MISSISSIPPI SOYBEAN PROMOTION BOARD
PROJECT 27-2015 (YEAR 3)
2015 FINAL REPORT

Title: Soybean yield and biomass response to supplemental nitrogen fertilization.

PI: Bobby Golden; Graduate Student Justin McCoy

BACKGROUND AND OBJECTIVES

Soybean requires more nitrogen (N) to achieve maximum yield than any other field crop currently cultivated in Mississippi (Leikam et. al. 2010). This fact goes unnoticed for most producers and researchers alike because of the unique symbiosis that soybeans have with soil bacteria that allows the crop to produce its own N requirement.

Many producers shifting from long-standing cotton acreage have understood the benefit that inoculation products can provide on acreage that has a limited history of soybean production. These acres are more than likely those that have the capability of producing ultra-high soybean yields. It is unclear if soybean is capable of producing enough N to meet demand in these ultra-high yield environments, and whether or not N addition may increase soybean yields in Mississippi.

There is a wealth of literature with results from across the U.S. describing the relationship between soil- and/or foliar-applied N products and soybean yield. Most of the observations to date have been highly variable and in many cases yield responses were not achieved. In general, a review of available literature suggests that soybean was more likely to respond to N in high-yield environments (> 65 bu/acre; Salvagiotti et. al. 2008).

The objectives of this research were to determine if soybean yields in Mississippi can be increased with the addition of varying rates of inorganic N, and determine the critical N addition timing and form of N for optimal soybean performance while minimizing possible detriment to N_2 fixation. The ultimate goal of the project was to determine if N additions are needed and economical to reach ultra-high yield levels in the Mississippi Delta.

REPORT OF PROGRESS/ACTIVITY

Field studies were conducted in 2014 and 2015 in Stoneville, MS, to evaluate soybean aboveground biomass and grain yield response to supplemental N fertilization. Studies were carried out on two commonly cropped Mississippi soils, soil with CEC <20 (Dubbs Silt Loam and Commerce Very Fine Sandy Loam) and soil with CEC >20 (Tunica Clay). All studies were irrigated according to MSU-ES guidelines. A MG IV variety was planted on April 19 and May 8 in 2014 and on April 16 and April 30 in 2015.

Each experiment was arranged as a randomized complete block design with 4 replications per treatment plus an unfertilized control. Soil samples were taken from each replication and composited to form one sample per replicate. Soil samples were oven-dried (50 deg. C), crushed to pass through a 2-mm sieve, mixed, and analyzed for pH (1:2 v/v soil/water), Lancaster extractable nutrients, and Mehlich-3 extractable nutrients to determine fertilization level for optimizing yields. Plant tissues were collected at the R5 stage of development from one of the top three nodes with fully expanded leaves from no less than 20 plants within each plot, followed by analysis for elemental concentration. Soybean seed were harvested with a small plot combine at maturity, and yields are reported at a standard moisture content of 13%.

To determine appropriate N addition and N source, the treatments were arranged in a factorial structure with 3 N sources applied at 4 rates and 2 application timings. The three N sources were urea, polymer coated urea, and ammonium sulfate. The rate structure ranged between 0 to 160 lb N/acre in 40 lb increments. Nitrogen applications were made at the V4 and R1-R2 stages of development. All site years were analyzed together using SAS 9.2. When appropriate, Fishers protected least significant difference (LSD) or regression analysis was used to make inference on treatment differences.

Soybean aboveground biomass (data not shown) was Influenced by the main effects of application timing, N source, and N rate on soil with CEC <20. Soil with CEC >20 exhibited no response across all factors with respect to aboveground biomass, apparently due to the greater organic matter content.

Nitrogen application at V4 produced greater aboveground biomass (data not shown) at R5 on soil with CEC <20. However, increases in aboveground biomass due to application timing did not influence seed yield in these studies, possibly due to the amount of available N during pod fill being greater for R1 application timing compared to that of V4 application timing on soil with CEC <20.

Urea+NBPT resulted in the greatest aboveground biomass on soil with CEC <20. However, no association between biomass and seed yield was observed. PCU (polymer coated urea) produced the greatest grain yield on soil with CEC <20, suggesting PCU was able to supply available N at critical times of N uptake (Table 1.1).

