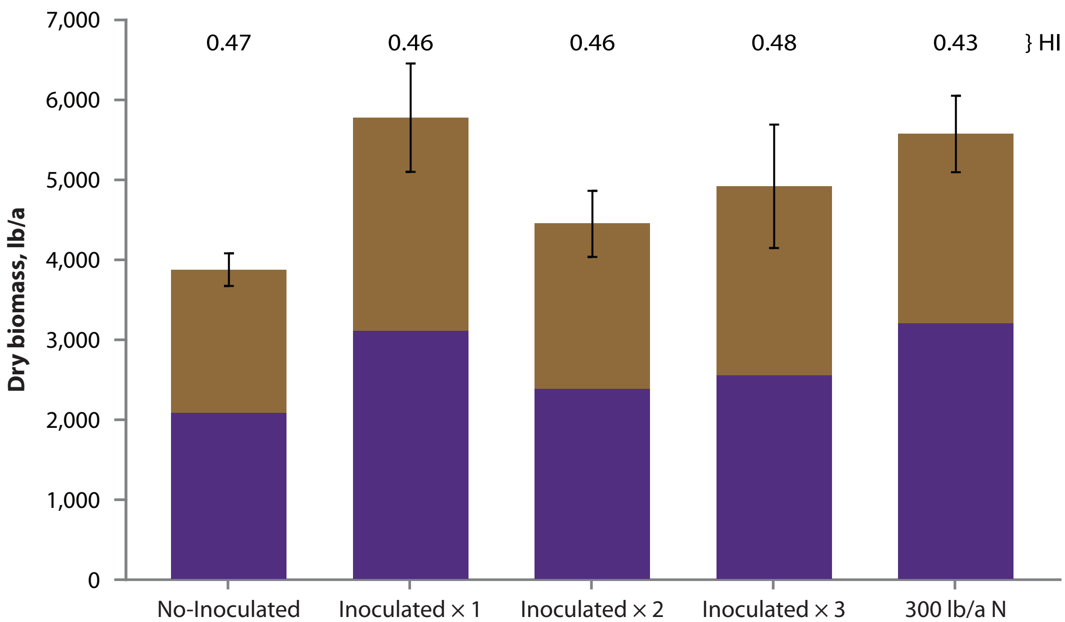

Figure 4. Dry biomass (expressed in lb/a) and seed harvest index (HI, expressed as percentage) at Ottawa, KS, during the 2017 growing season. Whiskers represent the standard error of total dry biomass means. Purple color represents vegetative biomass (non-seed tissues) and brown color represents dry biomass of seeds.

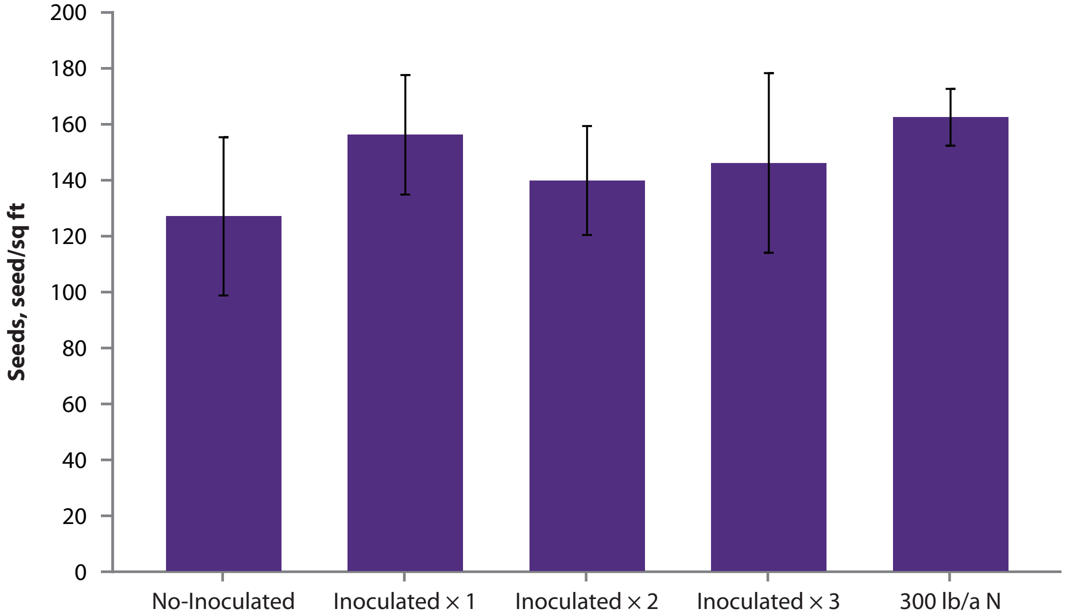

Figure 5. Seed number per unit of area expressed in seeds per square feet at Ottawa, KS, during the 2017 growing season. Whiskers represent the standard error of the mean.

