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Corn Yield in Monoculture and Intercropped with Cover Plants and Aggregates Stability

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ABSTRACT

The cultivation of corn intercropped with cover crops has been increasing in the western region of Paraná. However, more technical information about this type of cultivation is needed. Thus, the present study aims to evaluate the yield of corn intercropped with brachiaria and crotalaria and its effect on aggregate stability and soil consistency. The experiment was carried out at the experimental station of *Cooperativa Agrícola Mista Rondon* (Copagril), in the city of Marechal Cândido Rondon. The experimental design was randomized blocks with 8 replications. There were six treatments for corn cultivation (T1) Corn monoculture (control), (T2) Corn intercropped with Brachiaria (*Brachiaria ruzizienses*), (T3) Brachiaria in monoculture, (T4) Crotalaria spectabilis (*Crotalaria spectabilis*) in monoculture, (T5) Corn intercropped with Crotalaria, (T6) Black oats (*Avena sativum*) in monoculture. Corn yield in intercropping, dry matter added to the soil, aggregate stability and soil consistency were evaluated. The yield of corn intercropped with cover crops was similar to that of corn in monoculture. The cultivation of *Brachiaria ruziziensis* in monoculture or intercropped with corn produced a large amount of straw and favored soil aggregation. Therefore, the intercropping systems are recommended for the improvement of soil physical properties and the conservation of soil.

Keywords: green manure, soil physical quality, sustainable management.

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I. Introduction

In the Western region of Paraná, no-till farming is the soil management used by most producers. This type of management has brought many benefits to agriculture. However, over the years, farmers have stopped rotating crops, which is one of the basic premises of the no-till system [1]. Currently, farmers grow soybeans in the summer and “safrinha” (second crop) corn in the fall/winter.

The use of cover crops is a way to increase the sustainability of this agricultural production model [2], which can restore considerable amounts of nutrients to the system and promote physical improvements [3] and organic matter [4].

When implemented in accordance with its assumptions, the use of cover crops provides ground cover and reduces water losses [5], in addition to preserving and restoring the yield of areas under cultivation, with greater soil protection and better use of machinery and inputs [6].

However, many cover crop species do not result in marketable products at the end of the harvest, and therefore do not generate a source of income for producers in that growing season. One possible solution would be the implementation of the intercropping system between the main crop and cover crops. By intercropping corn with cover crops, the producer obtains an income and, at the same time, promotes improvements in the soil [3].

After several crop cycles, intercropping results in significant improvements in crop yield, in addition to providing a greater accumulation of organic matter and nutrients in the soil [7], [8].

Crotalaria and brachiaria are some of the most suitable cover crops for better soil management. Crotalaria are particularly well adapted to different soils and soil fertility conditions [9]. They promote increases in nutrients, especially nitrogen, as they are nitrogen-fixing plants that increase the levels of organic matter.

Crotalaria spectabilis (crotalaria) is also suitable for the management of areas with nematodes, acting as trap crops in soils infested with these worms [10].

Brachiaria are plants well adapted to the western region of Paraná, with an excellent biomass production [11]. They have a strong root system and are adapted to intercropping with corn.

Yield experiment by [12]-[14] demonstrate that corn productivity was not affected by intercropping with *brachiaria* and/or crotalaria. However, [15] observed a reduction in corn yield when intercropped with *brachiara* with density above 2 kg ha^{-1}.

According to [16], the intercropping of *safrinha* (second crop) corn with *brachiaria* improves soil quality, adds value to the land and generates more income to the farmers. It also promotes soil coverage and protection, improves the control of invasive plants, while corn crop provides income to rural households.

One way to assess soil quality is through aggregate stability. This property is very important, as it reflects the degree of soil structure, which is directly linked to gas exchange and water infiltration into the soil. The effect of corn intercropping on aggregate stability was demonstrated in the research of [17], [18].

