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SILAGE CORN IN SUCCESSION TO DIFFERENT GREEN MANURES IN THE CERRADO

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ABSTRACT: This study evaluated the effects of different green manures on the production of fresh and dry matter from corn, irrigated to silage, grown under no-tillage. The study was conducted in Iporá, Goiás, the experimental area was in the Cerrado Domain underlain by soil classified as Dystrophic Litholic Soil. The green manure treatments were: CON – Control (fallow area); CRO – Showy crotalaria; MAV – Mavuno brachiariagrass; LL – Lab-lab; and AG – Aries grass. At 88 days after emergence, the corn was harvested and a productive evaluation of the yields of fresh and dry matter was conducted. For the total fresh matter, Mavuno and showy crotalaria produced gains of 26% and 18%, respectively, when compared to the control. Mavuno resulted in the greatest difference for both dry and fresh matter compared to the other green manures and the fallow soil control. Crotalaria also resulted in better fresh matter productivity than the control.

Key words: Cover crop. *Crotalaria spectabilis*. Leguminous. Mulching.

MILHO PARA SILAGEM EM SUCESSÃO A DIFERENTES ADUBOS VERDES NO CERRADO

RESUMO: O objetivo do trabalho foi avaliar os efeitos de diferentes adubos verdes na produção de matéria fresca e seca do milho irrigado para silagem cultivado em sistema plantio direto. O estudo foi realizado em Iporá, Goiás, a área experimental estava localizada no Domínio Cerrado em um solo qualissificado como Neossolo litólico distrófico. Os adubos verdes utilizados foram: AP - testemunha (área de pousio); CRO - crotalária; MAV – Mavuno; LL – Lab-lab; CA - Capim Áries. Aos 88 dias após a emergência ocorreu a colheita quando foi realizada a avaliação produtiva para determinação da matéria fresca e seca. Para a matéria Fresca Total, nota-se que Mavuno e crotalária apresentaram ganhos de 26% e 18%, respectivamente, quando comparados a testemunha. Mavuno apresentou diferença entre outros adubos verdes e o solo em pousio ao analisar a matéria seca e fresca. A crotalária também proporcionou melhor produtividade de matéria fresca quando comparada com a testemunha.

Palavras-chave: Cobertura vegetal. Cobertura morta. *Crotalaria spectabilis*. Leguminosas.

INTRODUCTION

Corn (*Zea mays* L.) is one of the main crops grown globally (SILVA *et al*., 2020). In the 2019/2020 agricultural harvest, the Midwest region of Brazil showed increases in corn productivity of 10.6% in the first harvest, and 7.4% in the second harvest, thus remaining the main cereal-producing region in the country (COMPANHIA NACIONAL DE ABASTECIMENTO - CONAB, 2020). Brazil is the third largest producer of corn, second only to the United States and China (RAMOS *et al*., 2020). Several factors may influence the lower productivity of corn in Brazil, such as inferior technology used in cultivation (FORNASIERI FILHO, 2007); absence of economically viable information to support crop management in tropical conditions (KAPPES *et al*., 2015); and water deficit, which can reduce productivity (SILVA *et al.*, 2020).

In the Brazilian Cerrado region, the soils are exposed to intense solar radiation and wind erosion during the off-season, as well as erosion caused by intense rains, common at the beginning of the rainy season (CARVALHO *et al*., 2004). Several agricultural areas remain fallow for up to seven months per year, posing serious difficulties for the success of the no-till system (BARDUCCI *et al.*, 2009). According to Costa *et al.* (2019), the use of green manure is a programmed agricultural technique that incorporates plant residue into the soil or keeps it on the surface, which increases the amount of straw required for the no-till system. Green manure improves soil quality (KAILASH; TARUN; SINGH, 2017), soil microbial activity and CO_2 production (ALAGÖZ; ÖZER; PEKŞEN, 2020), providing additional nitrogen and organic matter (KUMAR; PAWAR, 2018), as well as nutrients and water that are present in the residues (SOSA-RODRIGUES; GARCÍA-VIVAS, 2019). Furthermore, the addition of plant residues improves soil structure and aeration, which promotes the lateral growth of storage roots and decreases the formation of crooked roots (SANTOS *et al*., 2006).

