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Soybean emergence and development under Brachiaria and wheat residues

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Abstract: Much of soybeans area cultivated in Brazil uses the no-till system, where the residues produced by crops remain over the soil, reducing its temperature, increasing its moisture and providing a better development of the plant. However, the excessive amount of residues can cause problems, reducing the germination of seeds and growing smaller plants. That said, the aim of this study was to determine the wheat (*Triticum aestivum*) and brachiaria (*Brachiaria ruziziensis*) straw volumes that enable better soybean plant growth, increase moisture and reduce soil temperature, and to minimize the negative effects on emergence plants in a sandy Ultisol of Sandstone Caiuá region of Northwest Paraná state. The experiment was conducted in vases, using a 2x6 factorial with two sources of residues, *Brachiaria ruziziensis* and *Triticum aestivum* and 6 doses of residues, 0, 2, 4, 8, 16 and 32 t ha^{-1}, with 4 repetitions. It was evaluated the seedling emergence at 14 days after sowing, the fresh and dried mass of the aerial part of plants and plant roots, and the average height of the plants at 45 days after sowing. It was also evaluated the gravimetric soil moisture, the minimum and maximum temperature of the day on the ground, as well as the thermal range due to the doses and straw sources. The increase in straw doses resulted in an increase of soil moisture, average height and dried mass of plants, there was a reduction in maximum temperature and thermal soil range. However, there was a reduction in seedling emergence percentage as was increased the dose of residues. It was determined the 2.52 (± 0.33) t ha^{-1} of residues of brachiaria and wheat deposited over the soil as the optimum range for the development of soybean plant.
Keywords: *Brachiaria ruziziensis,* criteria, *Glycine max,* soil cover, *Triticum aestivum.*

Introduction

Approximately 79% of the 34 million hectares cultivated with soybeans in Brazil, use no-till planting system (BRÜGGEMANN, 2011), a conservationist system, with minimum soil moving, preserve the physical, chemical and biological characteristics of those soils (EMBRAPA, 2011).

In the no-till, the crop rotation is an accessory process for maintaining the system working, which brings straw to the soil, raising the soil fertility and reducing the attack of pests and diseases (DUARTE JUNIOR & COELHO, 2010).

The choice of the plants that will cover the soil should be based on the species ability to produce higher biomass (SEDIYAMA, 2009). Thus, the crop-livestock integration system is presented as an alternative to direct plant by providing straw to the system, producing grains and rotating species in the area (CASTALDO et al., 2015).

Several studies have shown that the soil cover with straw raises the moisture and reduces soil temperature resulting in an positive effect on crop development (HAY et al., 1978; CUTFORTH et al., 2002; KLOCKE et al., 2009; MITCHEL et al., 2012), since the temperature is one of the main meteorological factors that affect the biomass accumulation and development of species (BERLATO, 1981), specifically to the soybean, which temperatures above 40°C result in an adverse effect on growth and flowering (EMBRAPA, 2011).

Practices that privilege covering the soil with straw, usually result in influence to physical attributes of sandy soils more than in clay soils (COSTA et al., 2003), making them important to the Sandstone Caiuá region of Northwestern Paraná, formed mainly by sandy soils and low production intensity (CASTALDO et al., 2015). However, most of the available literature, does not understand the climate and soil conditions present in this region and also have no tools to determine the optimal amount of straw to be deposited on the ground necessary to have the beneficial effects of soybean plant.

The establishment of crops in the integrated system can be adversely affected by the adopted mechanical practices (CASTALDO et al., 2016) or by deposition of straw on the ground, which can reduce the percentage of emergence of soybean seedlings by physical barriers imposed by straw and system to the plant development (KRUTZMANN ET AL., 2013; REIS et al**.**, 2014.).

The objective of this study was to determine the wheat (*Triticum aestivum*) and Brachiaria (*Brachiaria ruziziensis*) straw volumes that enable better soybean plant growth, increase moisture and reduce soil temperature, and to minimize the negative effects on emergence plants in a sandy Ultisol of Sandstone Caiuá region of Northwest Paraná state.

