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RESEARCH ARTICLE

RELATIONSHIP BETWEEN LATE NITROGEN FERTILIZATION IN SOYBEAN AND PRODUCTION, QUALITY AND ECONOMIC VIABILITY OF SEEDS

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ABSTRACT

Nitrogen (N) is one of the most limiting nutrients in agricultural systems, in this way, the production of high quality soybean requires the nitrogen management in the soil is related to the profitability of the production system. This study aimed to evaluate the yield, seed quality and economic viability of late nitrogen fertilization on soybean.The experiment was conducted in a randomized block experimental design with four replications, with different doses of N: 0, 30, 60, 90 and 120 kg ha^{-1}, in which were conducted two trials (with use of urea and Ammonium sulfate source). The fertilizers were applied at the transition phase between R4-R5. We evaluated vegetative growth components, yield and seed physiological quality and economic viability. The results indicated that the use of urea resulted in higher yield in terms of productivity and with dose of maximum agronomic efficiency of 78.7 kg ha^{-1}N. Urea and ammonium sulfate changed the variables of physiological quality.The economic viability analysis showed difference in gain between sources and between doses, and responses with the use of urea were substantially higher than with ammonium sulfate, and the optimal dose of ureawas 86.7 kg ha^{-1} N, with net revenue of R$ 8,188. It was concluded that late nitrogen fertilization on soybean provides productive and economic efficiency in seed production system, with lower operational risk with the use of urea as a source of nitrogen fertilizer.

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INTRODUCTION

In many cases, nitrogen can be the most limiting nutrient to plant growth, particularly in tropical countries (Hungria, 2006) This is the main component of amino acids, enzymes, proteins, saturated and unsaturated fatty acids, some vitamins and polyphenolic compounds (Ávila, 2007), important in the formation of seeds of legume species. On average, the fixation of N can account for 52% of total uptake of N by plants (Salvagiotti, 2008). A reduction in the assimilation of biologically fixed N by symbiont individuals in grain filling stage raised the hypothesis of a greater demand for nitrogen remobilization at that stage, which results in a shorter period of grain filling and consequently in lower production (Gan, 2003). Results of research on late nitrogen fertilization in soybean are contrasting. For instance, Mehmet OZ (Mehmet, 2008), found no response from the use of N on grain yield per plant. On the other hand, it was found that the yield of soybeans in the treatments with nitrogen fertilization, except 50 kg ha^{-1} N as ammonium nitrate (applied at the R5 stage), was superior to that in the treatment with only inoculation, with increased productivity of 154 kg ha^{-1} grain (Mendes, 2008). Late nitrogen fertilization is justified by the fact that the soybean plant loses root efficiency at the end of the development cycle, associated with the growing demands for nitrogen of soybean cultivars and high productivity cap, which cannot be fully supplied by biological fixation (Mendes, 2008 and Bahry, 2013). The production of soybeans involves application of technological packages for the production system to ensure optimalproduct quality standards. Therefore it requires greater financial investments. The agricultural production is a high risk business as it is associated with non-controllable variables, such as market and climate factors, demand for economic and financial feasibility analysis and risk management (Napolitano, 2012) to analyze the return on investment as profit, and reduce the failure chances of the farmer. The genetic potential of cultivars combined with different environmental conditions points to the necessity of providing N as a supplementary measure for soybean plants. Moreover, there is little research involving the assessment of economic feasibility of production and physiological quality of seeds with late nitrogen fertilization. From this perspective, the goal of the present study was to evaluate the effect of late nitrogen fertilization with different sources and levels of N,

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productivity, physiological quality of soybean seeds and economic viability of this management.

MATERIAL AND METHODS

Study area and experimental design

The experiment was conducted in 2015/2016 agricultural year, in a Cerrado area, southern Piauí state, at the following geographical coordinates: 9°3'25,69" S and 44°33'12,89" W, and 570 meters altitude. The climate is classified as Aw (hot tropical), according to Köppen classification, with hot and humid summer and warm and dry winter. Climatic data of the experimental area are shown in Figure 1.

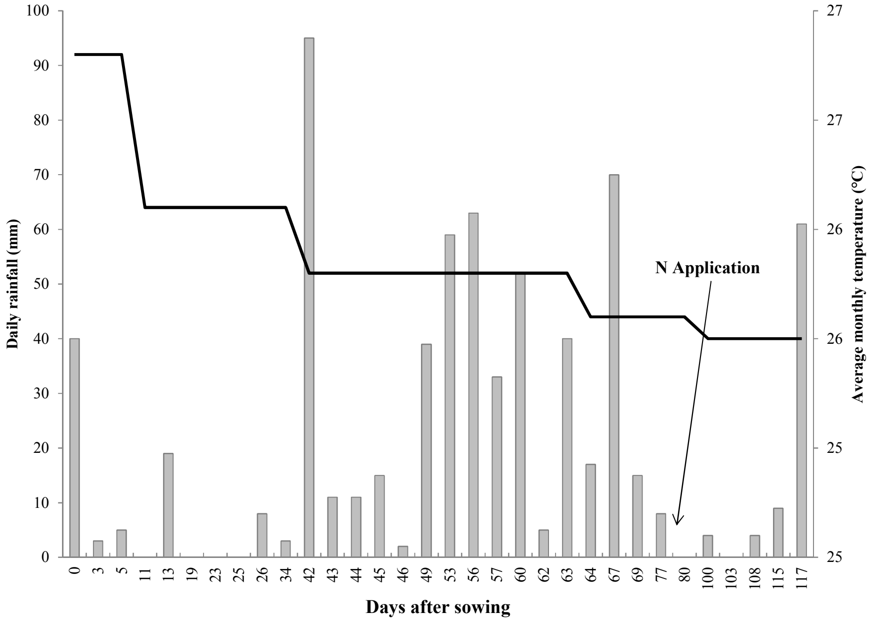

Figure 1. Daily values of rainfall (mm) and average temperature (°C), of the experimental area

