

Evaluation of the residual nitrogen effect liberated by the soybean straw on the maize yield in the second crop

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Abstract

The objective of this study was to evaluate the effect of Nitrogen (N) liberated by the early soybean straw, inoculated in function of dosage and application means of the inoculant, over the vegetative growth and grain yield of second crop corn, in succession. The hybrid corn Land® was sowed in January 1st, 2017 over the soybean straw from a former experiment in Sinop (MT). The trial design used was randomized blocks (DBC) with four replications and ten treatments. For the soybean treatments: witness without N application (only inoculated with *Bradyrhizobium japonicum* and *B. elkanii*); for the other treatments, it has been applied the dosage of 10 kg ha⁻¹ of N in different phenological stages and ways of application (by haul at sowing; in V2 by haul and leaf fertilization; in V4 by haul and leaf fertilization; in R1 by haul and leaf fertilization; in R2 by haul and leaf fertilization). Plant height, stalk diameter, total chlorophyll and grain yield were evaluated. The N mineralization from the soybean straw is not enough to fulfill the corn N demand. Even though there were no significant differences among the treatments, the N application in V2 and R1 stages, by topdressing on former soybean, provided the highest grain yield of corn.

Keywords: Zea mays L. Nitrogen demand. Vegetative growth. Soybean straw.

Introduction

The corn (*Zea mays* L.) is one of the most important cultivated and consumed cereals in the world, this is due to its productive potential, nutritive value and uses, in both human and animal feed. In Brazil, in the 2016/2017 crop, about 96 million tons of corn were produced, after the United States of America (USA) and China, which produced approximately 384.8 and 219.6 million tons, respectively. In Brazil, the second corn crop of 2017 produced almost 61 million tons, about 60% of the total corn production in the country (CONAB, 2015).

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Second harvest corn, after soybean crop, allows intensive use of soil, better workforce and machinery utilization, rotation/succession of leguminous plants with grasses, maintenance/increase of soil organic matter, as well as nutrient release from straw, mainly Nitrogen (N) (BASTOS et al., 2008).

In Brazil, the use of cover crops and rotation aims the no tillage sustainability and it is necessary to consider the usage of residual N from soybean straw, in N fertilization of the second corn, successively cultivated, through vegetal straw decomposition. The establishment of cover crops for formation and maintenance of cultural straws in soil surface, mainly in Cerrado regions, have been showing some obstacles because the climate conditions in these regions favor decomposition of vegetable residues. Usually, this decomposition is controlled mainly by the C/N relation, lignin level, and management, which will define the size of fragments and climate action, especially air temperature and precipitation (TORRES et al., 2005).

Amongst the existing nutrients in the soybean straw and that can be used by corn, N can be cited, which is the most required by both cultures. The corn crop responds to high rates of this nutrient, being recommended the use of cover plants, like crotalaria and crotalaria + millet as predecessors associated to the application of 120 kg ha⁻¹ in topdressing, what increases production costs (KAPPES et al., 2013).

This way, in decisions taking the usage of N fertilization must be considered: the cultivation system (no tillage system), sowing period (second crop), culture rotation and N sources, among others, highlighting the recommendations of N must be specific and not generalized (CHAGAS et al., 2007).