The slow release characteristics of PCU could have resulted in the least antagonism between NO_3^--N concentration within the soil solution and the N_2 fixation process, possibly limiting nodule inhibition on soil with CEC <20. However, with respect to overall soybean seed yield, N rate appears to be the most critical factor. Across soils, N fertilizer additions were able to supply available N at critical stages of soybean development (R3-R5) and seed yield increases were observed due to N fertilization (Tables 1.2 & 1.3).

Yield component analysis exhibited a similar trend to that of overall soybean seed yield, as N rate appeared to be the most critical factor. Soybean receiving N fertilization (> 0 kg N ha^{-1}) produced a greater number of seeds $plant^{-1}$ than soybean receiving no N fertilization (Tables 1.4 & 1.5).

N fertilizer additions positively impacted soybean seed yields across soils, suggesting that soil-N concentrations were insufficient to meet soybean N requirement in a high yielding (> 3500 kg ha^{-1}) environment. Remobilization of tissue N within the plant may have accounted for some percentage of the excess N requirement during pod fill. However, yield increases occurred across soils due to N fertilization, suggesting that available soil-N was able to fulfill the N requirement during critical stages of soybean seed development.

Although yield increases were less than the levels shown by others (Salvagiotti, 2008; Wesley et al.,1998), N fertilizer additions were able to fulfill the N requirement and increase the overall seed yields of the soybean in high yielding environments on two common Mississippi soils in the Midsouth production system. Although yield responses to N fertilization in high-yielding soybean were measured, the gains were not economically sufficient to warrant the adoption of this practice in Midsouth soybeans.

Soybean nodule inhibition and root growth as influenced by nitrogen source and nitrogen rate.

Greenhouse studies were conducted in 2016 in Stoneville, MS, to evaluate the influence of supplemental N fertilization on nodule formation and root growth of soybean. Two N sources were applied at three N rates to two soils commonly cropped to soybean in Mississippi.

Soil variation influenced root parameters as soil with CEC <20 produced greater belowground biomass, mean root length, root area, root diameter, and number of nodules (Table 1.6). Across soils and N source, the main effect of N rate was most critical as it influences soybean root growth.

Soybean receiving N fertilization exhibited a decrease across all belowground parameters compared with soybean receiving no N (0 kg N ha^{-1}) (Table 1.7). N fertilizer additions pooled across N rate resulted in an approximate 19% belowground biomass reduction across soils compared with soybean receiving no N (0 kg N ha^{-1}). Soybean receiving N fertilization produced less belowground biomass than soybean receiving no N fertilization (0 kg N ha^{-1}), and this directly corresponds to all other root parameters. However, soybean total aboveground biomass exhibited no response to N fertilizer additions, suggesting that adequate nutrients were taken up and converted to vegetative growth by soybean receiving N fertilization at the R2 growth stage.

Nitrogen availability directly corresponded to a decrease in root growth parameters along with the mean number of nodules present. N fertilizer additions (> 0 kg N ha^{-1}) resulted in an approximate 52% decrease in mean number of nodules present compared to soybean receiving no N (0 kg N ha^{-1}) (Table 1.8).

Soybean receiving PCU as an N source had less suppression of the number of nodules than did soybean fertilized with urea+NBPT (Table 1.9). The extended release properties of PCU possibly provided less available N to the plant, thereby limiting soil-N concentrations that would have caused a corresponding decrease in nodules due to N fertilization. Overall, N fertilizer additions negatively impacted root growth and nodulation, as a decrease across all belowground parameters was observed for soybean receiving N fertilization.

CONCLUSIONS

Even though soybean yield was significantly increased by adding N to both low- and high-CEC soils in this study, the increases were small (4.3-8.6 % and 3.7-5.9 bu/acre) and likely not economical. These small yield increases were the result of more seeds per plant where N was added.

Addition of N to soil in greenhouse studies had no positive effect on root growth parameters.

Addition of N to soil in greenhouse studies resulted in large and significant reductions in number of nodules present on soybean roots.

All of these results indicate that soybean grown on predominant soils in the Midsouth will not benefit economically from the addition of N fertilizer.

Table 1.1. Main effect of N source pooled across application timing and N rate as it influenced soybean seed yield for research established on soil with CEC <20 during 2014 and 2015 at the Delta Research and Extension Center.

N Source[¥]	Seed yield[†]
	kg ha^{-1}
AMS	5935 ab (88.2 bu/acre)
PCU	5984 a (89.0 bu/acre)
Urea+NBPT	5836 b (86.8 bu/acre)

†Means within a column followed by the same letter are not significantly different at $P \leq 0.05$.
¥PCU-polymer coated urea, AMS-ammonium sulfate.

