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Corn Agronomic Attributes in Succession of Leguminous Cover Crops and Nitrogen Doses

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Abstract

This study aimed to determine the dry biomass and nitrogen accumulation, the height and stem diameter of corn crop preceded by different leguminous cover crops, under different nitrogen doses. The study was conducted in the experimental area of Federal Technology University of Paraná, in Dois Vizinhos. The eigth cover crops consisted on: Sunn hemp; Crotalaria spectabilis; Jackbean; Cajanus cajan; Dolichos lablab; Velvet beans; Black velvet beans and Spontaneous species. The two dose nitrogen fertilization included: zero kg N ha^{-1}; 180 kg N ha^{-1} applied in a single dose, under conditions of adequate humidity, 47 days after corn seeding. Were evaluated the height, dry biomass and basal stem diameter corn and the decomposition and release of N from the cover plants. The use of leguminous before corn crop is a good option for the southwest region of Paraná because it promotes soil protection

and can promote increased carbon stock in the environment. The leguminous cover crop should be used like green manure, making them important species in the Brazilian agriculture sustainability context, once there are evidence of reducing or even not using mineral nitrogen fertilization in the subsequent agricultural crops, mainly the Jackbean.

Keywords: dry biomass, stem diameter, nitrogen accumulation, cover rate

1. Introduction

Brazil is the third largest corn producer in the world, yielding 82.9 million Ton in the 2017/2018 harvest and covering 16.7 million ha (SEAB/DERAL, 2020). The State of Paraná stands out as the second largest national producer of the grain, yielding 16.7 million Ton in the 2019/2020 harvest, in a cultivated area of 2.6 million hectares and average yield of 6 Mg ha^{-1} (CONAB, 2019).

Corn crop in State of Paraná is an example of aggregating the value of agricultural production because it uses part of the grain production in feed for poultry, pig and dairy cattle (Martin et al., 2011). Thus, corn cropping also becomes essential for the subsistence of family farmers, since about 60% of rural establishments produce and consume it on their own property (FEBRAPDP, 2014).

It is emphasized that most of the corn areas in the state of Paraná, just like in the country, are under no-tillage system (FEBRAPDP, 2014) linked to, in general, high nitrogen (N) doses from synthetic fertilizers (Martin et al., 2011). This reality demonstrates that no-tillage has been a fundamental system for Brazilian soil management, because the permanent maintenance of dry biomass in the surface soil, which promote erosion reduction (Pittelkow et al., 2015), and adding more carbon in agroecosystem ensures more robust soil ecosystem function (Vezzani et al. 2018), mainly on tropical soils (Shioga et al., 2016). However, the excessive use of nutrients of chemical origin goes on an opposite direction to the world tendency to establish a more sustainable agriculture, with lower production costs and greater conservation of natural resources (Reis et al., 2014). Therefore, the corn demand for N is very high (Martin et al., 2011), the use of organisms capable of fixing atmospheric N represents an alternative to supply this nutrient required by plants and reduces the synthetic nitrogen fertilizers usage for its production (Reis et al., 2014; Coombs et al., 2017).

Worldwide, the greater contributions of biological N fixation in terrestrial ecosystems come from leguminous plants, which can maintain a positive balance in the reserves of this nutrient soil (Reis et al., 2014). According to Conceição et al. (2005) and Costa et al. (2008), the cropping systems based on the succession or rotation with leguminous cover crops associated with no-tillage practices increase the carbon and nitrogen reserves in the soil, due to its high annual production of vegetal biomass, constituting an efficient strategy on the recovery of N stocks, from the environmental and economic point of view.

Thus, we hypothesize is that the use of leguminous cover crops in cropping systems is sufficient to promote satisfactory agronomic results in corn crop. Finally, this study aimed to determine the dry biomass and N accumulation, the height and stem diameter of corn crop preceded by different leguminous cover crops, under different nitrogen doses.

2. Material and Method

2.1 Location and Characterization of the Experimental Area

The study was conducted at the experimental area of Federal Technology University of Paraná, in Dois Vizinhos (latitude 25º41'S; longitude 53º05'W and 526 m altitude), State of Paraná. According to the Köppen classification, the climate of the region is humid subtropical (Cfa), without dry season defined, according to Alvares et al. (2013).