The no-till system is characterized by no turning of the soil and the production of plant biomass for soil cover, both prerequisites for the system to reach its potential (BIZARI *et al*., 2020). The choice of green manure plants, whether legumes or grasses, is based on factors such as better nitrogen fixation in the soil and increased production of plant biomass (ALBUQUERQUE *et al*., 2013). Green manure from grasses provides a large amount of phytomass, improving various physical and chemical aspects of the soil, and reducing weeds in the cultivated area (SEVERINO; CHRISTOFFOLETI, 2001). Grasses of the *Poaceae* family are species of fast establishment and high dry matter yield, with the ability to promote nutrient cycling (NASCIMENTO *et al*., 2019). Leguminous crops from the Fabaceae family are also included in production systems – either as isolated crops or intercropped with *Poaceae* plants in the second crop – to increase yields in succession crops (NASCIMENTO *et al*., 2019), mainly due to the availability of nitrogen (CHIEZA *et al*., 2017). The advantages of using legumes include greater accumulation of dry matter, improved physical quality of the soil, and increased productivity of subsequent crops (GITTI *et al*., 2012).

Traditionally, corn plants provide the material most used for silage production because of the cultivation tradition, and especially for high productivity and good nutritional value

(PAZIANI *et al.*, 2009). Even though corn silage is well known, there are still misconceptions relating to the choice of cultivars, their cultivation, and the production of silage where the quality of the final product is not prioritized (NUSSIO; CAMPOS; DIAS, 2001). The use of green manures can improve the production of corn for silage and requires an assessment of which green manure species bring the greatest benefits to the crop. This study evaluated the effects of different green manures on the production of fresh and dry matter from irrigated corn for silage and grown under no-tillage.

MATERIAL AND METHODS

The study was conducted on a 250 m^2 area located in the experimental field of IF Goiano School Farm in Iporá, Goiás (16º25'29" S, 51º09'04" W, 584 m above the sea). The experiment was carried out between October and December 2019. The climate is tropical savanna, with a mean annual temperature of 25.9 ºC and a mean annual precipitation of 1617 mm (Figure 1), characterized by two main rainfall periods: a dry season (May–September) and a rainy season (October–April).