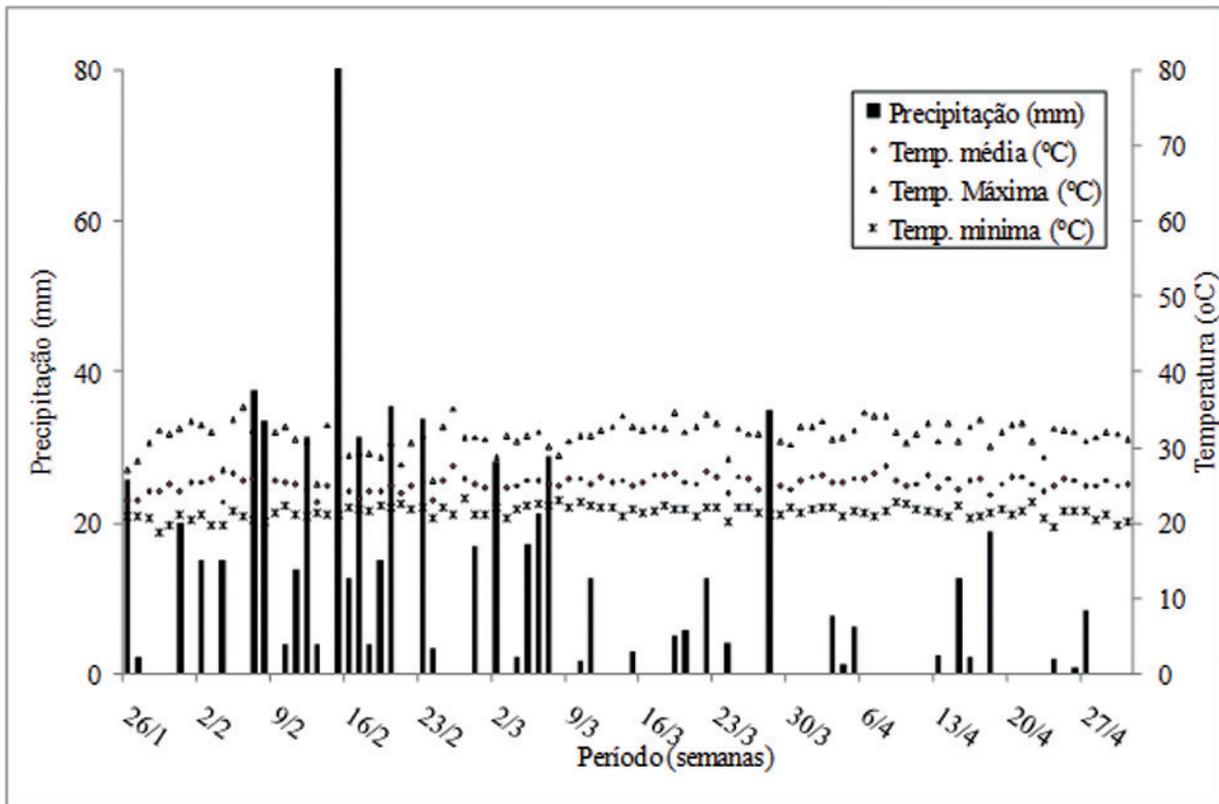
In the face of what was exposed, this study aimed to verify the effect of N released by the early soybean straw, inoculated in function of dosage and application means of the inoculant, over the vegetative growth and grain yield of second crop corn, in succession.

Material and methods

The experiment was carried out in a commercial area cultivated in minimum tillage system for more than five years, from February to July 2017, in the city of Sinop (MT). The place of the experiment is located at Latitude 11°57'05" S and Longitude 55° 23'51" W and average altitude of 380 m with flat topography. The climate, according to Koppen-Geiger, is classified as Aw, having two well-defined seasons, a rainy season between October and April, and another drought from May to September, with low annual temperature ranges from 24 to 27°C, the average annual rainfall is around 2.100 mm (GARCIA et al., 2013).

Climatological data of the conduction period of the experiment, between 01/26/17 and 04/27/17, are presented in Figure 1.

Figure 1 - Rainfall (mm), minimum average and maximum temperatures (°C) per week during the experiment period, 2016/2017, Sinop (MT).



Source: Elaborated by the authors (2017).

Soil was collected six months before sowing of soybean with the aid of a Dutch auger in the layer of 0 to 20 cm deep, and subsequent chemical analysis of the soil in laboratory. The chemical analysis of the soil obtained the following results: pH (CaCl₂) 5.1; M.O. ; 18.55 g dm⁻³; P (Melich); 6.07; K, 52.00 mg dm⁻³; Here; 2.84; Mg; 0.93; S; 0.40; Al; 00; H; 2.92; CTC pH 7.0; 6.82 cmol dm⁻³; V (%) = 57.2; Ca / Mg ratio; 3.05; Ca / K; 21.85; Mg / K; 7.16. The micronutrient values in mg dm⁻³ were: Zn; 5.51; Ass; 0.44; Faith; 199.16; Mn; 11.25; B; 0.15. The physical analysis of the soil obtained the values: Sand; 497; Silt; 125; Clay; 378, in g dm⁻³, respectively.

Soil analysis results showed the base saturation is in accordance with the crop demand. Liming was not necessary; in pre planting, the fertilization was haul made with 500 kg ha⁻¹ from the formulated 00:18:18, according to the farmer's management, supplying phosphorus and potassium to soybean. The soil of the region is classified as Red Yellow Latosol (SANTOS et al., 2013).