Methods

The experiment was conducted between October and November of 2015 in the experimental area of Maringa State University, regional campus of Umuarama, located in the northwestern region of Paraná (Sandstone Caiuá), the geographical coordinates S 23º47'20,4 "; W 53º15'25,2 " and altitude of 396 m above sea level. It was used as an experimental base one sandy Ultisol originally under native forest (Table 1).

The experiment was assembled in vases that measured 14 cm diameter x 14 cm height, which was filled with soil collected and incubated near field moisture capacity for 40 days for structural reorganization of their particles. It was used the experimental randomized block design with four replications. The experimental design was a factorial 6x2 (6 doses x 2 straw sources).

The straw doses analyzed were: 0, 2, 4, 8, 16 and 32 ton ha^{-1} (0, 3, 92; 7.84; 15.68; 31.36 and 62.72 g $vase^{-1}$, respectively). The origins of straw were *Brachiaria ruziziensis* (Brachiaria), obtained in cultivated pasture, cut at 15 cm from the ground and, *Triticum aestivum* (Wheat), obtained after commercial harvest in the region, consisted by all residues expelled by the harvester. Both materials were dried at 65°C with air circulation until they have reached constant weight. The number of sample units totaled 48 vases.

It was sown 30 seeds of soybean variety DONMARIO 6563 I-PRO in each vase at 3cm deep and then added to the volume of dried and weighed straw for each treatment over the ground. Systematic irrigations of 25 mm (500 ml $vase^{-1}$) were performed at intervals of 4 days to maintain satisfactory moisture for development of the crop during the whole cycle (GUERRA et al., 2005).

The seedling count to determine the emergence of the plants was performed at 14 days after sowing, were was counted only fully emerged seedlings and had the initial unifoliate expanded leaves and/or the first expanded trifoliate (BARROS & MARCOS FILHO, 1997). After counting of emerged seedlings, it was proceeded a roughing, remaining only two seedlings in each vase, for the evaluation of the soybean development. After 45 days of sowing, it was proceeded the evaluation of the development of soybean plants, where it was evaluated the average height of the plants (SCHUAB et al., 2002), the fresh and dried plants and roots mass, where fresh mass was obtained after cutting the plants and wash the roots with water, dried mass were obtained after drying the material for 48 hours at a temperature of 65^{o}C with air circulation (NOLLA et al., 2015).

To evaluate the soil temperature, two days after last irrigation, it was performed two temperature determinations, at 6:00 a.m. and 3:00 p.m., the first to set the minimum temperature of the day and the second, to determinate the maximum day temperature. It was used geothermometers settled at 3 cm depth in each vase (ELTZ & ROVEDDER, 2005). In addition, it was determined the ambient temperature on both times, using a Mercuric thermometer. The determination of the soil thermal range of the day was settled by the difference between the maximum and the minimum temperatures. The reduction of temperature of each time was determined by the difference between the soil and the ambient temperatures.

After analyzing the temperature, one sample of the soil measuring 50 cm^3 was collected in the 0 to 5 cm depth range, for evaluation of gravimetric moisture of the soil due to the used cover. It was proceeded to the weighing of fresh soil and after drying for 24 hours at a temperature of 105°C with air circulation, the dry soil weight, and then determine the percentage of humidity in the soil (EMBRAPA, 2011).

The data were subjected to ANOVA and when significant, the averages were compared by Tukey test at 5% significance for the types of straw and submitted to polynomial regression analysis, testing the linear and quadratic models, for cover doses.

Table 1. Chemical and granulometric characterization (0-20 cm) of a Ultisol used as the experimental base.

pH	Ca^{+2}	Mg^{+2}	K^{+}	Al^{+3}	H^{+}+Al^{+3}	CEC[1]	P	BS[2]	Al^{+3}	Clay
$CaCl_2$	-------------------$cmol_c$ dm^{-3}-------------------						mg kg^{-1}	---------------%-----------------		
4,10	0,34	0,13	0,04	0,93	3,18	3,69	3,14	13,82	25,20	13,56

[1]Cationic exchance capacity [2]Base saturation of CEC. Extractors: P e K^{+} = Melich I (HCl 0,05 mol + H_2SO_4 0,0125 mol); Ca^{+2}, Mg^{+} e Al^{+3} = KCl 1 mol; Granulometric analysis followed BOUYOUCOS (1926).