The soil is classified as Oxisol Yellow with sandy loam texture (EMBRAPA, 2013), and the results of chemical analysis of soil, sampled at the layer 0 - 0.20 m, before the implementation of the experiment, are listed in Table 1. For sowing, soybean seeds were previously treated with fungicides, insecticides and inoculated with *Bradyrhizobium japonicum* and *B. elkanii* at a dosage of 200 mL for 50 kg of seed. The soil was fertilized according to soil analysis and recommendations for the soybean crop, using 100 kg ha^{-1} MAP (9% N and 47.5% P_2O_5) and 100 kg ha^{-1}KCl (60% K_2O), with sowing. The cultivar used was maturity group 8.6, with 128-135 day growing cycle, with indicated population of 200,000 plants per hectare, suitable for the region. The experiment was conducted in a randomized block design with four replications. Two experiments were performed, one for each source of nitrogen fertilizer, ammonium sulfate (21% N and 24% S–$(NH_4)_2SO_4$) and urea (45% N–$CO(NH_2)_2$). Treatments consisted of five levels of N: 0 (control), 30, 60, 90 and 120 kg ha^{-1}. The area of the plots was 25 m^2, with 10 rows, 5 meters long, spaced 0.50 meters apart and population of 10 seeds per meter. Nitrogen fertilizer was applied in the transition phase of the R4-R5 reproductive stages (end of pod formation for beginning of grain filling). At the maturation stage for harvesting (R8), plants in the working area were collected. For evaluation, we considered the two central rows of 3 meters (useful area of 3 m^2), excluding the borders. Before the assessments of yield and physiological quality, we determined the moisture content of the seeds, defined by Seed Testing Rules - STR (BRASIL, 2009), Tests were performed to define the yield components and physiological quality of seeds. Before evaluating yield and physiological quality, the seed moisture content was determined by the rules of seed analysis [10]. Evaluations were performed to define the components of yield and physiological quality of seeds.

Plant assessment

Content of chlorophyll a (Cl_a), chlorophyll b (Cl_b) and chlorophyll (Cl_{total}) (Parente, 2014), productivity - in kg ha^{-1} (PROD), thousand seed weight - in grams (TSW) [10] and the stem dry weight - grams per plant (SDW), dry weigth of pods - in grams per plant (DWP) (Lazarini, 2000), number of pods per plant - in units (NP), number of pods in the upper third - in units per plant (NPUT), length of pods - in centimeters (LP).

Seed assessment

Physiological quality tests were performed at the Crop Science Laboratory of the Federal University of Piauí. For these tests, we used a completely randomized design with four replications, in which, the treatments consisted of seeds from soybean plants of the experiment in the field (1st phase of the experiment), with treatments with different N levels (0, 30, 60, 90 and 120 kg ha^{-1}), with the two sources of fertilizer, applied late. The tests were: Germination – in percentage (G), first count of germination - in percentage (FCG) (BRASIL, 2009) and germination speed index (GSI) (Maguire, 1962), length (LS) (in centimeters) and dry weight of seedlings - dry weight of root (DWR) and shoot (DWS), in grams seedling^{-1} (Nakagawa, 1999) electrical conductivity - in µS cm^{-1} g^{-1} (EC) (Marcos Filho, 1990).

Statistical analysis

Nitrogen sources were analyzed separately. The Shapiro-Wilk test checked the normality of the data, which were subjected to analysis of variance and F-test to test the differences between treatments. When there was a statistical difference, regression analysis was applied to evaluate the effect of N levels. Data were processed by the R software (R version 3.2.0, 2015) (version 3.2.5), using the method of ordinary least squares to identify the significance of the equation parameters, and the graphs were plotted with the aid of SigmaPlot software (version 10.0).

Economic viability

It was considered the thousand seed weight, seed germination and the recommended population for sowing the cultivar (200,000 plants ha^{-1}) to generate a final productivity in bags with 200,000 viable seeds. It was made the data simulation using the simulation methodology of Monte Carlo (Lima, 2008), to obtain normal distribution of residuals by adopting