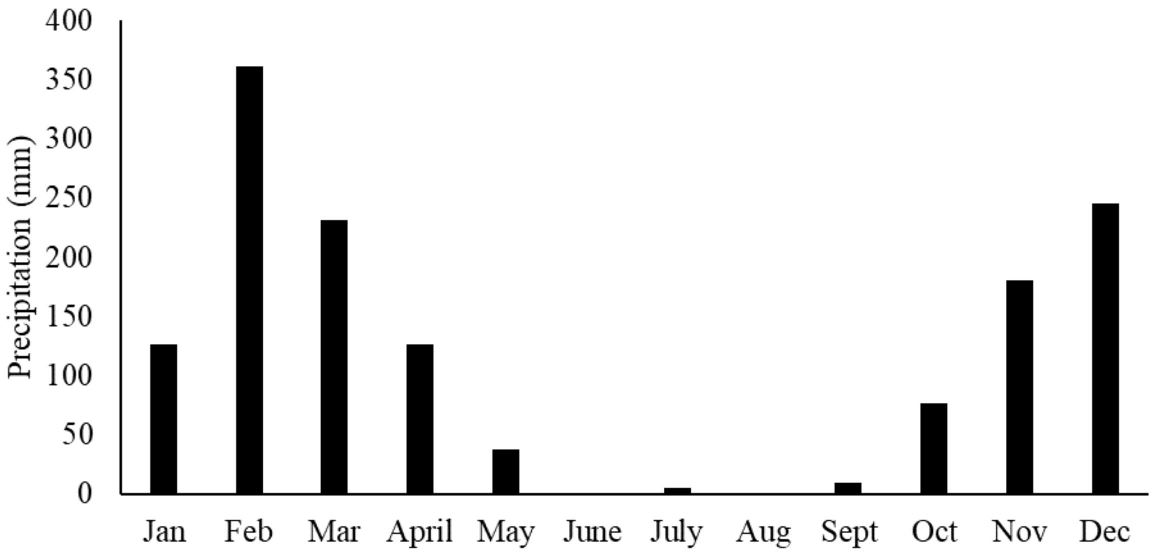

Figure 1. Annual precipitation in 2019 over the study area, Iporá, Goiás, Brazil.
Source: Brazilian National Institute of Meteorology (INMET).

The experimental area was in the Cerrado Domain underlain by soil classified as Dystrophic Litholic Soil (SANTOS *et al.*, 2018). The plow layer (0 –20 cm), sampled in 2019 for selected chemical and physical properties, showed the following results: pH ($CaCl_2$) = 5.3; P (mg dm^{-3}) = 18.63; S (mg dm^{-3}) = 2.02; B (mg dm^{-3}) = 0.32; K+ (cmolc dm^{-3}) = 0.81; Mg+2 (cmolc dm^{-3}) = 2.44; Al+3 (cmolc dm^{-3}) = 0.0; CTC (cmolc dm^{-3}) = 16.13; M.O. (g dm^{-3}) = 40.47; e V(%) = 69.25.

The broadcast sowing of green manures was carried out on February 15, 2019, with a sowing density of 10 kg ha^{-1} for all treatments except Lab-lab, which had a seeding rate of 5 kg ha^{-1}. Fifteen days after the herbicide application, common bean (*Phaseolus vulgaris* L.) was sown. The beans were harvested 90 days after sowing. Thereafter, the area remained fallow until the sowing of the corn hybrid (B2620PWV) on October 3, 2019. The corn manual sowing depth was 3 cm, with row spacing of 0.5 m, and a density of 60,000 plants per ha^{-1}. Sowing and covering fertilization were carried out according to the recommendations of Sousa, Lobato and Rein (2004). A selective weed-control herbicide for corn was applied at 25 DAE (V4 stage).

The experimental design used was the randomized complete blocks, comprising five treatments and four replications. The green manure treatments were: CON – Control (fallow area); CRO – Showy crotalaria (*Crotalaria spectabilis* Roth); MAV – Mavuno brachiariagrass (*Urochloa brizantha* × *Urochloa ruziziensis*); LL – Lab-lab (*Dolichos lablab* L.); and AG – Aries Guineagrass (*Magathyrsus maximus* Jacq). All treatments had common bean (*Phaseolus vulgaris* L.) as the crop preceding the corn. The experimental plots comprised four rows of corn, each 5.0 m in length, with 0.5 m spacing between rows. The useful area of each plot was considered to be the two central rows, excluding the 0.5 m borders.

The corn crop developed during different climatic periods, partly in the dry period and partly in the rainy period, therefore a drip irrigation system was used to meet the water demand of the corn. The rainfall volume at the beginning of the corn crop development was low, that is, there was still no accumulated precipitation to start the corn sowing (Vieira Filho *et al.*, 2020). During the first 15 days after sowing, a one-day irrigation interval was used to maintain the soil at field capacity. After this period, irrigation management started, based on climatic data, where the irrigation depth was equal to the daily evapotranspiration of the crop. Irrigation was managed using parameters such as the crop coefficient (Kc) and coverage coefficient (Kr). The crop coefficients were 0.50, from emergence to 12 DAE; 0.85, from 13 to 32 DAE; and 1.2, from 33 DAE to harvest (PEGORARE *et al.*, 2009). The coverage coefficients were 0.45, when the crop reached 20% ground cover; 0.71, when it reached 50%; and 1.0, when it reached 100% (ALBUQUERQUE; MAENO, 2000). The reference evapotranspiration (ET_0) was calculated using the Hergreaves-Samani (1985) empirical equation. This equation is the most suitable for the region's climate and for places where there is limited data availability (FERRONATO *et al.*, 2014), and it can be used by producers for irrigation management (NOIA *et al.*, 2014).