The experimental design was randomized block design (DBC), with four replications and ten treatments, totaling 40 plots. The treatments were: control without N application (only inoculated with *Bradyrhizobium japonicum* and *B. elkanii*). For the other treatments, the dose of 10 kg ha⁻¹ of N (Urea 45% N) was applied, corresponding to 22.5 kg ha⁻¹ of urea, at different times (phenological stages) and methods of application: by haul at sowing; in V2 by haul and leaf fertilization; in V4 by haul and leaf fertilization; in R1 by haul and leaf fertilization; in R2 by haul and leaf fertilization.

The experimental plots consisted of four rows and five meters length, totaling 10 m². We considered the useful area of the plot the two central rows and four meters length, totaling 4 m². As border, we discarded half meter in each edge of the portions and the two lateral lines (borders).

The cultivated soybean, previously to the corn, was the TMG 132 RR, at the density of 15 seeds by meter, aiming to obtain an average population of 260 thousand plants ha⁻¹. Before the sowing of soybean, we carried out the treatment of seeds (TS) applying the insecticides based on Fipronil of the pyrazole group and the fungicides benzimidazoles, in the dose of 2 mL kg⁻¹ of seed. We also applied the micronutrients cobalt and molybdenum, in the proportion of 5g of Co and 42 g of Mo to increase the efficiency of the nodulation (ALMEIDA, 2011). We also conducted, before the sowing, the inoculation of seeds with a peat inoculant for soybean, *Bradyrhizobium japonicum*, class SEMIA, 5079 and 5080, minimum concentration of rhizobacteria of 7 x 10⁹ cells/g, dose of 200g ha⁻¹, and in liquid form, dose 200 mL ha⁻¹ with the concentration of rhizobacteria of 5 x 10⁹ cell/mL, of *Bradyrhizobium elkanii*, class SEMIA 587 and 5019. The mixture was made in polyethene bags until the complete mixture of the inoculant into the seed.

The crop management followed the recommendations and was held by the farmer under the demands of the soybean. To control the rust, it was carried out four applications of fungicide of the chemical group (Estribirulina and Triazole) and (trifloxystrobin and Propiconazole); with the second application of fungicide, we applied the micronutrients Mn and Mo foliar.

Before the sowing, we hold the drying out of the weeds with the application of 1,5 kg ha⁻¹ of glyphosate (granular) and in post-emergency at 30 DAE we applied more 1,5 kg ha⁻¹ of glyphosate, with the volume of 100 L ha⁻¹, with the aid of a bar sprayer tractor-processed. The weed control was carried out within the recommended period, from the germination to thirty days after sowing, period considered of critical competition between the crop and the weeds.

The corn hybrid Land® spacing 0.45 m between rows and population of 60 thousand plants ha⁻¹ was sowed over the plots of the experiment of forms of fertilization with N in soybean on January 26, 2017 with the no till sower coupled to the subsequent tractor and on the same day after the soybean harvest, in order to evaluate the residual of mineral N from the treatments on soybean. In the sowing fertilization, it was used the dose of 40 kg ha⁻¹ of N; 98,4 kg ha⁻¹ of P₂O₅, and 52.5 kg ha⁻¹ K₂O according to the results from the soil analysis and the expectation of good performance conforming to Souza and Lobato (2004). The N application on topdressing in the level of 30 kg ha⁻¹ was held at the stage of four expanded leaves of corn with urea (45% N) and incorporated at 5 cm depth.

The evaluations of the corn hybrid began at full flowering (R2) and we assessed the levels of total chlorophyll, the height of plants and the stalk diameter, using the measurements of six plants by each useful plot. For the evaluation of chlorophyll level, we used a chlorophyll measurer of the brand ClorofiLOG (type CFL-1030) which estimates the level of chlorophyll in indirect form, by means of indirect readings of unities, which estimates with good accuracy the level of chlorophyll on leaves, being an efficient parameter for the follow-up N levels. The readings performed by the chlorophyll measurer shows proportional levels of chlorophyll on leaves and are calculated based on the amount of light transferred and absorbed through the leave in two wavelengths with different chlorophyll absorption (ARGENTA et al., 2001). We assessed six randomized plants in each useful plot, at the full flowering stage, measuring them in the superior leaf opposed to the main ear at the sixtieth day upon the corn germination.