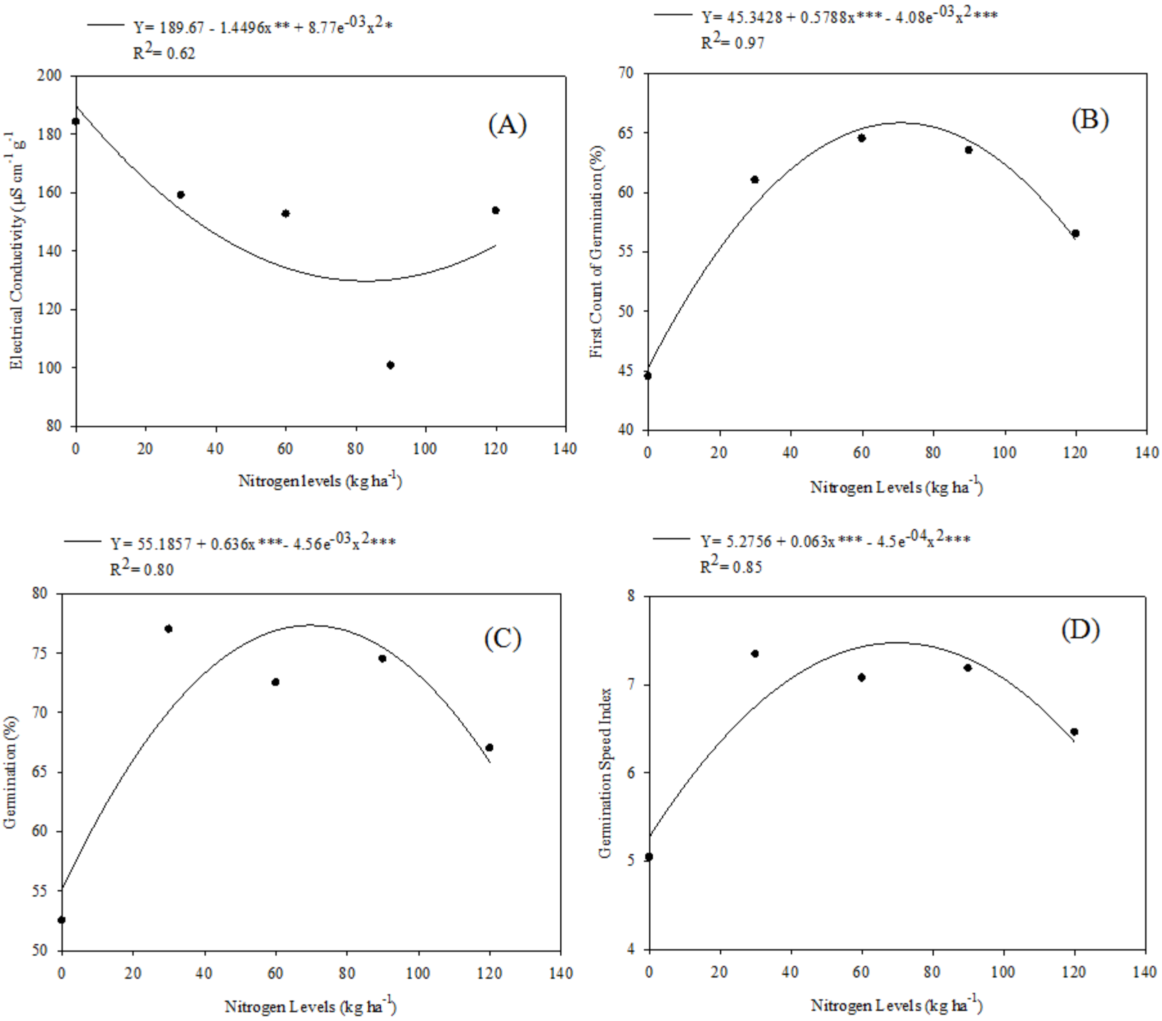

Figure 2. Regression analysis using the quadratic polynomial model of electrical conductivity (A), first count of germination (B), germination (C) and germination speed index (D) with ammonium sulfate as nitrogen source

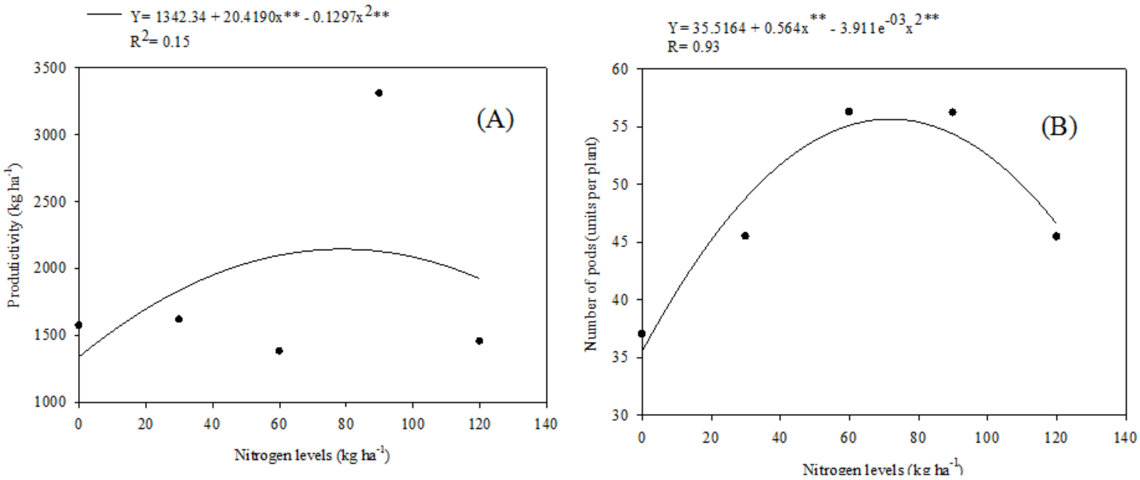

Figure 3. Regression analysis using the quadratic polynomial model of productivity (A) and number of pods per plant (B) for the experiment with the application of urea fertilizer

