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# Physical properties of soil and productivity of maize intercropped with different cover plants

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**The system of intercropping maize with other plant species has been a common practice for several years, but its use has been increasingly mainly to improve the quality of soil physical properties of no-tillage system. The objective of this study was to investigate the effect of intercropping using different cover plants on the physical properties of soil and the productivity of maize. Field experiments were conducted on the property of Mr. Arno Paulo Deimling, located in Linha São João, in the municipality of Quatro Pontes-PR. The experiment was carried out using a randomized complete block design, with four treatments and five repetitions. The treatments were winter maize intercropped with *Urochloa brizantha*, *Urochloa ruziziensis* or black oats (*Avena strigosa*), and maize sown in monoculture. In winter period, the production of maize used for silage and the production of dry matter from cover crops were assessed. The physical properties of soil samples were also investigated. Cover crops did not influence the productivity of winter maize used for silage, but it promoted improvements in soil macroporosity. The cover crops promoted improvements in the macroporosity of the soil and reduction at soil penetration resistance, particularly in the area planted with *U. brisantha*, demonstrating its potential in improving water infiltration and soil aeration.**

**Key words:** Direct seeding system, green manures, macroporosity, soil penetration resistance, conservationist system.

## INTRODUCTION

Increasing agricultural production without adversely affecting the environment is a big challenge for technology. The use of management practices and soil conservation is one of the means of maintaining or improving production systems. Among the management practices employed is the no-tillage system, the use of green manure and intercropping systems (Board and Modali, 2005).

Intercropping between grain and forage plants is possible due to the time and space differential in the

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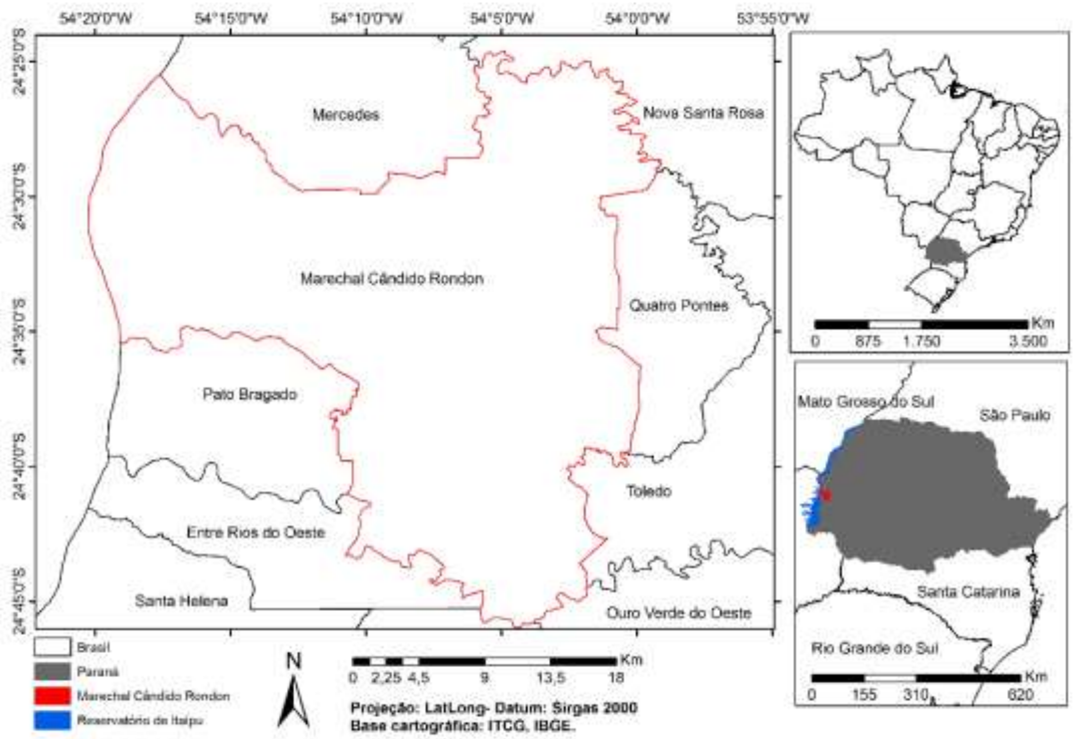


**Figure 1.** Location of Marechal Cândido Rondon/Paraná/Brazil.

accumulation of biomass between the species (Kluthcouski and Yokoyama, 2003). In the management system with intercropping plants, there is a higher production of dry mass of the aerial part, and of the root system. The roots release exudates and mucilage; involving the soil particles promoting their aggregation, reflecting on the increase of bulk density, macroporosity, aeration and infiltration of water in the soil. The objective of this system is to maintain the physical, chemical and biological properties of the soil, which reflects in the good development of the intercropped commercial culture, as well as in successor crops (Tirloni et al., 2012).