Results and discussion

Through data analysis of ANOVA (Table 2), it was found significant differences at 1% of probability for straw doses in variable gravimetric soil moisture, demonstrating that the origin of straw has no influence on soil moisture, only the deposited dose influences to change the soil moisture. For variable temperature range and reduction in the maximum temperature of the day, there was a significant interaction between the origins of the straw and the doses used, which shows different responses of origin and dose in these variables.

The soil moisture was adjusted to the linear regression model (Figure 1A), which indicates that the deposited straw volume directly influences the increase of moisture in the soil, probably by the less evaporation occurring in the soil due to the presence soil cover (HECKLER & SALTON, 2002). Adding to that, the reduction in maximum temperature and thermal range of soil observed in treatments with higher straw volumes (Figure 1B and 1D), which may have contributed to the lowest evaporation of water from the soil.

The maximum soil temperature had less reduction in the treatments with lower volumes of straw because, without straw, the solar radiation hits directly on the soil, increasing its surface temperature and facilitating its deep penetration (STRECK et al., 1994). With the heat of the soil subsurface, its reduce the temperature range and variation in surface soil moisture (PITELLI & DURIGAN, 2001). The best effect in reducing the soil temperature as it increases the straw volume deposited on the soil was also demonstrated by Gasparin et al. (2005), who observed a greater decrease in the temperature of the soil as the volume of straw deposited was increased.

The lack of influence of the treatments on the minimum temperature (Figure 1C), can be explained because, as the soil lose moisture and heat during the night, it tends to resume its minimum temperature in the morning, warming up only from the interception of sunlight during the day over its surface (GASPARIN et al., 2005). This was shown by Bortoluzzi & Eltz (2000), who also observed no significant change in the minimum temperature of the soil due to the presence or absence of straw over the ground, however, they observed, as in this experiment, significant reduction in the maximum temperature of the day when there was straw on the soil.

The difference in the maximum temperature reduction efficiency and thermal amplitude between the straw origins, observed in this experiment can be explained by their physical characteristics (color, type, and how they are distributed on the ground). Which results in different efficiencies of coverage and protection of the soil, affecting the influence of these covers on the soil thermal regime (SALTON & MIELNICZUK, 1995). Still, other studies have also found different responses in relation to the reduction of temperature and temperature variation in the soil, when evaluating different source materials used as ground cover (PERIN et al., 2004; TORRES et al., 2006; CARDOSO et al., 2013).

Wheat straw has a lower density (mass/volume), due to its composition, having stems, cylindrical and tender, which do not provide a perfect arrangement of the straw, enabling an efficient gas exchange between the atmospheric air and microenvironment inside the straw. The brachiaria, in other hands, presents primarily, thin sheets, which are accommodated to form a cohesive block, where the heat diffusion to the microenvironment of the atmospheric air is reduced.

Through ANOVA of the data of percentage of germination and development of soybean plants (Table 3), it was found significant differences at 1% probability for straw doses over the emergence percentage of seedlings at 14 days after sowing, average height and dry mass of aerial part of soybean plants at 45 days after sowing, demonstrating that the straw dose deposited in the soil has great influence on seedling emergence and its initial development.

Table 2. Summary of ANOVA and F values calculated according to test F and, average values for the variables gravimetric moisture in the soil (%Moisture), temperature range (Temp.Range), reduction in the minimum temperature of the day (Min.Temp.Reduction) and reduction in the maximum temperature of the day (Max.Temp.Reduction).

Source of variation	%Moisture	Temp.Range	Min.Temp.Reduction	Max.Temp.Reduction
Straw source (S)	0.048^{ns}	25.513**	0.000^{ns}	25.513**
Cover dose (D)	3.248**[1]	57.563**	0.500^{ns}	57.563**
S x D	1.564^{ns}	4.296*	0.300^{ns}	4.296**
Average	6.68	18.64	0.16	8.64
C.V. (%)	6.01	4.75	24.49	10.25

Where: C.V.: Coefficient of variation; [1] significant at 1% of probability by F test.