10,000 simulations per treatment. Subsequently, we tested the statistical difference for sources and levels. Next, a regression analysis was run to obtain the production function, whose model set for fit was a polynomial of degree 3. The calculations defined for this analysis follow the models prescribed by the Theory of the Firm (Camargos, 2008). After obtaining the regression function, considering the standard error, normality was adjusted. From the polynomial function, we calculated the stages 2 and 3 of production (Table 4) to define the rationality limits in the use of inputs. It was considered as the product price, the price of the bag of seeds of the soybean cultivar MONSOY 8644 IPRO, with risk-adjusted price for the study area, with a standard error of US$ 0.74 (Santos, 2014) whose price was US$ 21.44. The price of urea was US$ 353.61 and ammonium sulfate was US$ 254.6 per ton, quoted in the region. We also considered in the price of inputs, the cost of applying the fertilizer, 1 bag hectare^{-1}, with the bag of soybean quoted at US$ 0.23 for urea e US$ 0.25 for ammonium sulfate. The price of kg N with use of urea was US$ 0.79 and sulfate was US$ 1.24. The production cost was regarded here as the anterior total cost. As the use of zero kilograms of N, there would be no extra cost, it is considered only the production costs, which, in this case,is assumed to be equal to the total revenue. For the other levels, we used always as fixed costs, the anterior total cost. The optimal level is calculated from the price of soybean bags multiplied by the Marginal Physical Product (MPP), equaling this product to the price of the input (in R$ per kilogram of product). Optimal productivity is defined by the production equation, substituting x by the value found at the optimal level. All data subjected to economic analysis were processed by @Risk 7 software (Palisade, 2016).

RESULTS

Ammonium sulfate as nitrogen source

Based on Table 2, effect of N levels was detected only in pod length, which did not achieve significance of the equation parameters in the models tested. Regarding the physiological aspects of seed, the results in Table 3 indicate significant results for the variables indicative of seed vigor, electrical conductivity, first count of germination and germination speed index and indicative of viability, such as germination. The other variables showed no response to the effect of N levels.

Again, the model with the best fit was the quadratic polynomial, for electrical conductivity, first count of germination and germination speed index (Figure 2). The ideal electrical conductivity should have low values, in which the data point to a tendency to increase the loss of solutes from the application of 120 kg N. The maximum level of agronomic efficiency (MLAE) indicated by the equation was 82.64 kg ha^{-1} and EC of 129.77 µS cm^{-1} per gram of seed. In the first count of germination, the equation pointed MLAE of 70.8 kg ha^{-1} with 65.8% germinated seeds. As for the germination, the level of maximum efficiency was 69.7 kg ha^{-1} resulted in a germination of 77.3% seeds. The germination speed index estimates the germination speed of soybean seeds, which, with the optimal level of 69.9 kg ha^{-1} N, showed a value of 7.47.

Urea as nitrogen source

The variables, related to the plants, which had responses to the levels were number of pods and productivity (Table 4). The regression analysis of productivity (PROD) and number of pods (NP) (Figure 3) had adequate fit to the quadratic model. The productivity yield of 2145.99 kg ha^{-1} was achieved at the level of 78.7 kg ha^{-1}. Similarly to that observed for ammonium sulfate, the pod length did not respond to levels of urea applied. This explains the lack of increase in mass of pods and number of seeds per pod. This result is even more evident when analyzing the significant response for number of pods, which reached the maximum of 56 pods per plant at the level of 71.8 kg ha^{-1} (Figure 3B). Comparing the control (0 kg ha^{-1}) with the level of 60 kg N ha^{-1}, it can be seen an increase of almost 20 pods with the application of N, which may have contributed to the increase in seed yield. The analysis of physiological quality variables (Table 5) showed significance for the first count of germination, germination speed index and root dry mass. All quality variables that pointed response to the levels applied indicated a quadratic fit model with coefficient of determination around 60% (Figure 4). The maximum level of efficiency indicated for the first count (FCG) was 56.47 kg ha^{-1} and 66.19 percentage of germinated seeds. For germination, this level was 65.13 kg ha^{-1} at a total of 78.98% seeds. For the germination speed index (GSI), the efficiency level was 63.11 kg ha^{-1} with an index 7.55. The results from the germination test had a good fit, with low variation, which demonstrates the reliability of these data. This response may be associated with higher rate of enzymes in the seeds, which favor the germination process. These results show that late N application enables obtaining soybean seeds with higher physiological potential. The dry weight of seedling roots reached a MLAE of 69.0 kg ha^{-1} with mass of 0.009 g seedling^{-1}. With the acceleration of seed germination and increase in seed germination, it was expected a significance in the dry mass of roots, since the initial establishment of the seedling depends on a good development of the first roots.