We obtained the plants' height with the aid of a measuring tape applied to the six plants from the soil level to the last expanded leaf of the corn (leaf flag). The diameter of the stalk was identified close to the soil in the first node visible above the ground. The harvest was carried out manually on

June 15th, 2017, when we threshed the ears with the aid of a manual thresher. We quantified the grain yield by weighting the useful grains for each plot in the Fillizola precision scale and subsequently by adjusting the moisture to 13%, then we defined grain yield converted into kg ha^{-1} .

We submitted the data to analysis of variance (ANOVA), at the level of 5% of probability by the F test, with the aid of the statistical software SISVAR (FERREIRA, 2011). The means were compared by F Test at 5% probability.

Results and discussion

According to the analysis of variance (TABLE 1), the treatments with the N fertilization at different stages of soybean (before the succession of the second corn) did not present effect of any residual N on the traits of the total chlorophyll, nor the plant height or the stalk diameter and grain yield.

Table 1. Average of the analyzed characteristics on the second corn: total level of chlorophyll (CLO), plant height (PH), stalk diameter (SD), and grain yield (GY) after different forms and stages of application of 10 kg ha^{-1} of N in soybean. UFMT. 2016/2017 crop. Sinop (MT).

Treatments	CLO (SPAD)	PH (m)	SD (mm)	GY (kg ha^{-1})
Without N	66.25 a	1.89 a	17.50 a	5,224 a
N sowing	56.25 a	1.80 a	16.25 a	5,858 a
N V2 haul	57.50 a	1.82 a	17.00 a	7,019 a
N V2 leaf	60.25 a	1.84 a	18.00 a	7,299 a
N V4 haul	59.75 a	1.81 a	17.00 a	6,598 a
N V4 leaf	64.25 a	1.79 a	17.50 a	5,678 a
N R1 haul	63.00 a	1.91 a	16.75 a	6,912 a
N R1 leaf	62.00 a	1.86 a	18.00 a	7,491 a
N R2 haul	63.00 a	1.83 a	17.25 a	5,904 a
N R2 leaf	64.75 a	1.89 a	18.50 a	5,924 a
Average	61.70	1.84	17.37	6,391
C.V.(%)	10.93	3.62	5.05	19.95

The means followed by the same letter are not different from each other regarding the 5% of probability by the F test.

Source: Elaborated by the authors (2017).

For the chlorophyll index, the application of N on the different treatments did not modify the values and keep equal to the witness. The values of the chlorophyll readings at the flowering stage obtained in this study varied from 65.25 to 78.75 and are similar to those obtained by other authors in the corn (ARGENTA et al., 2001; AMARAL FILHO et al, 2005; FIORINI et al, 2017). Silveira and Damasceno (2003), working with the common bean, reported that the application of N by haul at topdressing did not modify the chlorophyll indexes among the treatments with N and the witness. According to such authors, probably the N absorbed by plants would be redistributed to the production of vegetative, reproductive structures and the nutrients accumulation would be transferred to the grains. This fact could have happened in the present study.

For the variable plant height, no significant effect was detected on the tested treatments and the values obtained varied from 1.79 to 1.91m. Such an event also happened on the stalk diameter, in which the values varied from 16.25 to 18.50mm with no statistical differences among the treatments. The absence of response regarding the plant height supports the statement of Valderrama et al. (2011), who evaluated the application of 0, 40, 80, and 120 kg ha of N in the form of urea for the same corn hybrid and did not observe any difference in the mentioned variable. Probably the residual soybean fertilization, with the application of only 10 kg ha⁻¹ of N, was not enough to get responses on the vegetative features of the corn growth and the total amount of chlorophyll.

For grain yield, we verified that, even though the fertilization treatments with N on soybean obtained higher values in such variable, in comparison to the witness without N, there were no significant differences among such treatments varying from 5,224.0 (witness) to 7,491.0 kg ha⁻¹, with an average of 6,390.7 kg ha⁻¹. Such values are considerably high for the region in which the experiment was carried out considering the climate conditions and the average yield of second corn in Brazil (CONAB, 2015). The results of various researches in Brazil show that the second corn has higher yield potential than 6.000 kg ha⁻¹, either cultivated in succession of soybean or not (DUARTE, 2013; SICHOKI et al., 2014; SILVA et al., 2015; FIORINI et al., 2015).