2.2 Soil Classification

The soil is classified as Oxisol (Rhodic Eutrudox, USA classification), clay textured (773 g kg^{-1}), and before the establishment of the experiment, the area had been cropped under no-tillage since 2010. The chemical characterization of the soil area indicated a pH in $CaCl_2$ of 5.3, SMP index of 6.4, P of 4.3 mg dm^{-3}, K of 0.2 $cmol_c$ dm^{-3}, Ca of 6.0 $cmol_c$ dm^{-3}, Mg of 2.8 $cmol_c$ dm^{-3}, H+Al of 3.8 $cmol_c$ dm^{-3}, CEC of 12.8 $cmol_c$ dm^{-3}, Base saturation of 70 % and MO of 40.8 g kg^{-1} in the 0.00-0.20 m layer (Ziech et al., 2015).

2.2 Experimental Design and Treatments

The experiment was implanted in a randomized block design, with a 8 x 2 split splot (cover crop x nitrogen fertilization), and three replications, totaling 48 plots with the dimensions of 5 x 10 m. The seven cover crops systems and seeding density consisted of: Sunn hemp *(Crotalaria juncea* L.*)* (25 kg ha^{-1}); crotalaria spectabilis *(Crotalaria spectabilis* Roth*)* (12 kg ha^{-1}); jackbean *(Canavalia ensiformes* L.*)* (100 kg ha^{-1}); pigeon pea (*Cajanus cajan* L.*)* (50 kg ha^{-1}); Dolichos Lablab *(Dolichos lablab* L.*)* (50 kg ha^{-1}); velvet beans (*Mucuna deeringiana*) (80 kg ha^{-1}) and black velvet beans *(Mucuna aterrima* L.*)* (60 kg ha^{-1}) and spontaneous species. All species implanted in February 2012/2013 did not was inoculated and not applied basic or cover fertilization.

The corn crop (P32R48) was implanted in September 2012 and 2013, with a population of 75.000 plants ha^{-1}, spaced 0.90 m between rows. The area was desiccated with 1.5 L ha^{-1} of Nicosulfuron 35 days after the seeding. The two dose nitrogen fertilization at corn included: (1) zero Kg N ha^{-1}; (2) 180 Kg N ha^{-1} applied in a single dose, under conditions of adequate humidity, 47 days after corn seeding.

Climatic data on mean air temperature and rainfall were obtained by the INMET meteorological station, installed at the UTFPR Experimental Station, from March 2012 to January 2014 (Figure 1).