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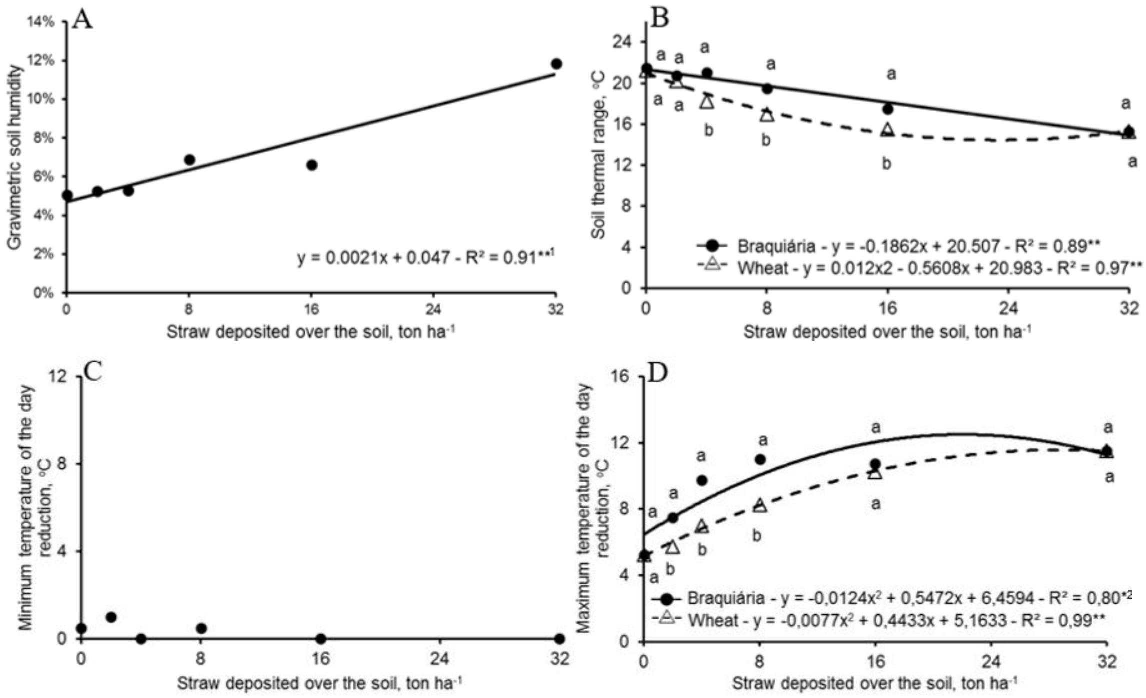

Figure 1. Gravity moisture in the soil (A), soil thermal range (B), reduction in the minimum temperature of the day (C) and reduction in maximum day temperature (D) of an Ultisol originated from Umuarama region PR due doses and sources of straw deposited over the soil. Where: [1] and [2]: significant adjust at 1% and 5% of probability, respectively. Averages followed by the same letter at the same dose, do not differ according to the Tukey test at 5% of probability.

Table 3. Summary of ANOVA, F values calculated according to test F, significance of the F values and average of values obtained for the seedlings emergence variables (%Emergence), average plant height (Height), Fresh (FreshAerial) and dried (DriedAerial) mass of aerial part of plants, fresh (FreshRoots) and dried (DriedRoots) mass of the roots of the soybean plants.

Source of variation	%Emergence	Height	FreshAerial	DriedAerial	FreshRoots	DriedRoots
Straw source (S)	0.772^{ns}	0.585^{ns}	1.012^{ns}	3.538^{ns}	1.285^{ns}	0.229^{ns}
Cover dose (D)	25.764**[1]	4.664**	1.373^{ns}	4.569**	1.654^{ns}	0.851^{ns}
S x D	0.299^{ns}	3.072*	0.898^{ns}	1.593^{ns}	0.419^{ns}	1.460^{ns}
Average	38.47	22.77	4.21	1.25	19.92	3.69
C.V. (%)	24.71	7.46	34.30	25.05	22.67	30.11

Where: C.V.: Coefficient of variation; [1] significant at 1% of probability by F test.