Economic viability for seed production

The economic analysis was performed to evaluate the economic viability of the sources and levels tested. The results of significance of the regression, the parameters and the coefficient of determination for this function are in Table 6, for both sources. With the equation, it was possible to calculate the production stages 2 and 3 (Table 6), to define the limits of rationalization of input use and define the optimal level to achieve the highest productivity. With the use of urea, the optimal level obtained was 85.2 kg ha^{-1} N, with optimum productivity of 91.25bags ha^{-1}. In the case of ammonium sulfate, the optimal level was 78.4 kg ha^{-1} N, with optimal productivity corresponding to 79.27 bags ha^{-1}. The total physical product (TPP), average physical product (APP) and the marginal physical product (MPP) were calculated from the production function, for both sources of fertilizer. Further, the total revenue and total cost for the maximization of profits were generated. As expected behavior of the response to the application of fertilizers. In this case, it is considered both the price of the product marketed as the price of the fertilizer. It is observed that with addition of inputs, net revenue tends to grow to the point of maximum utilization of fertilizer and then declines. This behavior is explained by the law of diminishing marginal returns (Serrano, 2002). The MPP indicates the growth rate of total physical product. When equals to zero, it indicates that from that point, the application of higher levels of fertilizer will no longer be reversed in profit. At that point, profit is maximized. This point coincides with the optimal level defined in the calculation of production stages (Table 6). The limit between stages 2 and 3 is the rationalization zone of input use in the production of seeds. The application of urea, which maximizes production profits, using 85.9 kg ha^{-1}N, generates a net income of US$ 932.83 per hectare to the producer. The application of ammonium sulfate, which maximizes profits, using 74.8 kg ha^{-1}N, generates a net income of US$ 731.33ha^{-1} produced. The production risk analysis (Figure 5) provides, with a 10% error margin, a net income between US$ 634 and US$ 865, for urea, and from US$ 630.12 to US$ 825.76, for ammonium sulfate. From this perspective, it is assumed that the risk of production of soybean seeds, under the management of late nitrogen fertilization, is lower with the use of urea, this because the profitability with the application of urea is higher, with 90% confidence probability.

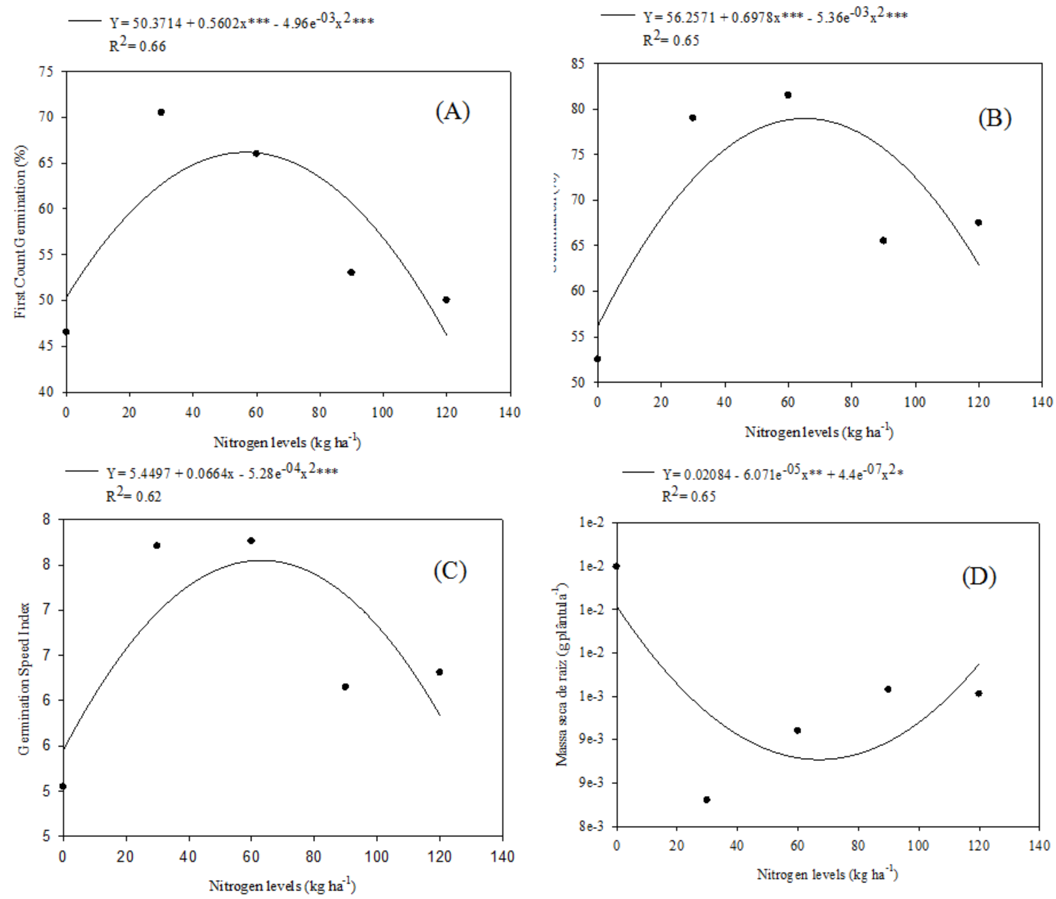

Figure 4. Regression analysis using the quadratic polynomial model of first count of germination (A), germination (B), germination speed index (C) and root dry weight (D) with urea as nitrogen source

