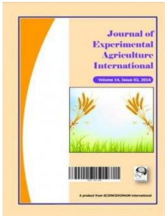

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Response to Late Foliar Nitrogen Application in Soybean Productivity

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Authors' contributions

This work was carried out in collaboration between all authors. Author JTP designed the study, wrote the protocol, wrote the first draft of the manuscript and identified the plants. Author FM reviewed the experimental design and all drafts of the manuscript. Authors LPS and JCM managed the analyses of the study and performed the statistical analysis. All authors read and approved the final manuscript.

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ABSTRACT

To achieve high productivity in soybeans, a balanced fertilization and careful management is necessary during the period in which the plant requires larger amounts of nitrogen is essential. This study evaluated the effect of foliar nitrogen fertilization using ammonium sulfate at early grain filling stage of soybean crop. The experiment was performed during 2015/2016 crop in the state of Piauí, Brazil. Nitrogen was applied at doses of, 3, 6, 9, 12, and 15 kg ha^{-1} in a randomized block design with four replications. Data was recorded for number and length of pods, thousand seed weight and yield. Late foliar application of nitrogen showed no significant difference in grain yield of soybean plant.

Keywords: Glycine max; plant nutrition; foliar application; yield.

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1. INTRODUCTION

Soybean is very important for food and feed and it is a rich source of protein. Soybean production has been growing over the years and the harvest of 2014/15 Brazilian production reached a record 96.24 million tons [1].

Nitrogen is part of most organic compounds such as proteins, chlorophyll, hormones, nucleic acids and amino acid making it essential for plant life [2]. The increased demand for nutrients is observed at the flowering and when there is the maximum volume of grain in plants [3,4]. Much of nitrogen required by the crop comes from fixation by symbiont *Bradyrhizobium* bacteria; the remainder is obtained via soil by mineralization of organic matter [5]. However, several factors hamper the fixation process, i.e. water deficit or excess, acidity, soil temperature, fertility, competition with wild strains and presence of excess nitrate [6,7].

Nitrogen fertilization represents an alternative to complement the biological fixation process, therefore, ammonium sulfate ($(NH_4)_2SO_4$) is often used; the second most widely used source in Brazil [8]. This formula shows 21% nitrogen and also has, on average, 24% sulfur (S), in addition, it has advantages, such as low hygroscopicity and nitrification, less volatilization of N and good physical properties. It increases phosphorus solubility and soil manganese through the sulfur [9].

The aim of this study was to evaluate the efficacy of late foliarly applied nitrogen in soybean to improve nitrogen deficiency at grain filling and yield.

2. MATERIALS AND METHODS

The research was conducted at the São João Farm, in the agricultural frontier region with the Brazilian Cerrado, state of Piauí (9° 3'25.69"S and 44° 33'12.89" W), 570 m altitude. The study was conducted on soybean crops Monsoy 8644 IPRO. The climate is warm tropical, according to Köppen classification, with rainy and hot summer. The meterological data was monitored during the study period from November 2015 to March 2016, rainfall was 617 mm, as shown in Fig. 1, and the average temperature was 26.5°C.

Fertilization was based on soil analysis (Table 1) and recommendation for the culture. Seeds were treated and inoculated with *Bradyrhizobium* bacteria at 5 x 10^9 colony forming unit.

Sowing of soybean was made in late November 2015, the cultivar presented a determinate growth habit, 77 cm average height, 110 days average cycle, 8.6 maturity group. This cultivar has a high yield potential and good adaptation to regions with less than 600 meters altitude. The experimental design was a randomized block design, using six doses of ammonium sulfate ($(NH_4)_2SO_4$): D1 to D6 control, 0, 3, 6 9, 12 and 15 kg ha^{-1} with four replications.

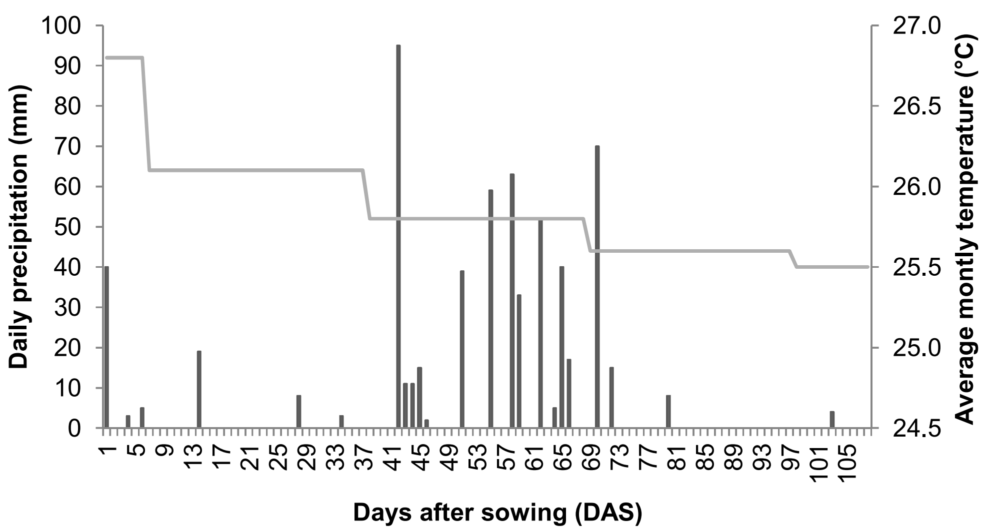

Fig. 1. Rainfall, in millimeters and monthly temperature in ºC from November 2015 to March 2016

Table 1. Physico-chemical analysis of soil samples collected at different depths from experimental area