Thus, the present study attempts to shed light on the cultivation of second-crop corn intercropped with different species of cover crops in the western region of Paraná. It aims to evaluate the stability of aggregates and soil consistency after cultivation of black oat, *Brachiaria ruziziensis* and *Crotalaria spectabilis* in monoculture or intercropped with corn, as well as evaluating corn yield in monoculture or intercropped.

II. Materials and Methods

A. Site of the Experiment

The experiment was carried out at the experimental station of *Cooperativa Agrícola Mista Rondon* (Copagril), in the city of Marechal Cândido Rondon, Western region of Paraná, Brazil.

According to Köppen climate classification, the climate of the region is subtropical (Cfa), with hot summers, infrequent frosts and rainfall concentration in the summer months, with no defined dry season. The region is characterized as subtropical [19]. The predominant soil is eutrophic Red Latosol, with clayey texture. The average temperature in the region is lower than 18 ºC and the average annual precipitation is 1840 mm.

B. Experimental Design

The experimental design was randomized blocks with 8 replications. Six treatments were implemented for the cultivation of corn. (T1) Corn monoculture (control), (T2) Brachiaria ruziziensis monoculture, (T3) *Crotalaria spectabilis* (*Crotalaria spectabilis*) monoculture, (T4) Black oats (*Avena sativum*) in monoculture, (T5) Corn intercropped with Crotalaria, (T6) Corn intercropped with Brachiaria ruziziensis (*Brachiaria ruziziensis*). Each plot was 4 meters wide and 10 meters long, totaling 40 m^2.

C. Conducting the Experiment

The experiment started in February with the sowing of corn using a mechanical no-tillage seeder. In both corn crops, intercropped or monoculture, there was a 0.5 m spacing between rows. The number of plants per linear meter was 3 plants, totaling a population of 60,000 plants ha^{-1}. Twenty-one days later, the cover crops were manually sown between the corn rows. 10 kg ha^{-1} of brachiaria seeds with 30% purity and 30 kg ha^{-1} of crotalaria were used. Crop treatments were carried out according to the technical recommendation. Manual harvesting was used in the two central rows, and 0.5 m of the border rows was discarded.

D. Data Collection

After harvesting, the corn cobs were threshed, and the grains weighed. Then the sub-samples were collected and placed in a forced circulation oven at 65 º C until constant mass was reached. The moisture content was adjusted to 13%. The mass of a thousand grains was also determined with the aid of a precision scale.

For evaluation of the dry mass of cover crops and corn after harvest, a metal square of known area (0.25 m^2) was used, which was randomly placed in each plot, and all dry matter inside was collected, placed in a bag of paper and in a forced circulation oven until constant mass was obtained. Two samples were obtained per plot. The result obtained was extrapolated to kilograms per hectare.

To determine aggregate stability, undisturbed soil samples (monoliths) were randomly collected in each plot at depths from 0.0 to 0.10 and 0.10 to 0.20 m. The samples were taken to the laboratory, air-dried and then passed through a 9-mm and a 4.76 mm sieve. The soil retained in the first sieve was discarded and the soil retained in the last sieve was used to determine stability.

Determination was carried out by quantifying the soil volume in aggregate size classes of the collected natural samples, by wet sieving. The sample was exposed to turbulent flow in the vertical direction for 15 minutes in a device recommended by [20]. 50 grams of soil from each sample were placed in the upper sieve of a set of sieves of different diameters (2.0, 1.0, 0.5, 0.25 and 0.10 mm). The water level of the apparatus was set at the highest position of the sieves so that the water only covered the bottom of the 2-mm sieve. Each sample was analyzed in quadruplicate.

The mass of the material retained in each of the sieves was transferred to aluminum capsules through weak water flows and then dried in a forced air circulation oven at 105ºC, for 24 hours or until it reached constant weight. It was later weighed using a precision scale. After determination of the percentages retained in each sieve, the weighted mean diameter of aggregates (WMD), geometric mean diameter (GMD) and soil aggregates stability index (ASI) were calculated.