In the western region of Paraná, farmers carry out diverse agricultural activities, including pig farming, dairy farming, beef cattle, and cultivation of grains, mainly soybean and maize. It is a common practice to produce maize silage, which is used to feed dairy cattle. With silage production and even with grain production, there is insufficient plant cover for a no-tillage system (Mendonça et al., 2014) due to the transportation of plant material during the silage process. This leaves the soil completely unprotected, making it more susceptible to erosion, compaction and degradation. To help reverse the physical degradation of the soil, as well as avoid the loss of crop productivity, numerous soil management practices are recommended, such as no-tillage, green manuring, intercropping and crop rotation (Andreola et al., 2000).

According to Castoldi et al. (2011), when maize is associated with cover crops such as oats (*Avena* species) and Brachiaria, this provides a sustainable production system. In this system, management and conservation ensure that natural resources are used in a more appropriate way.

In addition, this system is considered to be economically viable. The maize crop is one of the most favorable to the practice of the intercropping, due to plant height and height of spike insertion. Therefore, maize harvesting, either as dry grain or as silage, can be carried out without interfering with the development of forage plants (Alvarenga et al., 2006).

The objective of this experiment was to evaluate the effect of intercropping maize with different cover plants on soil porosity, soil penetration resistance, as well as maize yield.

## MATERIALS AND METHODS

### Description and location of the experimental site

The experiment was conducted on a commercial property belonging to Mr. Arno Paulo Deimling, located in the São João Line, municipality of Quatro Pontes-PR, coordinates 24°34'8.32 "S 54°0'2.46" O (Figure 1), during the season 2014 to 2015. The soil was classified as an Oxisol with clayey texture (Santos et al., 2013). Before the planting started, samples of soils were collected at a depth of 0 to 0.20 m, for the purpose of chemical characterization. The analyses were performed according to the methodology described by Donagema et al. (2011), and soil granulometry according to the recommendations described by Santos et al. (2013).

### Soil sampling and analyses of chemical properties

Before the experiment started, soil samples were collected at a depth of 0 to 0.20 m, and analysed for chemical properties and particle size characteristics. Chemical and physical analyses were performed according to the methodology proposed by Raij et al. (2001). Clay content was 532.5 g $kg^{-1}$, silt was 422.62 g $kg^{-1}$ and sand was 44.88 g $kg^{-1}$. The results of chemical analysis of soil samples are as follows:

pH ($CaCl_2$) 4.83; organic matter 28.71 g $dm^{-3}$; P ($Mehlich^{-1}$) 45.77 mg $dm^{-3}$; $Ca^{2+}$ 5.84 $cmol_c$ $dm^{-3}$; $Mg^{2+}$ 2.02 $cmol_c$ $dm^{-3}$; $K^+$ 0.46 $cmol_c$ $dm^{-3}$; $Al^{3+}$ 0.00 $cmol_c$ $dm^{-3}$; and base saturation (V%) 59.09%.

### Experimental design and treatments

The experiment was conducted using a randomized complete block design, with four treatments and five replicates. The treatments used were maize intercropped with *Brachiaria brizantha* (*Urochloa brizantha*), *Brachiaria ruziziensis* (*Urochloa ruziziensis*) and black oats (*Avena strigosa*) and maize sown alone (control).

### Soil sampling and analyses of porosity, bulk density and soil penetration resistance

The evaluation of the total porosity, macroporosity, microporosity, soil bulk density and soil resistance to penetration were made after desiccation of the cover plants. Physical analysis of soil samples was carried out using the methodology proposed by Santos et al. (2013).

Soil samples were collected with their structure preserved using metallic rings of known volume, at depths of 0 to 0.10 m and 0.10 to 0.20 m. After collection, samples were saturated for 24 h in a tray containing water at a depth of up to two-thirds of the ring height.

After the saturation period, samples were drained at the potential equivalent to -0.006 MPa using a tension table method. The macropores volume was estimated as the difference between the water content of the saturated soil and the water content of the soil after applying the potential of -0.006 MPa.

The micropores volume was calculated as the water content retained at the potential of -0.006 MPa. The total porosity was calculated as the sum of macroporosity and microporosity. Soil bulk density was determined using the volumetric ring method, in which undisturbed soil samples were oven-dried at 105°C for 24 h (Santos et al., 2013).