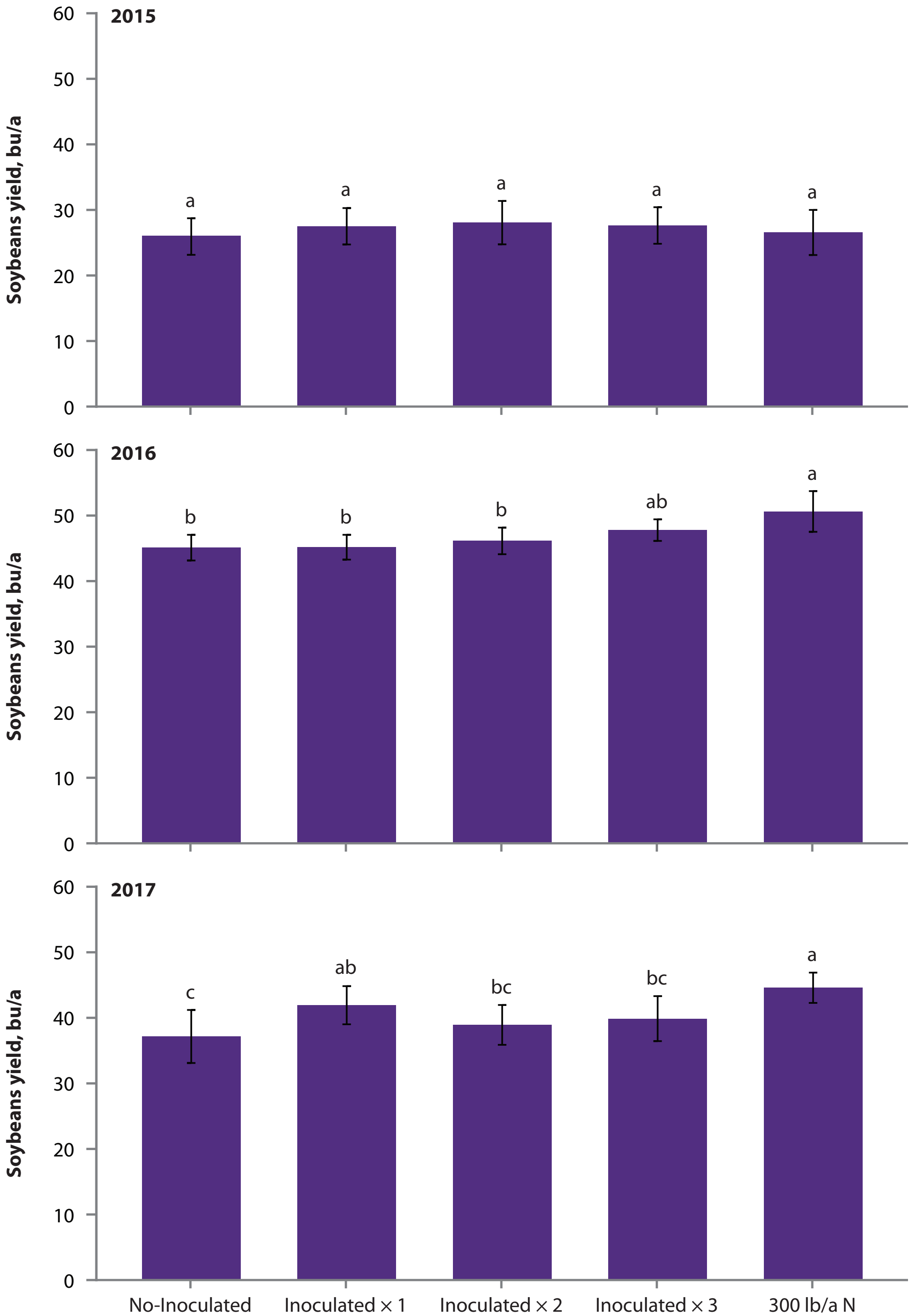

Figure 6. Soybean yield (13% moisture) at Ottawa, KS, for the 2015, 2016, and 2017 growing seasons. Whiskers represent standard error of the mean, and different letters indicate significant differences at (*P* < 0.05).