The corn was harvested at 88 DAE, after which a productive evaluation was carried out to determine the yields of fresh and dry matter. All plants occurring in the useful area of the plot (without the border) were collected, and the culm, leaves, husk of ear, and ear without husk were separated and weighed. To determine the percentage of dry matter, sub-samples were removed and placed in a forced ventilation oven for 72 h, until they reached constant weight. For the evaluations, the length of two meters were marked in each of four rows, chosen randomly, always to evaluate the same plants. The plants were cut manually, 0.20 m from ground level, and removed, together with the remaining culm (stub).

The results were subjected to analysis of variance, and the means were compared using the Tukey test at the level of 5% probability, using the SISVAR statistical analysis program (FERREIRA, 2011).

RESULTS AND DISCUSSION

Figure 2 shows the green manures grown in early 2019 and the initial development of corn at 27 days after emergence (November 2019). The phytomass productivity of green manures can be seen in Andrade (2021).

Figure 2. A) Green manures grown in January 2019, from left to right: fallow area, Showy crotalaria, Mavuno, Lab-lab and Aries grass. Each white stake delimits the planting area for green manures. B) Distribution of corn over the experimental area in October 2019 (27 DAS).
Source: Own authorship (2021).

When analyzing the data presented in Table 1, it is observed that the dry matter (DM) averages for the isolated components: culm, leaf and husk; showed no significant difference (P<0.05) between treatments and the control. As for total DM and DM of the ear, only Mavuno showed a significant difference (P<0.05) when compared to the control, presenting the greatest average followed by Showy crotalaria. According Paziani *et al.* (2009) among the most desirable characteristics in a silage crop are the high production of dry matter and the high dry matter content in the harvest, in order to favor fermentation.

In addition to the total matter production, the quality of the silage must also be considered, which is influenced by the proportion of the plant components (KLEIN *et al.*, 2018). The proportions of ears (36% of DM) for Mavuno, which showed a difference between the other treatments and the control, were below those reported in the literature (PIAZANI *et al.*, 2009; ROSA *et al.*, 2004). According Nussio (1991) it is ideal that the share of the ear is below 64-65%. The importance of knowing the values of the fractions of the components also allows establishing correlations between these variables and the quality of corn for silage (PAZIANI *et al.,* 2009).

When analyzing the fresh matter (MF) of the husk, it was observed no difference between treatments (P<0.05). Regarding the fresh weight of the leaves, there was no difference (P<0.05) when cultivated in succession to Showy crotalaria and Mavuno, which presented means greater than the other treatments. For fresh culm matter, only the succession with Mavuno provided greater means for corn plants when compared to the control. For fresh ear matter, succession with Mavuno provided better means when compared to other treatments but did not differ from the control (P<0.05).

Table 1. Means referring to the aerial parts of the plants determined in fresh matter (ton ha^{-1}) and dry matter (ton ha^{-1}) of corn planted in succession to different green manures, 88 days after emergence.