The weighted mean diameter (WMD) and the geometric mean diameter (GMD) were calculated according to the expression:

$$\textbf{DMP} = \sum_{i=1}^{n} Xi * Wi \quad (1)$$

$$\textbf{DMG} = \sum_{i=1}^{n} \frac{Wi * Log\ Xi}{peso\ da\ amostra} \quad (2)$$

E. Statistical Analysis

Data are tabulated and submitted to analysis of variance and, when significant, submitted to Tukey's range test (5% significance level).

III. Results and Discussion

The average mass of 1,000 grains was 248.36 g and intercropping had no effect on this agronomic trait. The average yield of “safrinha” (second-crop) corn was 7,755 kg ha^{-1}, above the average production in the state of Paraná, 5,289 kg ha^{-1} [21]. The yield of corn cultivated with crotalaria (7988 kg ha^{-1}) was higher than that of corn cultivated in monoculture (7488 kg ha^{-1}). However, this difference was not statistically significant (Fig. 1).

This result demonstrates that the species intercropped with corn may not have competed for nutrients, water and light, which was also reported by [12] and [22].

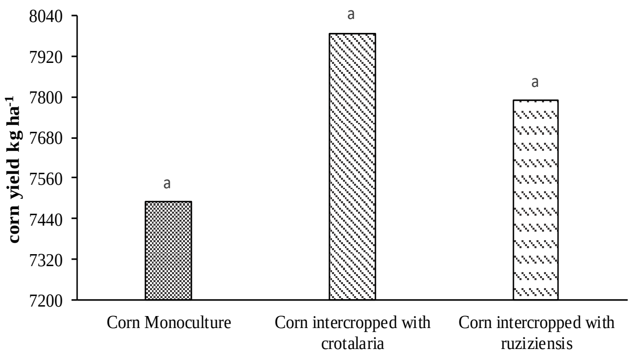

Fig. 1. Yield of second-crop corn in monoculture and intercropped with cover plants.

Corroborating these results, [13] evaluated corn yield in different types of cultivation with *Brachiaria ruziziensis* and the average yield was 7905 kg ha^{-1}. According to the authors, corn grain yields were more influenced by the types of cultivation than by the presence of the forage.

The results reported by [15] contrast with those mentioned above. These authors found that sowing corn with *Brachiaria ruziziensis* at a density of 8 kg ha^{-1} reduced corn yield by 30.8% because without intercropping with the cover crop, there was greater availability of water (depth of 0.30 m) for the corn.

Evaluation of the dry mass of cover crops and corn straw added to the soil showed that the greatest depth occurred in the area where *Brachiaria ruziziensis* was cultivated in monoculture with 11,675 kg ha^{-1} of dry matter (Fig. 2).

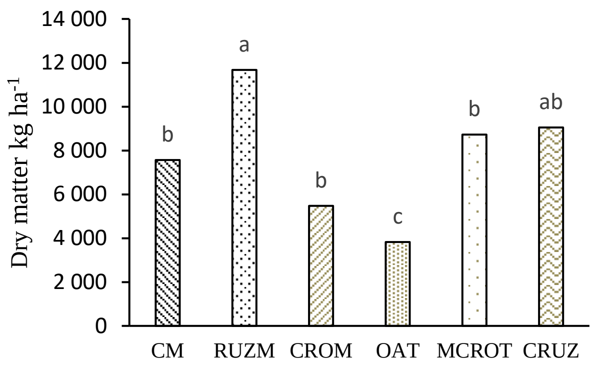

Fig. 2. Yield of dry matter of cover crops grown in monoculture or intercropped with second-crop corn.
CM= Corn in monoculture, RUZM=ruziziensis in monoculture, CROM= crotalaria in monoculture, OAT= oats, CCROT= corn intercropped with crotalaria, CRUZ= corn intercropped with ruziziensis.

This high yield was probably due to the local climate conditions that favored the development of this species.

The lowest dry matter yield (3,825 kg ha^{-1}) was obtained in the treatment with black oat. In other words, *Brachiaria ruziziensis* produced 7,890 kg ha^{-1} more dry matter. This result is significant, given the difficulty in obtaining sufficient straw for the no-tillage system and maintenance of organic carbon in the soil.