Table 1.2. The main effect of N rate pooled across application timing and N source as it influenced soybean seed yield for research established on soil with CEC <20 during 2014 and 2015 at the Delta Research and Extension Center.

N rate	Seed yield[†]
kg N ha^{-1}	*kg ha^{-1}*
0	5764 b (85.7 bu/acre)
45	5941 a (88.3 bu/acre)
90	5901 ab (87.7 bu/acre)
135	5975 a (88.8 bu/acre)
179	6011 a (89.4 bu/acre)

†Means within a column followed by the same letter are not significantly different at $P \leq 0.05$.

Table 1.3. The main effect of N rate pooled across application timing and N source as it influenced soybean seed yield for research established on soil with CEC >20 during 2014 and 2015 at the Delta Research and Extension Center.

N rate	Seed yield[†]
kg N ha^{-1}	*kg ha^{-1}*
0	4626 b (68.8 bu/acre)
45	4818 ab (71.6 bu/acre)
90	5023 a (74.7 bu/acre)
135	4827 ab (71.8 bu/acre)
179	4963 a (73.8 bu/acre)

†Means within a column followed by the same letter are not significantly different at $P \leq 0.05$.

Table 1.4. The main effect of N rate pooled across application timing and N source as it influenced mean total seeds plant^{-1} for research established on soil with CEC <20 during 2014 and 2015 at the Delta Research and Extension Center.

N rate	Mean Total Seeds†
kg N ha^{-1}	*# seeds plant^{-1}*
0	111 b
45	120 a
90	122 a
135	121 a
179	124 a

†Means within a column followed by the same letter are not significantly different at $P \leq 0.05$.

Table 1.5. The main effect of N rate pooled across application timing and N source as it influenced mean total seeds plant^{-1} for research established on soil with CEC >20 during 2014 and 2015 at the Delta Research and Extension Center.

N rate	Mean Total Seeds†
kg N ha^{-1}	*# seeds plant^{-1}*
0	127 b
45	142 a
90	147 a
135	143 a
179	145 a

†Means within a column followed by the same letter are not significantly different at $P \leq 0.05$.

Table 1.6. The main effect of soil pooled across N rate and N source as it influenced mean belowground biomass, mean root length, mean root area, and mean root diameter for research established during 2016 at the Delta Research and Extension Center.

	Measurement†			
Soil	Mean Belowground Biomass	Mean Root Length	Mean Root Area	Mean Root Diameter
	g per pot	*cm per pot*	*cm^2 per pot*	*mm*
Dubbs Silt Loam (CEC <20)	1.44 a	819.45 a	139.38 a	0.5310 a
Tunica Clay (CEC >20)	1.23 b	584.52 b	87.58 b	0.4789 b

†Means within a column followed by the same letter are not significantly different at $P \leq 0.05$.

Table 1.7. The main effect of N rate pooled across soil and N source on mean belowground biomass, mean root length, mean root area, mean root diameter, and mean root volume for research established during 2016 at the Delta Research and Extension Center.

	Measurement†				
N rate	Mean Belowground Biomass	Mean Root Length	Mean Root Area	Mean Root Diameter	Mean Root Volume
kg N ha^{-1}	*g per pot*	*cm per pot*	*cm^2 per pot*	*mm*	*cm^3 per pot*
0	1.53 a	775.42 a	130.18 a	0.5236 a	1.763 a
45	1.30 b	707.92 ab	112.17 ab	0.4982 b	1.429 ab
135	1.17 b	622.62 b	98.10 b	0.4929 b	1.249 b

†Means within a column followed by the same letter are not significantly different at $P \leq 0.05$.

Table 1.8. The main effect of N rate pooled across N source and soil as it influenced the mean number of nodules present per pot for research established during 2016 at the Delta Research and Extension Center.

N rate	Mean Number of Nodules†
kg N ha^{-1}	*# of nodules per pot*
0	72 a
45	38 b
135	33 b

†Means within a column followed by the same letter are not significantly different at $P \leq 0.05$.

Table 1.9. The main effect of N source pooled across N rate and soil as it influenced the mean number of nodules present per pot for research established during 2016 at the Delta Research and Extension Center.

N source¥	Mean Number of Nodules†
	# of nodules per pot
PCU	52 a
Urea+NBPT	42 b

†Means within a column followed by the same letter are not significantly different at $P \leq 0.05$.
¥PCU – Polymer Coated Urea.