

Corn and Soybean Productivity in Succession to Family Coverage Plants *Poaceae* and *Fabaceae*

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Abstract

The use of soil cover plants has varied effects on crops grown in succession, depending on the cover plant used. The objective of this study was to evaluate the effect of soil cover plants from the Poaceae and Fabaceae families grown in the autumn and winter on yields of corn and soybean grown in succession. The experiment was carried out for two years and the experimental design used was randomized block design, with six replications. Both in the first year and the second, the plots consisted of the cultivation of corn or soybeans on the different biomasses of four cover crops cultivated in autumn and winter intercropped with corn. The cover crops were two *Poaceae* plants (black oats and brachiaria) and two *Fabaceae* plants (forage pea and white lupine). The production and productivity parameters of summer corn and soybean commercial crops were evaluated. Cover plants of the Poaceae (black oat and brachiaria) and Fabaceae (pea and white lupine) families intercropped with corn grown in autumn-winter did not affect their yield components and yield; as well as the productivity of soybeans in succession. According to the results of this work, the cultivation of black oat, brachiaria, forage pea and lupine increases the number of species that the farmer can cultivate intercropped with corn, favoring the crop rotation system in no-till.

Keywords: sustainable agriculture, No-till, crop rotation, green manure

1. Introduction

Corn and soybean are considered to be amongst the most important crops in the world with 1525.38 billion tons (Mendes, 2020). Brazil is the third largest corn producer with a production of more than 84.7 million tons (CONAB, 2015) and the second largest soybean producer at over 96.2 million tons (USDA, 2015).

To increase the productivity of agricultural areas there are necessity to improve in soil

management. The main technology to increase soil quality is the no-till system (Bai et al., 2018). Other measures are: the adoption of crop rotation, the cultivation of cover crops, in intercropped or in succession with commercial crops (Steiner et al., 2011; Wutke et al., 2014; Carvalho et al., 2015). the increase in organic matter content (Giongo et al., 2011; Souza et al., 2014) and the adoption of conservation practices. These measures can reduce the impacts of conventional farming, which tend to increase soil degradation

There are countless advantages of using the rotation system and/or crop succession, among them the stability of grain yield from crops of economic interest, the breakdown of the cycle of disease and pests (Silva et al., 2007), and reduction of weed infestation (Franchini et al., 2011). Other advantages are nutrient cycling, with the diversified use of species with different root systems, maintenance or improvement of soil properties (Lopes et al., 2007), reduction in soil temperature variation (Boer et al., 2008) and evapotranspiration (Giongo et al., 2011), and greater soil protection against erosion (Lanzanova et al., 2010).

In this context, several hedging plants have been used and researched as soil cover as part of a rotation and/or succession system (Costa et al., 2014). Plants of the *Poaceae* family have great potential for use in rotation, as they have a rooting system fasciculated denser, with greater contact with soil particles (Brancalião et al., 2015), which contributes to soil aggregation. In addition, they present a large contribution of biomass on the surface and persistence in soil cover due to the high carbon/nitrogen ratio, thus reducing the decomposition process (Calvo et al., 2010).

Plants of the *Fabaceae* family present a carbon/lower nitrogen and are more effective in a short time due favouring the rapid decomposition (Brancalião et al., 2015), providing a large volume of biomass for decomposition. However, the amount of nutrients released by *Poaceae* may be equal or even superior to those added by *Fabaceae* plants (Doneda et al., 2012).

It is worth mentioning that the use of soil cover plants provides effects on crop behavior when grown in succession (Matoso et al., 2015), and these effects vary as a function of each cover plan used (Cardoso et al., 2014). In this context, the objective of this study was to evaluate the effect of soil cover plants from the *Poaceae* and *Fabaceae* families grown in the autumn and winter on yields of corn and soybean grown in succession.

2. Material and Methods

2.1 Location, Climate and Soil of the Experimental Area

The work was carried out on the private agricultural property Água Vitória in the municipality of Tupãssi – PR, located at the geographic coordinates 24° 38' 18.72" of south latitude and 53° 34' 33.49" of west longitude, at 488 meters of altitude in relation to sea level.