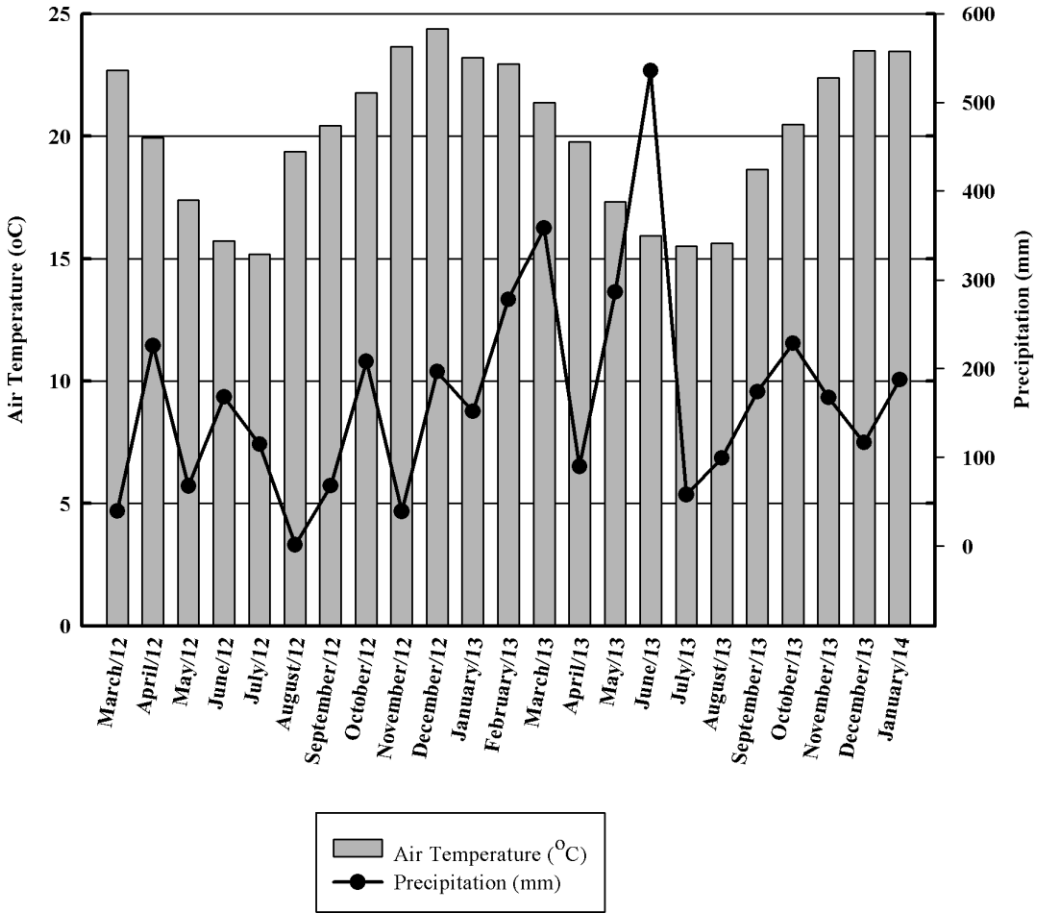

Figure 1. Monthly averages of air temperature and rainfall during March 2012 to January 2014

2.3 Evaluations and Determination

The evaluation of the height and basal stem diameter corn was carried out 82 days after sowing (DAS) in 2012 and 2013. The corn dry biomass was carried out at 102 and 98 DAS in 2012 and 2013 harvest respectively, by collecting 5 random plants in each plot. The plants were dried in a forced air circulation oven at approximately 55 °C for 72 hours, until reaching constant weight and after that, they were weighed, crushed and stored.

The decomposition and release of N from the cover plants was provided, using the decomposition bags. These contained dry plant material, were divided into approximately 10 cm pieces. The amounts of DM in the litters were representative of the DM, per hectare for each cover crop. One of the samples was stored in a dry and protected place (time zero). The leftover was deposited on the soil in each subplot. The quantification of the decomposition rate was performed by loss of mass, in collections of litter bags carried out at regular intervals of time, corresponding to 15; 30; 45; 60; 75; 90 and 120 days. After each collection, the samples were dried in a forced air oven for 48 hours at 60 °C (± 5 °C), weighed and grounded.

In order to evaluate the residual effect of nitrogen fertilization on leguminous development, the soil cover rate of the species in the 2013/2014 harvest was evaluated. The soil cover rate was evaluated through the photographic method (Rizzardi et al., 2004), which consisted on collecting images at 15, 21, 45, 60 and 75 days in an area delimited by a metallic frame of 0.25 m^2, placed on the surface soil at two fixed points of each plot. Afterwards, a grid with 100 points of intersection was inserted on each image and the points coinciding with the coverage plants were quantified. The leguminous dry biomass was determined in two representative points of each plot at 141 days, using a metal frame of 0.25 m^2. The determination of the total nitrogen contents in corn and leguminous biomass was performed by Embrapa (1999).

2.4 Statistical Analysis

The data were subjected to analysis of variance (F test, $p<0.05$). When the effects of the treatments were significant, means were compared by Tukey’s test ($p<0.05$). All data analysis were performed by using the statistical software Assistat v.7.7 Beta (Silva & Azevedo, 2006).

3. Results and Discussion

In the 2012/2013 harvest, no significant difference was observed in corn dry biomass, height and stem diameter when grown in succession to leguminous cover crops, regardless of absence or addition of nitrogen fertilization. However, there was a significant N accumulation in corn dry biomass when it was submitted to a 180 kg N ha^{-1} dose, mainly when the crop was preceded by the vegetable cover compared to spontaneous species (Table 1). Similar result was observed as stated by Amado et al. (2000).