In order to evaluate soil resistance to penetration, an impact penetrometer model (Stolf, 1991) was used. For determination of the gravimetric moisture content of soil, samples were collected at the time of analysis at depths of 0 to 0.10 m and 0.10 to 0.20 m.

### Management and cropping systems

In February 2014, maize (Pioneer 30F53 variety) was mechanically sown in a no-tillage system at a density of 50,000 plants $ha^{-1}$, with 0.70 m spacing between rows. Basic fertilizing was performed using 310 kg $ha^{-1}$ of a 10-15-15 formulation (N, $P_2O_5$ and $K_2O$, respectively).

Thirteen days after sowing, the forage species used for intercropping was manually sown in inter-row spaces at rates of 12 kg $ha^{-1}$ for *B. brizantha* (*U. brizantha*), 12 kg $ha^{-1}$ for *B. ruziziensis* (*U. ruziziensis*) and 80 kg $ha^{-1}$ for black oats (*A. strigosa*). During the course of the experiment, rainfall data were collected on a monthly basis.

Harvesting of maize for silage was performed when the maize was in the R5 stage of growth (farinaceous grains). The plants of the three central rows were cut manually. The cutting height was 0.20 m above ground level. Plants were then crushed, collected in sacks and taken to the laboratory to be weighed on a digital scale with a precision of 5 g. The results were used to calculate silage production (kg $ha^{-1}$).

After cutting the maize for silage, the area was fenced and intercropping plants remained in the area until August. After that, production of dry matter within each treatment was determined. This assessment was performed using an inventory square. The area was then desiccated using 2.75 L $ha^{-1}$ of glyphosate.

### Statistical analysis

The data were subjected to analysis of variance with a significance level of 5% for the F-test. When significant, the averages were compared using the Tukey's test at 5% probability, using the statistical software SISVAR® (Ferreira, 2011).

## RESULTS AND DISCUSSION

### Production of dry mass of cover plants

At the beginning of maize crop growth (February, 2014), a water deficit occurred with a monthly precipitation of 33 mm. This was anticipated to affect the development of maize silage and consequently its productivity (Figure 2).

Table 1 shows the average productivity results for the dry mass of maize silage and cover crops. It was verified that there was no effect of the intercropping in the production of dry mass of the winter maize silage, even with water deficit. It is observed that the average production of silage was of 2,497 kg $ha^{-1}$. This result is considered to be low for the region.

Reduced production occurs due to a water deficit occurring at the beginning of crop development. According to results obtained by Pinho et al. (2002), the average production of corn silage is 12.400 to 20.000 kg $ha^{-1}$, and for Pinho et al. (2007) values it varied from 8.000 to 23.000 kg $ha^{- 1}$. These yields are well above those reported in this experiment.

Dry mass production data for the intercropped plants showed significant differences between treatments (Table 1). The highest dry mass production was with black oats (3027.31 kg $ha^{-1}$), which was significantly higher than with *U. brizantha* (2287.84 kg $ha^{-1}$; $p<0.05$) or controls (spontaneous plants) which produced the lowest yield (892 kg $ha^{-1}$).

Therefore, black oats contributed 29.5% dry matter to the soil. Increased amount of cover straw in the no-tillage system will result in greater soil protection from rainfall impact, lower incidence of solar rays under the soil, and consequently increase in available water for plants