According to Köppen's climate classification, the region's climate is of the humid subtropical mesothermal (Cfa) type, with hot summers, with average temperatures above 22°C and winters with average temperatures below 18°C and an average annual rainfall of 1600 - 1800 millimeters (CAVIGLIONE, 2000).

The soil of the experimental unit is classified according to Santos et al. (2013) as typical Red

Eutrophic Oxisol, with a very clayey texture and smooth undulating relief. Prior to the experiment, the area had been cultivated with oats in the winter period and corn in succession in the summer.

Prior to the implementation of the experiment, deformed soil samples were collected at depths of 0–0.20 m for the determination of chemical and granulometric characteristics. Chemical analysis was performed according to the methodology of Raij et al. (2001). Results were as follows: pH (CaCl₂) = 6.05; MO = 24.61 g dm⁻³; P = 2.36 mg dm⁻³; Ca²⁺ = 6.61 cmol_c dm⁻³; Mg²⁺ = 1.77 cmol_c dm⁻³; K⁺ = 0.25 cmol_c dm⁻³; Al³⁺ = 0.0 cmol_c dm⁻³; H⁺ + Al³⁺ = 2.54 cmol_c dm⁻³ and V (%) = 77.26. In the granulometric analysis, the soil presented 763 g kg⁻¹ clay, 136 g kg⁻¹ silt and 101 g kg⁻¹ sand.

2.2 Experimental Design

The experiment was carried out for two years and the experimental design used was randomized block design, with six replications. Both in the first year and the second, the plots consisted of the cultivation of corn or soybeans on the different biomasses of four cover crops cultivated in autumn and winter; two *Poaceae* plants (black oats (T₁) and brachiaria (T₂) and two *Fabaceae* plants (pea forage (T₃) and white lupine (T₄)). Each plot was 10.0 m long and 5.40 m wide, totaling 54 m². The useful area of the plot was determined by discarding 0.50 m and 0.45 m at each end and each side, respectively, totaling 40.5 m².

2.3 Conducting the Experiment

Sowing of crops in autumn and winter was mechanically performed with a seeder share on 09/05/2014, using 70 kg ha⁻¹ of oat (*Avena strigosa* S.) cultivar Iapar 61 Ibiporã; 8 kg ha⁻¹ brachiaria (*Urochloa ruziziensis*) with cultural value of 73.06; 60 kg ha⁻¹ of pea (*Pisum sativum* L.) cultivar Iapar 83 and 50 kg ha⁻¹ of white lupine (*Lupinus albus* L.). The spacing used was 0.20 m to 0.40 m for *Poaceae* and *Fabaceae*. No base and/or cover fertiliser was used.

At 120 days after sowing, plant cover was managed by using 3 kg ha⁻¹ of glyphosate acid equivalent. Planting of commercial summer crops was performed mechanically and harvesting manually. The corn crop was sown after the management of the cover plants (25 days) using the variety Capixaba Incaper 203 with between-row spacing of 0.70 m and 5.1 seeds/linear meter. Basic fertilizer application of 279 kg ha⁻¹ of a 10-15-15 formulation, with 70 kg ha⁻¹ of nitrogen, was carried out when plants were in the vegetative stage V3 (third developed sheet).

Sowing of the soybean crop was carried out in December, due to the drought in the region. The cultivar used was Vtop 1059 Syngenta at a spacing of 0.50 m between rows, with 17 seeds/linear meter. Basic fertilizer application was at the rate of 268 kg ha⁻¹ with a 2-20-18 formulation. The control of weeds and insects was carried out as necessary, based on the technical recommendations of Embrapa (2011). For the soybean crop, preventive control of fungal diseases was carried out.