These high grain yield values of the corn are explained by the high capacity of the soil in providing plants with N, as well as by the adequate climate conditions during the crop cycle with good precipitations during the critical period of grain filling (AMARAL FILHO et al., 2005). The soil of the experimental area had good fertility conditions with good levels of nutrients and with the sowing and topdressing fertilization, besides the residual N arising from the soybean straw was not a limiting factor to the productivity of the second corn. According to Ritchie et al. (2003), at the moment of eggs number definition and the size of the ear (V12 stage), the lack of moisture and nutrients may reduce severely the potential number of grains and the size of the ears harvested, which explains the smaller length of the ears and lower yield of the second corn in comparison to the first crop ones.

Despite the inexistence of significant differences, the N application on soybean at the V2 and R1 stages, both by leaf or haul fertilization in topdressing, provided higher grain yield in the second corn. The results of this work supported the ones obtained by Souza et al. (2003), which also did not have any response on the corn yield to the application from 0 to 120 kg ha⁻¹ of N.

Nevertheless, Rezende et al. (2003) apud Amaral Filho et al. (2005) observed that the increase on grain yield, both for the row spacing or for the better density of plants, depended on the climate conditions in the agricultural year. He spaced the rows of 0.80 m with a population density of 40,000 plants ha⁻¹ without N fertilization and obtained the lowest grain yield on his study (6,048 kg ha⁻¹).

Caione et al. (2016) observed that the maximum yield of corn occurred with the application of 180 kg ha⁻¹ of N. In a study of N fertilization for corn, Araújo et al. (2004) verified an increase of 28% on the grain yield and 37% on the dry matter in comparison to the non-application of N, with the highest responses reached at the dose of 240 kg ha⁻¹.

Probably, the low doses of mineral N generated by the forms and ways of the N fertilization of soybean and the release of N by its straw, in addition to the low doses of N employed in the fertilization of the second corn, were not enough to cause responses on the second corn. Fornasieri Filho (1992) apud Amaral Filho et al. (2005) reported that in soils with adequate availability of organic matter and under the favorable occurrence of rain precipitation, the effects of N fertilization are, as a rule, barely apparent. We still need further research on the effects of residual N from soybean on the

second corn in different places, climate conditions, type of soils with different varieties and doses of N in the previous soybean.

Conclusions

The application of the N fertilization with 10 kg ha⁻¹, under the different ways studied here in the previous soybean crop, was not enough to increase the plant height, stalk diameter, total chlorophyll and grain yield of the second corn.

Despite the non-occurrence of significant differences, the application of N on topdressing in soybean at the V2 and R1 stages provided the highest values of grain yield on the second corn.

Avaliação do efeito residual do nitrogênio liberado pelos restos culturais da soja na produtividade do milho segunda safra

Resumo

Objetivou-se verificar o efeito de nitrogênio (N) liberado pela palhada da soja precoce inoculada em função de doses e formas de aplicação do inoculante sobre o crescimento vegetativo e a produtividade de grãos da cultura do milho segunda safra em sucessão. A semeadura do milho híbrido Land® ocorreu em 26 de janeiro de 2017 sobre a palhada de um experimento de soja em Sinop (MT). O delineamento experimental utilizado foi em blocos casualizados (DBC), com quatro repetições e dez tratamentos. Para os tratamentos na soja: testemunha sem aplicação de N (apenas inoculada com *Bradyrhizobium japonicum* e *B. elkanii*) e para os demais tratamentos foi aplicada a dose de 10 kg ha⁻¹ de N em diferentes estádios fenológicos e modos de aplicação (a lanço em cobertura na semeadura; em V2 a lanço em cobertura; em V2 via foliar; em V4 a lanço em cobertura; em V4 via foliar; em R1 a lanço em cobertura; em R1 via foliar; em R2 a lanço em cobertura e em R2 via foliar). Foram avaliados: altura de plantas, diâmetro de colmo, clorofila total e produtividade de grãos. A mineralização do nitrogênio dos restos culturais da soja não é suficiente para atender à demanda de N do milho. A aplicação de nitrogênio nos estádios V2 e R1 em cobertura na cultura antecessora da soja proporcionou os maiores valores de produtividade de grãos ao milho.

Palavras-chave: *Zea mays* L. Demanda de nitrogênio. Crescimento vegetativo. Palhada da soja.

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