Depth	pH	OM	P	K	Ca	Mg	Al	SB	Sand	Clay	Silt
cm	CaC_2	g/dm³	mg/dm³	---------mmolc/dm³--------					--------------g/kg-------------		
0-10	4.8	26.4	30.3	3.8	38.3	7.6	0	49.7	660	280	60
10-20	4.2	20.5	11.1	1.4	14.4	2.9	5	18.7	610	300	90
20-40	3.1	14.3	6.3	0.7	1	0.9	12	2.6	590	330	80

Depth = Soil depth; pH = Potential of hydrogen; OM = Organic matter; P = Phosphorus; K = Potassium; Ca = Calcium; Mg = Magnesium; Al = Aluminum; SB = Base saturation

Each plot size was 25 m^2 having 10 rows which were5 meters long and 0.5 m spaced apart. The useful area of the experimental unit was formed by the three central rows, excluding 0.5 m from each end of the rows. Ammonium sulfate (21% N and 24% S) was used as a source of fertilizer. For the application of N in liquid form, we used a knapsack sprayer of 20 liters in the period from the end of the pod formation stage (R4) to the beginning of the grain filling stage (R5). For the assessments, plants were collected only in the useful area of the plot. Harvest was done manually; when the plants have reached the R8 developmental stage (95% of the pods had the typical color of mature pod). The yield components of the crop were evaluated as:

Soybean yield: Plants of the useful area of the plot were measured for total weight of the grains of the collected plants. The result was presented in kg ha^{-1} (with moisture adjusted to 13%).

Thousand seed weight: Eight samples of 100 seeds were taken at random from each plot, and each sample was weighed on a scale and then applied the formula described in [10]. The results were expressed in grams.

Number of pods per plant: Five plants of each plot were collected, and counted the number of pods and later calculated the average of 5 plants.

Length of pods: Of the five plants collected for determining the number of pods, 10 pods per were taken plant to measure the length, using a digital caliper and then obtaining the average per plant.

Data was tested by analysis of variance (ANOVA) using F-test and processed by the R software (version 3.2.3).

3. RESULTS AND DISCUSSION

Table 2 lists the results of the analysis of variance. For the number of pods and length of pods, different doses applied to leaves of soybean plants at R4-R5 stages had no significant influence. This result differs from that reported by [11], who tested N foliar applications in soybeans, which had a significant increase in the number of pods per plant compared to the control. The length of pods may be related to lack of biological nitrogen fixation at the final stage of the crop.

For TSW (Table 2), significant differences were not detected, this may have occurred because of high water stress in the region during the grain filling period (R5), thus providing pods with malformed grains and low weight. [12] in Iran, conducted an experiment with urea and observed that the treatments with application of 50 kg ha^{-1} and 100 kg ha^{-1}, at the R1 and R5 stages, caused no significant difference in 1000 grain weight between treatments, thus demonstrating that late applications caused no significant response.

Yield, in kg ha^{-1} (Table 2), was also not affected by the late application of ammonium sulfate. These results contradict [13], who verified a production of 3890.50 and 3940.50 kg ha^{-1} using foliar application of N (25%) at a dose of 10 L ha^{-1} at the stage of R5 and R1 + R5. However, [14], in an experiment with nitrogen (32%) as nitrate, ammonium and amidic in the same fertilizer applied on soybean noted an increase in yield at doses of 3 and 5 L ha^{-1}, however the results were not significantly different. [15] also reported that the application of foliar N (30%) at the R4 and R5 reproductive stages have not increased yield when used in two doses of 4 L ha^{-1}.

For application via foliar, toxicity symptoms were observed at doses of 6, 9, 12 and 15 kg ha^{-1}, only the dose of 3 kg ha^{-1} caused no symptoms, but the plants were able to recover and complete their cycle. According to [16], the foliar application of considerable levels of nitrogen may cause toxicity, which can be minimized by the choice of the nutrient source, the nozzle and spray volume, as well as the time of application.

Table 2. Analysis of variance for number of pods (NP), length of pods (LP), thousand seed weight (TSW) and yield

Source of variation	Degrees of freedom	NP (unit/plant)	LP (cm)	TSW	Yield
Dose	5	147.94^{ns}	3.07^{ns}	35.16^{ns}	126.69^{ns}
Blocks	3	116.02^{ns}	0.09^{ns}	27.99^{ns}	25.89^{ns}
Residue	15	164.85	1.54	17.31	92.73
Coefficient of variation (%)		23.08	2.82	6.77	30.18

^{ns}*: non-significant*

Table 3. Average number of pods (NP), length of pods (LP), thousand seed weight (TSW) and yield of different nitrogen doses applied

Dose	NP unit/plant	LP cm	TSW g	Yield kg/ha^{-1}
0	58.35	42.45	95.85	1750.20
3	63.15	44.84	95.63	2406.10
6	49.85	43.82	93.75	1667.97
9	61.00	43.63	88.38	1406.29
12	52.95	44.15	91.63	2013.47
15	48.45	44.76	90.58	2139.71

Discussion has taken place about the inefficiency of nitrogen fixation to supply the demand at the grain filling stage (R5). Nevertheless, it should be noted that some practices and chemicals used for seed treatment are incompatible with N_2 fixing bacteria, leading to their death [17] and thus impairing the final production. The mineral forms of N, NH_4^+ and NO_3^-, affects not only the biological fixation but also the nodulation of the plants by inhibiting nodules initiation or causing their senescence [18].

4. CONCLUSION

The foliar application of ammonium sulfate ($(NH_4)_2SO_4$) at the grain filling phase (R4 and R5) had not increased they yield of soybean compared to the control. Therefore, inoculation in seeds with nitrogen-fixing bacteria is sufficient to achieve high productivity.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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