Table 1. Soil chemical analysis of the experimental area, southernPiauístate, Brazil – 2016

depth	**OM**	**pH**	**P**	**S**	**K**	**Ca**	**Mg**	**Al**	**H+Al**
m	g.dm^{-3}	($CaCl_2$)	-----mg dm^{-3} -----			----------- mmol$_c$.dm^{-3} ----------			
0 - 10	26.50	4.60	4.61	6.20	2.19	33.59	10.11	1.00	49.00
10 - 20	19.58	3.84	13.91	18.95	0.98	6.70	2.41	8.50	52.64
	SB	CEC	V	M	Fe	Mn	Cu	Zn	
	---- mmol$_c$.dm^{-3} ---		----- % ------		--------------mg dm^{-3} --------------				
0 - 10	45.89	94.87	48.25	2.94	102.83	8.49	0.56	4.54	
10 - 20	10.09	62.72	14.93	50.73	108.66	1.89	0.09	1.09	

Legend^2: OM: organic matter; pH: potential of hydrogen, P: phosphorus, S: sulfur, K: potassium, Ca: calcium, Mg: magnesium, Al: aluminum, H+Al: potential acidity, SB: sum of bases, CEC: cation exchange capacity, V: base saturation, m: aluminum saturation, Fe: iron, Mn: manganese, Cu: copper, Zn: zinc.

Table 2. Summary of analysis of variance for all the experimental variables with increasing levels of ammonium sulfate

Meansquare						
SV	DF	Cl_a	Cl_b	Cl_{total}	PL	SDW
Level	4	1.93^{ns}	1.17^{ns}	4.81^{ns}	4.42*	6.21^{ns}
Block	3	6.92^{ns}	0.94^{ns}	12.39^{ns}	5.16*	9.67^{ns}
Residual	12	2.35	0.46	3.59	1.25	6.07
CV (%)		3.27	5.79	3.23	2.71	25.93
	DF	PDW	NP	NPUT	TSW	PROD
Level	4	14.38^{ns}	195.37^{ns}	14.92^{ns}	25.49^{ns}	480124^{ns}
Block	3	1.65^{ns}	111.77^{ns}	53.20^{ns}	24.02^{ns}	152859^{ns}
Residual	12	21.70	273.17	39.33	14.90	234430
CV (%)		35.59	32.05	34.64	3.85	29.85

*Legend^2: Cl_a=chlorophyll-a, CL_b= chlorophyll-b, CLtotal= total chlorophyll, PL=pod length, SDW=stem dry weight, PDW=pod dry weight, NP=number of pods, NPUT=number of pods in the upper third, TSW=thousand seed weight, PROD=productivity, SV=source of variation, DF=degrees of freedom. Legend^3: CV=coefficient of variation. Legend^4: ns=non- significant, *= significant at 5% probability, ***= significant at 0.1% probability.*

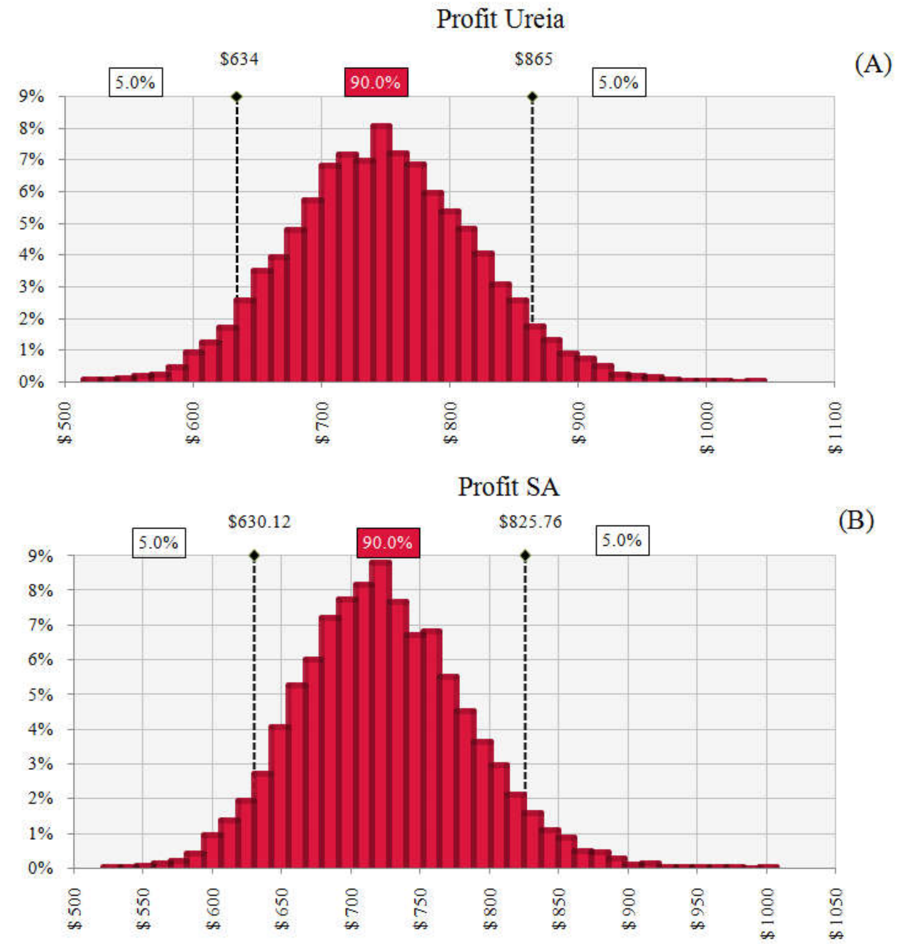

Figure 5. Probability distribution of net revenue, with a margin of 90% confidence of the result, with maximum, minimum, mean and standard deviation values, with *n* of 10,000 samples for testing with urea (A) and ammonium sulfate (B)