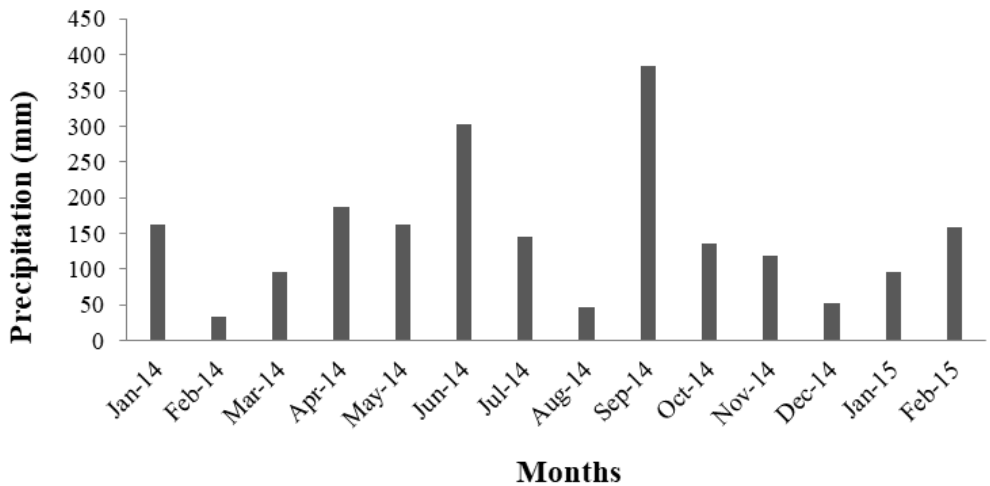


**Figure 2.** Monthly accumulated precipitation during the experimental period. SM: Sowing maize. Source: Agrícola Horizonte Ltda., Quatro Pontes-PR, Brazil.

**Table 1.** Mean results for dry mass of silage from intercropped maize and cover crops used in intercropping.

| Treatment | Dry mass of silage (kg ha$^{-1}$) | Dry mass of cover plants (kg ha$^{-1}$) |
|---|---|---|
| Maize + Brachiaria ruziziensis | 2526.77$^{a}$ | 2723.88$^{ab}$ |
| Maize + oats | 2609.06$^{a}$ | 3027.31$^{a}$ |
| Maize + Brachiaria brizantha | 2360.80$^{a}$ | 2287.84$^{b}$ |
| Maize not intercropped (spontaneous plants) | 2493.00$^{a}$ | 891.76$^{c}$ |

Means followed by the same lowercase vertical letters do not differ significantly from each other according to the Tukey's test (5%).

**Table 2.** Mean results for macroporosity, microporosity, total porosity and soil density in soil samples collected at depths of 0-0.10 and 0.10-0.20 m, after intercropping using different winter cover crops.

| Treatment | Macroporosity (m³ m$^{-3}$) | | Microporosity (m³ m$^{-3}$) | |
|---|---|---|---|---|
| | **0-0.10 m** | **0.10-0.20 m** | **0-0.10 m** | **0.10-0.20 m** |
| Maize + *Brachiaria ruziziensis* | 0.06$^{Aab}$ | 0.06$^{Aab}$ | 0.44$^{Aa}$ | 0.41$^{Aa}$ |
| Maize + oats | 0.05$^{Ab}$ | 0.06$^{Ab}$ | 0.47$^{Aa}$ | 0.48$^{Aa}$ |
| Maize + *Brachiaria brizantha* | 0.07$^{Aa}$ | 0.07$^{Aa}$ | 0.49$^{Aa}$ | 0.49$^{Aa}$ |
| Maize not intercropped | 0.04$^{Ab}$ | 0.04$^{Ab}$ | 0.48$^{Aa}$ | 0.47$^{Aa}$ |
| | **Total porosity total (m³ m$^{-3}$)** | | **Bulk density (mg m$^{-3}$)** | |
| Maize + *Brachiaria ruziziensis* | 0.50 $^{ns}$ | 0.47 $^{ns}$ | 1.31 $^{ns}$ | 1.35$^{ns}$ |
| Maize + oats | 0.52 | 0.54 | 1.29 | 1.27 |
| Maize + *Brachiaria brizantha* | 0.56 | 0.56 | 1.30 | 1.28 |
| Maize not intercropped | 0.52 | 0.51 | 1.28 | 1.29 |

Means followed by the same capital letters in horizontal and low in the vertical do not differ statistically from each other by the Tukey test (5%).

(Bescansa et al., 2006).

## Porosity and bulk density of soil

Table 2 shows that there was effect of cover plants for macroporosity, microporosity, and soil bulk density. In the area planted with *B. brizantha* (*U. brizantha*), soil samples collected at a depth of 0 to 0.10 m presented the highest values for macroporosity (0.07 m³ m$^{-3}$).