2.4 Evaluation of Agronomic Characteristics and Productivity

At the time of the corn harvest (18–25% moisture content of the grain) 10 corn ears were collected at random in the useful area to assess the ear length (tape), measuring the base of the tip of the spike; Diameter of the pin (caliper graduated in centimeters), determined in the medial part of the spike; number of rows of grain per ear (counting rows of grain of each ear, individually); mass of 1000 grains (average of 8 subsamples of 100 grains in precision scale, corrected for 13% of humidity), thus estimating the mass of 1000 grains; and productivity (mass of grain produced in the portion corrected to 13% moisture estimating productivity for Mg ha^{-1}).

The soybeans were harvested with 14–16% moisture content of the grain. Before the harvest, 20 plants per plot were randomly collected and sent to the laboratory for evaluation. The following parameters were determined: number of pods per plant; number of grains per pod; number of pods with 1, 2 or 3 grains; and number of grains per plant. The mass of 1000 grains was also determined, based on the mean of the mass of eight subsamples of 100 grains using a precision scale and corrected for 13% humidity. Productivity was calculated as the mass of grain produced in the portion corrected to 13% moisture and expressed as Mg ha^{-1} .

2.5 Statistical Analysis

The data obtained were tabulated and submitted to analysis of variance considering a level of significance of 5% for the F-test. When significant, the means were compared by the Scheffe test at 5% probability, using the statistical software Sisvar (Ferreira, 2011). The contrasts used in the comparison of treatment means the ground cover plants grown in autumn and winter by Scheffe test were: C₁: Comparison of households (+1T₁ +1T₂ -1T₃ -1T₄); C₂: Comparison within the *Poaceae* family (-1T₁ +1T₂) and C₃: Comparison within the *Fabaceae* family (-1T₃ +1T₄).

3. Results and Discussion

3.1 Corn Cultivation

Table 1 shows the mean results for the production and yield components of the corn crop grown in succession to the soil cover plants. Based on Table 2, it was found that there was no effect ($p < 0.05$) of cover crops grown in the autumn and winter on ear length, ear diameter, number of rows of grains, mass of 1000 grains, yield and number of plants per hectare of corn grown in succession.

Table 1 - Average results for the parameters of production and productivity of corn grains, according to cultivation in succession to cover crops

Coverage plants	Ear length	Ear diameter	Number of rows of grains	1000 grain mass	Productivity	Number of plants per hectare
	cm			g	Mg ha ⁻¹	
Family <i>Poaceae</i>						
Oats (T ₁)	17.83	50.33	16.0	352.17	7.43	73511
Brachiaria (T ₂)	17.67	50.0	16.0	355.33	7.60	74404
Average	17.75	50.17	16.0	353.75	7.51	73958
Family <i>Fabaceae</i>						
Peas (T ₃)	19.0	50.33	16.0	354.50	8.08	71428
Lupine (T ₄)	17.67	49.17	16.0	364.50	6.95	73214
Average	18.33	49.75	16.0	359.50	7.51	72321
F (treatments)	2.36 ^{NS}	0.58 ^{NS}	0.81 ^{NS}	1.83 ^{NS}	0.70 ^{NS}	2.05 ^{NS}
CV (%)	5.69	3.55	5.24	2.75	18.15	2.92

*: Significant by the Scheffé test at 5% probability, within each parameter evaluated; NS: Not significant by the Scheffé test at 5% probability, within each parameter evaluated.

Table 2 - Values of contrasts for the parameters of production and productivity of corn grain as a function of growing in succession to cover plants

Coverage plants	Ear length	Ear diameter	Number of rows of grains	1000 grain mass	Productivity	Number of plants per hectare
	cm			g	Mg ha ⁻¹	
C ₁	-0.58 ^{NS}	0.42 ^{NS}	0.0 ^{NS}	-5.75 ^{NS}	0.00 ^{NS}	1637 ^{NS}
C ₂	-0.16 ^{NS}	-0.33 ^{NS}	0.0 ^{NS}	3.16 ^{NS}	0.17 ^{NS}	893 ^{NS}
C ₃	-1.33 ^{NS}	-1.16 ^{NS}	0.0 ^{NS}	10.0 ^{NS}	-1.13 ^{NS}	1786 ^{NS}

Legend: C₁: (+1T₁ +1T₂ -1T₃ -1T₄); C₂: (-1T₁ +1T₂); C₃: (-1T₃ +1T₄).