It is important to note that in the plots where no N dose was applied, the N accumulation in the corn biomass was only 10 to 39% lower than the one which received nitrogen fertilization, evidencing the symbiotic association between leguminous and N-fixing native bacteria in the first year of implantation of the species. This result diverges from Vargas et al. (2004), who mentioned that the effectiveness of leguminous nodulation with native bacteria only occurs during successive crops in the area.

The probable synergism among the atmospheric N fixation by leguminous and nitrogen fertilization is more evident in the 2013/2014 harvest, when a significant increase of up to 35% in dry biomass and up to 60% in N accumulation was observed in the treatments that received the dose of 180 kg ha^{-1} (Table 1). These results meets with Weber et al. (2009) and Torres et al. (2014).

Table 1. Corn dry biomass, N accumulation, height and stem diameter after leguminous cover crops, dose of zero (0 N) and 180 kg N ha^{-1} (180 N) in the years 2012 and 2013

Treatments	Dry Biomass ($Mg\ ha^{-1}$)		N Accumulation ($Kg\ ha^{-1}$)		Heigth (m)		Stem Diameter (cm)	
	---------------- 2012/2013 ----------------							
	0 N	180 N	0 N	180 N	0 N	180 N	0 N	180 N
Sunn hemp	8.3	8.4	85.1	125.1	1.6	1.6	1.9	1.9
Crotalaria spectabilis	7.1	7.9	84.9	110.0	1.6	1.8	1.9	2.2
Jackbean	8.9	8.5	96.9	118.0	1.6	1.6	2.0	1.9
Pigeon pea	10.3	10.6	105.9	145.9	1.4	1.5	1.8	1.8
Dolichos Lablab	7.9	7.8	71.5	116.8	1.6	1.5	1.9	2.0
Velvet beans	9.4	7.8	102.8	114.5	1.5	1.6	1.9	1.9
Black velvet beans	10.0	11.7	100.8	152.3	1.6	1.7	1.9	2.0
Spontaneous species	8.3	8.2	77.8	79.3	1.4	1.4	1.8	1.8
Mean	8.8 ^{ns}	8.9 ^{ns}	90.6 B	122.7 A	1.5 ^{ns}	1.6^{ns}	1.9 ^{ns}	1.9 ^{ns}
	---------------- 2013/2014 ----------------							
Sunn hemp	6.8	6.9	66.6	83.9	1.5	1.5	1.6	1.9
Crotalaria spectabilis	4.7	7.1	51.9	95.0	1.5	1.5	1.6	1.8
Jackbean	6.1	6.2	68.8	101.2	1.5	1.7	1.8	1.8
Pigeon pea	4.7	6.8	45.2	97.8	1.4	1.5	1.5	1.8
Dolichos Lablab	7.6	9.3	78.1	144.6	1.5	1.5	1.6	1.9
Velvet beans	5.5	8.4	49.9	126.3	1.4	1.5	1.6	1.9
Black velvet beans	7.6	9.0	89.9	121.8	1.4	1.6	1.8	1.9
Spontaneous species	4.3	6.8	41.4	79.3	1.4	1.4	1.5	1.6
Mean	5.9 B	7.6 A	61.5 B	106.2 A	1.4 B	1.5 A	1.6 B	1.8 A

^{ns}: not significant; Means followed by the same capital letter in the line do not differ statistically from each other by the Tukey test (p<0,05).

Both in 2012/2013 and in 2013/2014 harvest, the highest N accumulation in corn dry biomass observed where 180 kg N ha^{-1} was added (Table 1), it was expected once this nutrient is readily available for plant absorption, while the N provided by the leguminous cover needs to be mineralized, in order to be available to others plants (Rangel et al., 2009). Nevertheless, the importance of N release by leguminous plants is evidenced by Figure 2, which shows an average release of 65-70 kg N ha^{-1} (between 45 and 60 days after the leguminous cover crop management) in the period when corn needed more N (stage v4 to v6) to guarantee a development and production satisfactory (França et al., 2011; Pereira et al., 2013;). Highlight should be given to Canavalia ensiformis, that was available around 170-175 kg N ha^{-1} (Figure 2).