According to the significance observed in Table 3, the data of the emergency percentage of seedlings 14 days after sowing, average height and dried plant mass at 45 days after sowing, was submitted to the linear and quadratic adjustments polynomial regression (Figure 2).

According to the volume of straw deposited on the ground, the emergence percentage of seedlings 14 days after sowing had a significant quadratic effect (Figure 2A), whereas it increased the volume of straw deposited on the ground, it dropped the percentage of seedling emergence, and, at the maximum tested straw dose, emergence practically inhibited in its entirety.

This result occurs because when adding straw on the ground, it creates a physical barrier that the seedling will have to overcome in the emergence process. Thus, when this barrier becomes thicker and voluminous, with increasing straw dose, it is needed by the seedling, a greater strength to overcome this physical barrier, hindering plant establishment (HECKLER & SALTON, 2002).

As increased the volume of straw over the soil, the average height (Figure 2B) and dry mass of aerial part (Figure 2C) of soybean plants behaved in a quadratic regression, where the optimum dose obtained by derivation of regression equations for these variables, were observed at doses of 20.92 and 17.87 t ha^{-1}, for medium height and dry weight of plants, respectively.

The drop in average height and plant dried mass observed in higher doses can be explained because, in situations with excessive volume of straw, the plants tend to have reduced stature (REIS et al., 2004), due to the natural decomposition process of straw, increasing the population of microorganisms (MOREIRA & SIQUEIRA, 2002), which can be harmful to the plants, or by release of allelopathic compounds during decomposition of the material deposited on the ground (GUENZI et al., 1967), especially in *Brachiaria ruziziensis* and wheat (BORTOLINI & FORTES, 2005; SOUZA et al., 2006).

The development of data observed at emergence and dried aerial part of plant mass and average height of plants suggest that as it increases the amount of straw over the soil, the plant develops better, however, the emergence of these, drops, annulling the gain of plant development. Trough that, it was assumed that the highest values of germination percentage, average height and dried aerial part of plant mass obtained represented 100% of the straw enhancement to the crop, and it was overlapped the resulting charts of this transformation. According to this, it is possible to suggest ranges of straw doses, where there is the best performance of the soil cover (Figure 3).

Analyzing the charts and evaluation of the intersection point of the resulting curves and standard deviations observed in the data analysis, it is recommended a straw dose of both *Brachiaria ruziziensis* as wheat, at 3.05 (± 0.33) t ha^{-1} for the best establishment and dry mass accumulation at 2.05 (± 0.34) t ha^{-1} for establishment and plant height in soybean in sandstone Caiuá. That way, the average value of 2.52 (± 0.33) t ha-1 for both straws represents the best dose to this location. This value is lower than the recommended by Franchini et al. (2008), at 8 t ha^{-1} of straw distributed to provide a complete and lasting soil cover.