*: Significant by the Scheffé test at 5% probability, within each parameter evaluated; NS: Not significant by the Scheffé test at 5% probability, within each parameter evaluated.

The components of corn crop production (length of ear, ear diameter and number of rows of grains) were similar to those reported by Lázaro et al. (2013). It is worth mentioning that ear length, ear diameter and grain density is characteristics that determine the yield potential of corn, with diameter being directly related to the number of grain rows per spike (Ohland et al., 2005). The value for the mass of 1000 grains obtained in this study (356 g), regardless of the predecessor cultivated, was higher than the average value reported by Debiasi et al. (2010), which was 304 g. This feature is influenced by genotype, nutrient availability and climatic conditions during grain filling stages (Ohland et al., 2005).

The population of plants per hectare in corn ranged from 71000 to 74000 plants ha⁻¹, getting close to the value for the highest net revenue, namely 80000 plants ha⁻¹ (Primaz et al., 2015). However, it should be remembered that the ideal population depends on the cultivar, soil

fertility, water availability and sowing time (Amaral Filho et al., 2005).

The corn yield (7.51 Mg ha^{-1}) regardless of the family of the soil cover crop used in the autumn and winter cover crops was higher than the national average of 6.56 Mg ha^{-1} (CONAB, 2015) and, on average, exceeded national productivity by 14.48% (Table 1). However, this productivity was below the average value for West Paraná (9.4 Mg ha^{-1}). This is probably because this variety (Incaper 203) does not have high yield potential and is usually grown in organic systems. These results corroborate those of Martins and Rosa Junior (2005) who evaluated this cultivation under similar conditions.

The results reveal that not all the plants from the *Fabaceae* family predated the corn are able to add nitrogen to the system, providing the highest grain yield when compared to *Poaceae* family. However, contrasting results were reported by Carvalho et al. (2015) when evaluating productivity in two consecutive years under cultivar brachiaria, millet, sorghum, wheat, crotalaria, wild beans, pigeon pea, mucuna, forage turnip and spontaneous vegetation. In the first year, showed that corn crop yields were similar, but in the second year, found significant differences ($p > 0.05$) between some plants of different families and also within each of the plant families. This is related to the more rapid decomposition of the vegetal residues of some plants, being influenced by the accumulated amount of dry mass, nitrogen (Carvalho et al., 2015) and lignin (Carvalho et al., 2013).

3.2 Soybean Cultivation

The average results for the production of components and soybean yield in succession with the different hedge plants are shown in Table 3. Based on Table 4, it was found that there was no effect of different families of plants used and neither among the species. The results are similar to those of Carvalho et al. (2004) and Santos et al. (2006), who did not find differences in the production components between different crop rotation/succession systems during a five-year period.

The average yield of 2.66 Mg ha^{-1} (Table 3) was below the national average of about 3.0 Mg ha^{-1} , a difference in yield of approximately 13%. This occurred due to the sowing time of the soybean crop, which affected the vegetative and productive performance of the crop (Cruz et al., 2010).

The sowing time is considered to be a factor that influences the yield of the soybean crop (Embrapa, 2003). Late sowing increases plant exposure to more severe pest attack (Motta et al., 2002) and to variation in climatic factors (Garcia et al., 2007). These results are corroborated by Barbosa et al. (2011) and Sanchez et al. (2014), who did not find significant differences for soybean cultivation in succession using different cover crops.

The population of soybean plants did not show significant effects of the different families and species of cover crops. The population was in the range 192000 to 215000 plants ha^{-1} , within the accepted range for soybean crops of 20000 to 500000 ha^{-1} (Embrapa, 2011).

Plant populations higher than recommended levels increase seed expenditure, can cause bedding and do not provide increases in productivity. Plant populations below the

recommended levels favor the development of weeds and can result in highly branched plants and reduced plant height, which increases losses at harvest (Vazquez et al., 2008). It is worth mentioning that the low population of plants did not significantly interfere with the productivity of the soybean crop, since it was able to withstand large population reductions (Vazquez et al., 2008).