These values differed significantly from the area planted

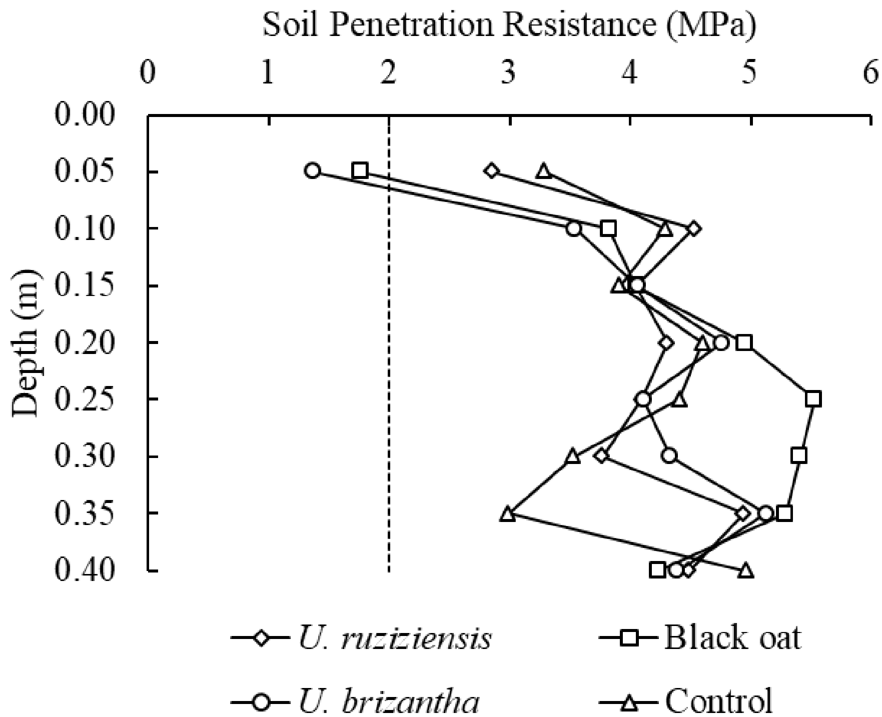


**Figure 3.** Soil penetration resistance after cultivation of maize intercropped with different winter cover crops.

with oats (0.05 m³ m⁻³) and the control area (0.04 m³ m⁻³), but were not significantly different to the area planted with *B. ruziziensis* (*U. ruziziensis*; 0.06 m³ m⁻³).

A similar result was observed in samples collected at a depth of 0.10 to 0.20 m, demonstrating the potential for *Brachiaria* species to improve this physical property of soils. Brachiaria plants have a fasciculate root system with extensive root production. This large root volume decompresses the soil, releases exudates and increases soil microbiota, resulting in an increase in soil aggregation and consequently changes in the macroporosity (Salton and Tomazi, 2014).

Macroporosity values for the control samples (0.04 and 0.04 m³ m-³) are low, indicating physical impediments to root development (Table 2). Macroporosity values should be 7 to 10% (0.07 to 0.1 m³ m-³) of the total soil volume to allow gas and liquid exchange between the soil and the atmosphere (Drewry et al., 2003). Values below 10% hinder the aeration process and water conduction in the soil (Beutler et al., 2001; Secco et al., 2005). This can lead to a reduction in productivity in adverse climatic conditions.

Results for microporosity, total porosity and soil density showed no significant differences between treatments. These results agree with those of Almeida et al. (2008) who reported that, with only one crop cycle, these physical characteristics of the soil were not altered. The extensive root systems of cover crops promoted the decomposition, due to the presence of channels that facilitate water infiltration and diffusion of gases. This leads to improvements in soil physical quality for the next crop (Foloni et al., 2006).

For clay soils, the appropriate values of total porosity vary between 0.43 and 0.52 $m^3$ $m^{-3}$ (43 and 52%), and are strongly influenced by the type of crop, vegetation and soil compaction (Michelon et al., 2009).

## Soil penetration resistance

The determination of soil penetration resistance was performed when the soil presented gravimetric moisture of 0.23 kg $kg^{-1}$ or 23%. The soil penetration resistance at different depths was statistically different in layers 0 to 0.05 m. Treatment with *U. brizantha* resulted in lower penetration resistance values at a depth of 0 to 0.05 m, and differed significantly from values obtained with *U. ruziziensis* (Figure 3). The results of soil penetration resistance at different depths showed that the values increased in the depth of 0.05 to 0.10 m, indicating soil compaction from this depth. Most values were above 2 MPa, therefore, above the critical value of 2.0 MPa, considered critical for a majority of crops (Santos et al., 2015), but this limit may vary from 2 to 3 MPa (Imhoff et al., 2000) as a function of the soil unit at the time of evaluation.

## Conclusion

The highest production of dry mass from the cover crops investigated was reported for oats and *U. ruziziensis*, and the cover plants used in this study did not reduce the productivity of maize used for silage. These results indicate that the intercropped system is an excellent option for the producer to increase the organic matter content of the soil, increase the straw on the surface, resulting in less impact of the raindrops, and decrease in soil temperature. The cover crops promoted improvements in the macroporosity of the soil and reduction at soil penetration resistance, particularly in the area planted with *U. brisantha*; demonstrating its potential in improving water infiltration and soil aeration.

## CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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