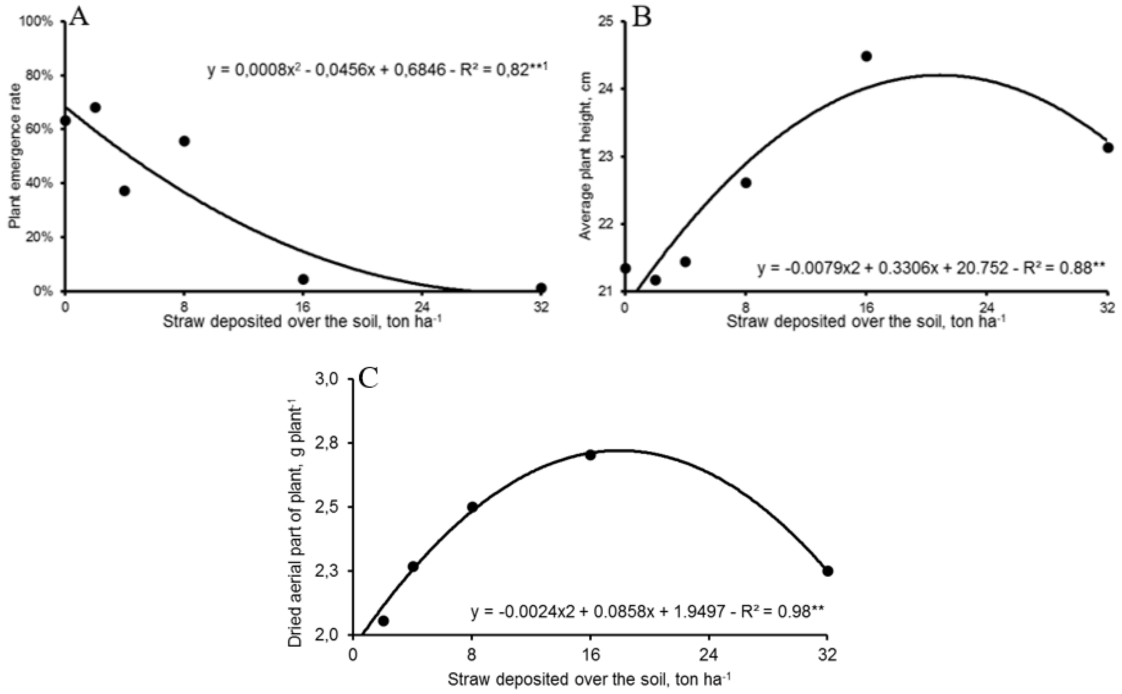

Figure 2. Percentage of seedling emergence at 14 days after sowing (A), average plants height (B) and dried mass of the aerial part (C) of soybean plants at 45 days after sowing, grown in an Ultisol from the region of Umuarama, PR, due to straw doses deposited over the ground before soybean sowing. [1]adjust significant at 1% of probability.

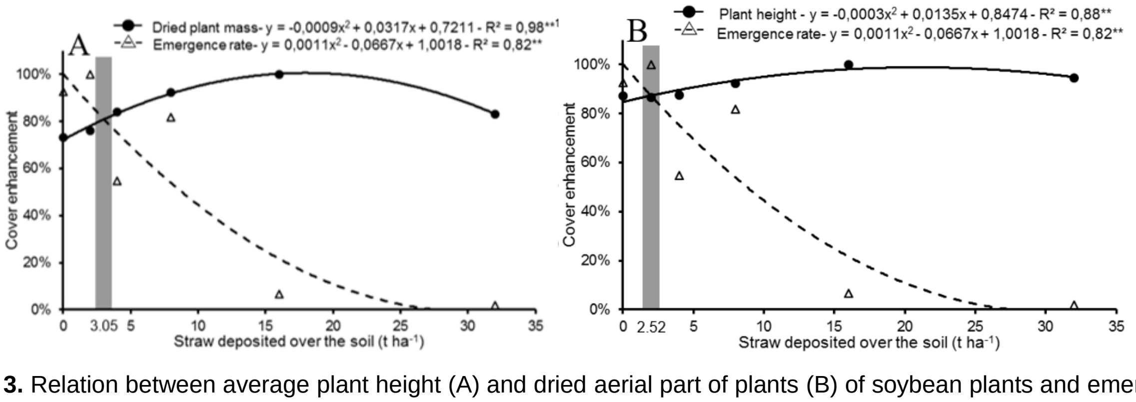

Figure 3. Relation between average plant height (A) and dried aerial part of plants (B) of soybean plants and emergence due to straw doses of *Brachiaria ruziziensis* and *Triticum aestivum* deposited over the ground before soybean sowing. [1]adjust significant at 1% of probability.

Conclusions

The addition of increasing amounts of wheat straw and *Brachiaria ruziziensis* over the soil increased similarly the moisture content of the soil, the height and the dried mass of soybean plants but reduced the percentage of emergence of soybean seedlings.

There were different results to the origin of straw in the reduction of the maximum temperature of the day and day temperature range, where the wheat straw showed a greater reduction of these values at doses lower than those of the *Brachiaria ruzizien*sis.

The deposition of 2.52 (± 0.33) t ha^{-1} of straw over the ground provides the best enhancement of land cover for soybean.

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