Yield obtained with both corn and soybean crops demonstrated that only one crop cycle of soil cover crops (oats, brachiaria, forage peas and lupine) did not directly influence the increase or reduction of the productive potential of the crops in succession. This demonstrated that the cover crops evaluated in the present study can be included in a system of rotation and/or succession of crops without losses in productivity, since grain yield did not show significant differences.

Table 3 - Average results for the parameters of production and productivity of corn grains, according to cultivation in succession to cover crops

Coverage plants	Number of pods per plant	Number of grains per pod	Number of pods with 1, 2 or 3 grains			Number of grains per plant	1000 grain mass —g—	Productivity —Mg ha ⁻¹ —	Number of plants per hectare
			—1—	—2—	—3—				
<i>Family Poaceae</i>									
Oats (T ₁)	52.0	2.0	21.0	21.0	10.0	104	145.0	2.45	215416
Brachiaria (T ₂)	64.0	2.0	23.0	27.0	14.0	128	144.83	2.74	186250
Average	58.0	2.0	22.0	24.0	12.0	116	144.92	2.60	200833
<i>Family Fabaceae</i>									
Peas (T ₃)	63.0	2.0	24.0	27.0	12.0	126	137.67	2.72	192916
Lupine (T ₄)	54.0	2.0	20.0	24.0	10.0	108	136.33	2.73	210833
Average	58.0	2.0	22.0	25.0	11.0	116	137.0	2.72	201875
F (treatments)	4.01 ^{NS}	1.09 ^{NS}	1.68 ^{NS}	2.84 ^{NS}	3.48 ^{NS}	3.28 ^{NS}	1.04 ^{NS}	0.28 ^{NS}	1.67 ^{NS}
CV (%)	12.86	3.64	13.60	16.45	18.55	14.45	7.86	23.94	13.18

*: Significant by the Scheffé test at 5% probability, within each parameter evaluated; NS: Not significant by the Scheffé test at 5% probability, within each parameter evaluated.

Table 4. Values of contrasts for the production parameters and productivity of soybean grain as a function of growing in succession to cover plants

Contrasts	Number of pods per plant	Number of grains per pod	Number of pods with 1, 2 or 3 grains			Number of grains per plant	1000 grain mass —g—	Productivity —Mg ha ⁻¹ —	Number of plants per hectare
			—1—	—2—	—3—				
C ₁	0.0 ^{NS}	0.0 ^{NS}	0.0 ^{NS}	-1.0 ^{NS}	1.0 ^{NS}	0.0 ^{NS}	7.92 ^{NS}	-0.12 ^{NS}	-1042 ^{NS}
C ₂	12.0 ^{NS}	0.0 ^{NS}	2.0 ^{NS}	6.0 ^{NS}	4.0 ^{NS}	24.0 ^{NS}	-0.17 ^{NS}	0.29 ^{NS}	-29166 ^{NS}
C ₃	-9.0 ^{NS}	0.0 ^{NS}	-4.0 ^{NS}	-3.0 ^{NS}	-2.0 ^{NS}	-18.0 ^{NS}	-1.34 ^{NS}	0.01 ^{NS}	17917 ^{NS}

Legend: C₁: (+1T₁+1T₂-1T₃-1T₄); C₂: (-1T₁+1T₂); C₃: (-1T₃+1T₄).

*: Significant by the Scheffé test at 5% probability, within each parameter evaluated; NS: Not significant by the Scheffé test at 5% probability, within each parameter

4. Conclusion

Cover plants of the Poaceae (black oat and brachiaria) and Fabacea (pea and white lupine) families intercropped with corn grown in autumn-winter did not affect their yield components and yield; as well as the productivity of soybeans in succession.

According to the results of this work, the cultivation of black oat, brachiaria, forage pea and lupine increases the number of species that the farmer can cultivate intercropped with corn, favoring the crop rotation system in no-till.

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