B.

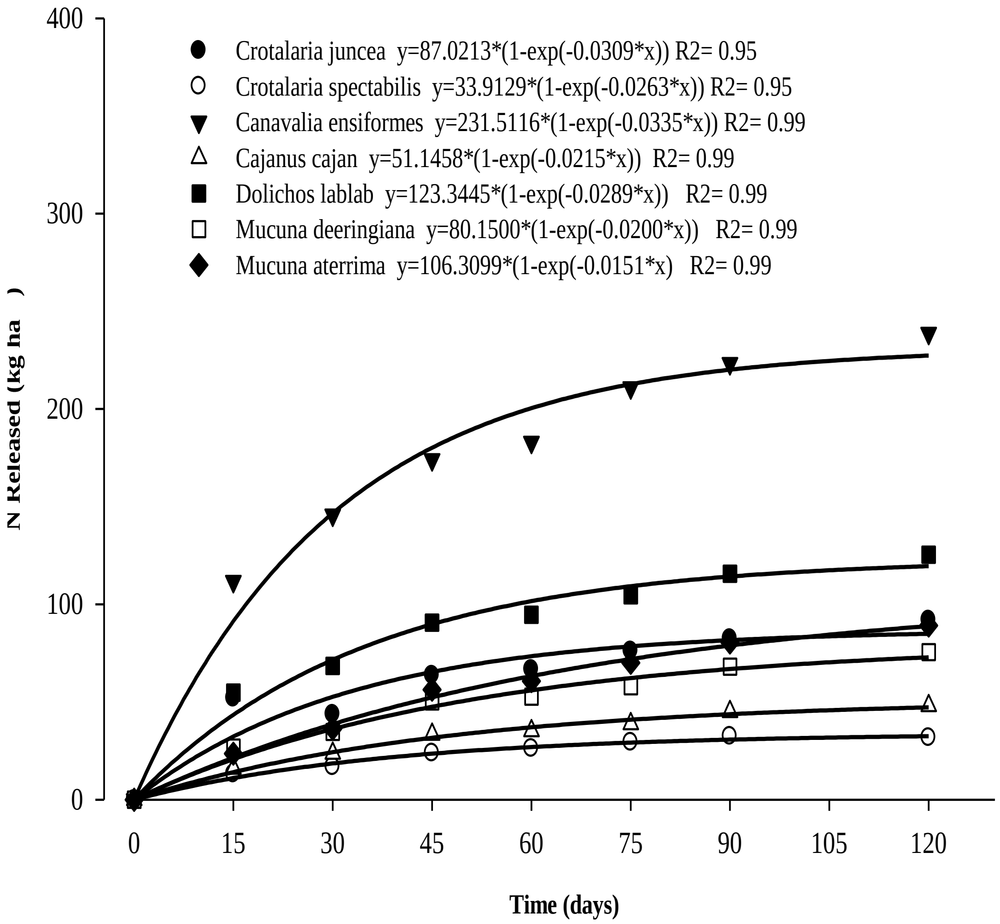

Figure 2. Total nitrogen released by leguminous residues in the 2013/2014 harvest

The amount of N released by the leguminous cover crops (Figure 2) combined to 180 kg N ha^{-1} added to the plots, promoted significant increase in corn height and stem diameter, compared to plots that did not receive the dose 0 kg N ha^{-1} (Table 1). According to Kappes et al. (2013), Repke et al. (2013) and Torres et al. (2014), the height and stem diameter are indirect indicators of corn yield, since they generally present a positive correlation between each other. On the other hand, the differences in corn height with 180 kg N ha^{-1} added to the plots, were 1 to 13 % higher than plots that N was not added, while the corn stem diameter under nitrogen fertilization was 1 to 16% higher in relation to plots which did not receive N of chemical origin (Table 1). This result evidenced that the productivity in the areas which received nitrogen fertilization, may be close to or relatively higher than those in which the N was supplied by the predecessor plants, such as leguminous cover.