Table 3. Summary of analysis of variance for the variables analyzed from laboratory tests, of the experimental variables with ammonium sulfate conducted in the laboratory

Mean square					
SV	DF	SL	EC	FCG	G
Level	4	1.4268^{ns}	3668.1***	266.0**	382.3***
Residual	15	1.8766	460.9	44.8	23.0
CV (%)		4.32	14.31	11.54	6.98
SV	DF	GSI	SDW	RDW	
Level	4	3.5620***	0.0000766^{ns}	0.00000267^{ns}	
Residual	15	0.2361	0.0000893	0.00000161	
CV (%)		7.34	16.02	13.45	

*Legend[2]: SL=seedling length, LE=electrical conductivity, FCG=first count of germination, G= germination, GSI= germination speed index, SDW=shoot dry weight, RDW=root dry weight, SV=source of variation, DF=degrees of freedom.Legend[3]: CV= coefficient of variation. Legend[4]:ns= non- significant; **= significant at 1% probability, ***= significant at 0.1% probability.*

Table 4. Summary of analysis of variance for the variables analyzed from tests in the field, of experimental variables with urea

Mean square						
SV	DF	Cl_a	Cl_b	Cl_{total}	PL	SDW
Level	4	2.6344^{ns}	0.27803^{ns}	3.6937^{ns}	10.7397*	5.2580^{ns}
Block	3	11.4768*	0.91496^{ns}	10.0094*	2.7382^{ns}	1.8453^{ns}
Residual	12	2.2614	0.31661	2.5615	2.2280	5.0853
CV (%)		3.23	4.76	2.74	3.61	24.2
	DF	PDW	NP	NPUT	TSW	PROD
Level	4	31.888^{ns}	269.154*	19.203^{ns}	16.4262^{ns}	2625367***
Block	3	0.437^{ns}	12.964^{ns}	2.983^{ns}	5.1967^{ns}	38491^{ns}
Residual	12	19.371	53.996	40.115	13.5598	67283
CV (%)		32.08	15.28	34.29	3.67	13.89

*Legenda[2]: Cl_a= chlorophyll-a, CL_b= chlorophyll-b, CLtotal= total chlorophyll, PL= pod length, SDW= stem dry weight, PDW=pod dry weight, NP=number of pods, NPUT=number of pods in the upper third, TSW=thousand seed weight, PROD=productivity; SV=source of variation, DF=degrees of freedom. Legend[3]: CV= coefficient of variation. Legend[4]: NS: non- significant; *= significant at 5% probability, ***= significant at 0.1% probability.*

Table 5. Summary of analysis of variance for the variables analyzed from laboratory tests, of the experimental variables with urea, conducted in the laboratory

Mean square					
SV	DF	SL	EC	FCG	G
Level	4	3.9122^{ns}	1744.6^{ns}	438.3***	542.80***
Residual	15	2.0568	1133.8	50.8	53.33
C.V.(%)		4.6	18.45	12.46	10.55
SV	DF	GSI	SDW	RDW	
Level	4	5.2668***	0.0000435^{ns}	0.00000430*	
Residual	15	0.4798	0.0000690	0.00000105	
CV (%)		10.5	13.1	10.73	

*Legen^2: SL=seedling length, EC=electrical conductivity, FCG=first count of germination, G= germination, GSI= germination speed index, SDW=shoot dry weight, RDW=root dry weight, SV=source of variation, DF=degrees of freedom.Legend^3: CV= coefficient of variation. Legend^4:ns= non- significant; *= significant at 5% probability, ***= significant at 0.1% probability.*

Table 6. Summary of regression analysis of variance, production equation parameters and coefficient of determination

Regressionanalysisofvariance					
		Meansquare			
	DF	Urea		Ammonium sulfate	
Explained	3	6314883.146***		3022275.029***	
Non-explained	49996	311.393		406.937	
		Regression			
		Urea		Ammonium sulfate	
		Parameters	Standard error	Parameters	Standard error
	Coefficient	46.03708***	0.17519833	37.2681***	0.200280646
	cx	0.92589***	0.014856223	0.9415***	0.016983118
	bx^2	0.04085***	0.000314412	0.00475***	0.000359425
	ax^3	0.000273***	1.7223E-06	1.2695e-05***	1.96888E-06
	R^2	0.5489		0.3083	

*Legend^2: DF=degrees of freedom. Legend^3: R^2=coefficient of determination. Legend^4: ***=significant at 0.1% probability.*