Treatment	***Culm***	***Leaf***	***Husk***	***Ear***	***Total***
			Dry matter		
Showy crotalaria	2.2 a	1.8 a	0.6 a	3.2 ab	7.8 ab
Mavuno	3.3 a	2.0 a	0.8 a	3.5 a	9.6 a
Lab-lab	2.5 a	1.7 a	0.6 a	2.2 ab	7.0 b
Aries grass	2.9 a	1.7 a	0.6 a	2.2 b	7.4 b
Control	2.3 a	1.7 a	0.7 a	2.1 b	6.8 b
Mean	**2.6**	**1.8**	**0.7**	**2.6**	**7.7**
CV_e (%)	**19.0**	**13.0**	**19.0**	**18.0**	**11.0**
Treatment			***Fresh matter***		
Showy crotalaria	13.3 ab	7.5 ab	2.7 a	7.8 ab	31.4 a
Mavuno	14.6 a	8.7 a	2.8 a	8.4 a	30.7 a
Lab-lab	11.2 b	6.3 b	2.5 a	6.0 b	26.0 b
Aries grass	13.0 ab	6.0 b	2.5 a	5.8 b	27.3 b
Control	10.7 b	6.1 b	2.5 a	6.6 ab	26.0 b
Mean	**12.9**	**7.1**	**2.6**	**7.1**	**28.3**
CV_e (%)	**12.0**	**16.0**	**22.0**	**14.0**	**12.0**

Note: Means followed by the different letters in the column differ statistically from each other by Tukey's test at 5% probability. CV: coefficient of experimental variation.
Source: Own authorship (2021).

In relation to total MF, Showy crotalaria and Mavuno had the greast means, respectively, and were the only green manures that differed from the control (P<0.05). The production of fresh matter is one of the main parameters to be evaluated when looking for information on the silage quality of a given cultivar; in addition to being a parameter for silo sizing (FERRARI JÚNIOR *et al.*, 2005), it also contributes to the dilution of crop implantation costs by raising productivity (PAZIANI *et al.*, 2009). For the total fresh matter, it is noted that Mavuno and Showy crotalaria presented greater gains when compared to the control, equivalent to 26% and 18%, respectively.

The average yields of fresh matter and dry matter were below the ranges of 31.37 to 50.47 t MF ha^{-1} and of 11.46 to 18.69 t MS ha^{-1} observed in the literature (FERRARI JR. *et al*., 2005; PIAZANI *et al.*, 2009). These low values may be related to the type of soil used (SANS *et al.*, 2001) and the fact that it is the first crop to use the area, which has reduced the productivity found. Another factor that interferes with productivity is the hybrid chosen for the growing region, since the use of more productive corn hybrids adapted to local conditions has been identified as responsible for the greatest gains in productivity (BUSO *et al.*, 2018). However, the productivities found can be considered optimal in comparison to the averages obtained in practice (PAZIANI *et al.*, 2009)

About the culm proportions the Mavuno showing greater values (34% of the DM) than those reported by Almeida Filho *et al.* (1999), Piazani *et al.* (2009) and Rosa *et al.* (2004). The reduction in culm participation results in a reduction in cell wall components and an increase in grain proportions, which increases the digestibility values of DM and total digestible nutrients (NUSSIO *et al.*, 2001).

Throughout the evaluations the green manures that stood out the most were Mavuno. According to Scivittaro *et al.* (2000) in the production of cereals, the cultivation of legumes, as green manure, during the fallow period, has been considered a promising alternative to meet the nitrogen demand of crops, considering their potential for biological N2 fixation. Kappes *et al.* (2015) when evaluating the production of irrigated corn, in different production systems in the Cerrado, found that in succession to crotalaria, corn cultivation showed the best performance in relation to the other treatments evaluated. Mavuno standing out is not a common result to be found, which can be explained by the fact that corn is irrigated, where soil moisture has been maintained in the field capacity. Grasses have a high C/N ratio, and therefore have lower decomposition rates and their residues remain longer in the soil. However, soils with greater moisture accelerate the decomposition of organic matter (CALVO *et al.*, 2010), which can explain the prominence of mavuno compared to the other green manures studied.

CONCLUSION

Mavuno as a green manure produced more dry and fresh matter than the other green manures and the control with fallow soil.

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