In the intercropping, the average dry matter yield was 8,888 kg ha^{-1}, while in corn monoculture it was 7,565 kg ha^{-1}, but the differences were not statistically significant because in the intercropping there was a satisfactory production of dry matter by brachiaria, but lower in corn, which was also found by [23].

An excellent style manual and source of information for science writers is [9].

Greater weighted mean diameter (WMD) and geometric mean diameter (GMD) were observed at depths of 0 to 0.10 m, except for the GMD of corn intercropped with crotalaria. This can be explained by the fact that this layer has the highest content of organic matter and concentrates most of the root system, which directly influences aggregate stability (Table I).

TABLE I: WEIGHTED MEAN DIAMETER (WMD), GEOMETRIC MEAN DIAMETER (GMD) AND AGGREGATE STABILITY INDEX AFTER SECOND CORN CROP INTERCROPPED WITH COVER CROPS

Management	WMD (mm)		GMD (mm)	
	Depth (m)			
	0 - 0.10	0.10-0.20	0-0.10	0.10-0.20
CM	2.93 Aa	2.21Ab	1.88 Aa	1.26 Bb
RUZM	3.36 Aa	2.51 Bab	2.08 Aa	1.48 Bab
CROM	3.82 Aa	2.67 Bab	2.43 Aa	1.59 Bab
OAT	3.34 Aa	2.84 Bab	2.17 Aa	1.79 Aab
MCROT	3.27 Aa	3.27 Aa	1.88 Ba	2.03 Aab
CRUZ	3.52 Aa	3.35 Aa	2.26 Aa	2.17 Aa
	Aggregate stability index %			
CM	93.67 Aa	89.25 Ba		
RUZM	91.60 Aa	89.30 Aa		
CROM	92.98 Aa	91.12 Aa		
OAT	94.04 Aa	93.27 Aa		
MCROT	91.00 Aa	92.39 Aa		
CRUZ	92.21 Aa	92.38 Aa		

Mean followed by the same uppercase letter in the row and lowercase letter in the column does not differ by Tukey's test ($p \leq 0.05$).
CM= Corn in monoculture, RUZM=ruziziensis in monoculture, CROM= crotalaria in monoculture, OAT= oats, CCROT= corn intercropped with crotalaria, CRUZ= corn intercropped with ruziziensis.

At the 0-0.10 m depth there was no statistically significant difference between the treatments regarding weighted mean diameter (WMD) and geometric mean diameter (GMD). On the other hand, at a 0.10-0.20 m depth, corn intercropped with *Brachiaria ruziziensis* and crotalaria obtained the highest weighted mean diameter (WMD) values (3.27 and 3.35 mm, respectively) and differed significantly from corn in monoculture. This increase was, on average, 49%. The role of roots in the stabilization of aggregates, especially of plants of the *Poaceae* family, was demonstrated by [17].

The best aggregation in treatments with cover crops was provided by the roots of these plants because when they grow, the roots bring the particles closer to the soil and favor aggregation [8]. Moreover, they release organic exudates that act as aggregating agents. The exudates in the rhizosphere favor the development of the soil microbiota, producing polysaccharides that also act in soil aggregation [24].

The aggregate stability index was higher than 90%, which demonstrates high stability. There was no significant difference for the stability index between the different treatments and cultivated species because in Oxisols, with predominance of iron and aluminum oxides, stability is more related to these oxides than to the organic matter content [25].

However, evaluation of the stability index at the depths assessed revealed a significant difference for corn grown in monoculture. At a 0-0.10 m depth there was an increase of4.9% in the stability index and this can promote greater resistance to erosive processes**.**

IV. Conclusion

The yield of corn intercropped with cover crops was similar to that of corn grown in monoculture.

Brachiaria ruziziensis grown in monoculture or intercropped with corn produced a large amount of straw and favors soil aggregation. Thus. it is a good way to improve soil physical properties and soil conservation.

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