DISCUSSION

Ammonium sulfate as nitrogen source

At the reproductive development stage, the main sinks are the fruits, the import of carbohydrates, amino acids and other materials (Lacerda, 2016). This explains the inefficiency of fertilization, made as top dressing, at the vegetative development of the crop. Nitrogen fertilization, for this experiment, had a negative effect on pod formation and, consequently, the final yield of the crop. Furthermore, in terms of productivity, water stress, especially after application of the fertilizer (Figure 1), may explain the lack of response to different levels of ammonium sulfate applied, since the soybean plants require high rainfall and high temperatures during the final developmental stage, especially from pod formation to grain filling (Divito, 2015). Although the effect of levels has been positive for the EC variable, these values were higher than expected for lots of high vigor soybean seeds. Even under these circumstances, it is believed that the late addition of N, between the R4 and R5 stages, possibly incorporated integral proteins in the phospholipid complex of the cell membrane (Taiz, 2009), during the grain filling process, which lowered the leaching of solutes by the seeds. The degradation of the cell membrane by the action of free radicals is one of the most accepted theories about the deterioration of seeds (Lacerda, 2016), which is closely linked to the storage potential of seeds. In the case of ammonium sulfate, the aspects of physiological quality were substantially favored by N levels in the seeds, even without mass increase in grains. Once soybean seeds contain about 40% protein (Moraes, 2006), both structural (components of membranes) and in the form of amino acids accumulated in reserve tissue and enzymes (Taiz, 2009), the positive results with respect to N are evident through these analyses. Whereas methionine and cysteine are limiting amino acids in soy protein (Moraes, 2006) and that these amino acids are composed of sulfur, it is considered that possibly the physiological response of seeds was also due to the formation of this type of amine group. Although soybean contains a large proportion of protein, seeds are deficient in amino acids with sulfur in their composition. A high ratio between glycine (11S) and β-conglycinin (7S) can indicate an increase in sulfur-containing amino acids, 11S and 7S, and different genes that decode these proteins are important in the physiological quality of seeds (Ma, 2016).

Urea as nitrogen source

The effect of water stress (Figure 1), with rainfall between 0-8 mm in the application period (at 80 days after sowing) and after, may have influenced these results, considering that, during the final phase of seed development, nitrogen redistribution process is accelerated in vegetative tissues, under these conditions. Moreover, at this phase, it shortens the grain filling period, affecting the yield and viability of soybean seeds. Nevertheless, under conditions of water stress in which the plant has a good reserve or supply of N, in late cycle genotypes, it may occur a decrease in protein remobilization, which facilitates recovery of plants after the drought during the end of the grain formation period (Mastrodominico, 2013). In bean cultivation in soil under conventional tillage, Farinelli *et al.* (Farinelli, 2006) observed that the germination values related to fertilization fitted to a linear function, causing an increase in the percentage of normal seedlings germinated with the addition of N. Under specific conditions, urea can react with water in the soil, and form ammonia, a gas easily volatilized to atmosphere (Rojas, 2012). In soils with low pH and low moisture, the activity of urease, responsible for the hydrolysis of urea (Pereira, 2008) is not significant, which prevents loss of N in the soil-atmosphere system, by means of ammonia volatilization. This enzyme shows maximum activity at pH between 6.5 and 9.0 (Lara Cabezas, 2007), and the soil analysis presents values lower than 5. N of urea reacts in two ways in the soil, by hydrolysis and nitrification, until reaching the form of nitrate (Neiverth, 2013), Plants grown in tropical conditions prefer nitrate as the form of acquisition of N from the soil (Marschner, 1995). In this way, by observing the higher efficiency of urea fertilizer, under the conditions of the experiment, in relation to ammonium sulfate, understanding the soil and climate conditions of the cultivation area is essential for the maintenance of soybean productivity. From this perspective, the management of nitrogen fertilization is an important premise to be followed in soybean production, particularly when using high technological level.

Economic viability for seed production

This result is expected as productivity analysis, without taking into account the prices of input and product also showed a significant response for the use of urea, compared to ammonium sulfate. This difference is due both to the increase in seed production in volume, and in the germination rate, which is higher with the managed use of fertilizers. Moreover, the cost of N of urea is relatively lower than the cost of ammonium sulfate. N is absorbed by roots in two forms, nitrate (NO_3^-) and ammonium (NH_4^+), and nitrate is the most available form in aerated soils, where nitrification is not inhibited, in which the choice of the source of nitrogen fertilizer is defined by environmental conditions, such as soil conditions and availability of the two forms (Jadoski, 2010), As explained in the previous section, urea may react in the soil, producing nitrate (NO_3^-) or ammonia (NH_3^+). Despite the energy demand for the use of nitrate, growth of plants is best when supplied with NO_3^- (Barker, 1980), which may explain why urea is the most indicated for management with late nitrogen fertilization. Furthermore, Xiao-Jun Tang *et al.* (Xiau-Tang, 2009), found large surplus of N in the form of nitrate in the soil profile, which helps in indicating that this compound is mostly absorbed at higher rates, compared to others.

Conclusion

It can be concluded that the late nitrogen fertilization, applied between the reproductive stages R4 and R5, favored the production of seeds, from the productive, physiological and economic point of view. The most efficient use with lower operational risk was achieved using urea as nitrogen fertilizer.

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