In our study we observed in 2013/2014 harvest the corn dry biomass without nitrogen fertilization ranged from 4.7 to 7.6 Mg ha^{-1} (Table 1). Considering the carbon content in the crop residues, ranged of 40-45% (Aita et al., 2014), it is estimated that the carbon stock added to the soil in this condition (no addition of N) was from 1.88/2.12 to 3.04/3.42 Mg ha^{-1}, very close to the annual carbon required to maintain carbon stocks in the no-tillage conditions in the southern Brazil, which should be between 3,09 (Bayer et al., 2006) and 4,05 Mg ha^{-1} (Vieira et al., 2009). This result shows the effectiveness of green manures, when associated to sustainable practices of soil management, in the progressive increases of soil organic carbon, converging to the studies reported by Sisti et al. (2004), Zanatta et al. (2007), Costa et al. (2008) and Vieira et al. (2009).

The leguminous efficiency in the soil cover rate was also observed in our study, as indicated in Table 2, with emphasis on the Jackbean and Black velvet beans , which presented 35 % of the area covered at 15 DAS, regardless of absence or presence of nitrogen fertilization. The others leguminous provided around 30% of the soil cover only at 30 DAS, while the Jackbean and Black velvet beans had already more than 55% of the area covered in the same period, and a total soil cover at 60 DAS. The high efficiency of these species in the soil cover was also observed by Silva et al. (2011) and Carvalho et al. (2013).

Despite the lower efficiency in the initial soil cover, the Crotalaria spectabilis, the Cajanus cajan, the Dolichos Lablab and the Velvet beans had a soil cover rate higher than 20% at 30 days (Table 2). This result is important because during this time there was a precipitation of 350 mm (March 2013) in the experimental area (Figure 1).

Table 2. Soil cover rate of leguminous cover crops (%) up to 75 days after seeding (DAS) in soil under 0 kg N ha^{-1} and 180 kg N ha^{-1} in the 2013/2014 harvest

Leguminous cover crops	DAS					
	15	21	30	45	60	75
	Soil cover rate (%) under 0 kg N ha^{-1}					
Sunn hemp	ND	ND	ND	ND	ND	ND
Crotalaria spectabilis	5.6	11.9	27.3	41.6	64.6	75.9
Jackbean	35.3	41.7	55.1	88.2	99.1	99.4
Pigeon pea	7.0	16.4	27.8	37.1	51.6	69.1
Dolichos Lablab	11.6	22.7	31.0	51.4	76.7	77.2
Velvet beans	10.3	15.6	28.8	41.2	64.7	80.9
Black velvet beans	37.6	42.6	56.3	75.1	89.2	99.4
	Soil cover rate (%) under 180 kg N ha^{-1}					
Sunn hemp	ND	ND	ND	ND	ND	ND
Crotalaria spectabilis	5.8	12.8	27.6	42.3	65.1	76.8
Jackbean	36.5	42.1	56.3	88.3	99.5	99.8
Pigeon pea	7.8	16.8	28.1	38.3	52.5	70.6
Dolichos Lablab	12.3	23.0	31.3	52.0	78.6	93.6
Velvet beans	10.5	15.6	30.3	42.0	65.3	82.0
Black velvet beans	38.8	43.3	57.5	76.3	89.8	99.6

ND: not determined

According to Bertol et al. (2002), the 20% soil coverage with plant residues contributes to reduce around 50% soil losses by erosive processes compared to bare soil. In this context, the potentiality of the use of all the species tested as soil protective cover crops is more visible when the precipitation data from the subsequent months after March were observed (Figure 1). That is, during the occurrence of 300 mm precipitation in May 2013, all leguminous covered more than 50% of the area and during the occurrence, and more 500 mm in June 2013 the soil coverage exceeded 70% (Table 2).

4. Conclusions

The use of leguminous before corn crop is a good option for the southwest region of Paraná, in South Brazil, because it promotes soil protection.

The leguminous cover crop, mainly the Canavalia ensiformis, should be used like green manure, making them important species in the Brazilian agriculture sustainability context, due to the possibility of reducing, or even not using mineral nitrogen fertilization in the subsequent agricultural crops.

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