Scientia Agraria Paranaensis – Sci. Agrar. Parana.
ISSN: 1983-1471 – Online

PRODUCTIVITY OF CASSAVA GROWN ON MARANDU GRASS STRAW MANAGED THROUGH DIFFERENT GRAZING INTENSITIES

Katia Fernanda Gobbi[1*], Mario Takahashi[2], Jonez Fidalski[3]

SAP 22845 Received: 15/07/2019 Accepted: 13/10/2019
Sci. Agrar. Parana., Marechal Cândido Rondon, v. 18, n. 4, oct./dec., p. 324-333, 2019

ABSTRACT - For cassava farming, conventional soil preparation is traditionally used. However, in recent years, some producers have been showing interest in adopting no-tillage system. We evaluated the cassava yield in conventional tillage or no-tillage systems with marandu grass straw, as well as the straw decomposition and the physical and chemical soil attributes. A completely randomized design with five treatments and four replicates was used. The treatments were no-tillage (NT 0% - no-grazing pasture; NT 25%, NT 50%, NT 75% - grazing intensities to obtain an intake of 25%, 50% and 75% of forage mass, by animals) and conventional tillage (CT 50% - grazing intensity to obtain an intake of 50% of forage mass, before tillage). The soil tillage did not influence fresh and dry weight of cassava roots, with averages of 31.84 and 10.88 Mg ha^{-1}. After 448 days of cassava planting, straw decomposition did not differ between treatments, with an average value of 53%. The half-life time of straw was 221, 218, 263 and 321 days to treatments NT 0%, NT 25%, NT 50%, NT 75%, respectively. We observed that soil physical quality was improved in no-tillage treatment NT 50%, when compared to CT 50%. The residual straw of Marandu grass did not influence the cassava yield in no-tillage, when compared to conventional tillage. Part of the forage available in the pasture can be used for animal feed, before cassava planting.
Keywords: decomposition, integrated crop-livestock system, annual pasture, no-tillage, soil physical quality.

PRODUTIVIDADE DE MANDIOCA CULTIVADA SOBRE PALHADAS DE CAPIM-MARANDU MANEJADO SOB DIFERENTES INTENSIDADES DE PASTEJO

RESUMO - Na cultura da mandioca, tradicionalmente realiza-se o preparo convencional do solo, contudo, nos últimos anos alguns produtores têm demonstrado interesse em adotar o plantio direto. Avaliou-se a produtividade de mandioca em plantio convencional ou plantio direto, sobre palhadas de capim-marandu, bem como a decomposição da palhada e os atributos físicos e químicos do solo. Utilizou-se delineamento inteiramente casualizado, contendo cinco tratamentos e quatro repetições. Os tratamentos avaliados foram plantio direto de mandioca (PD 0% - pasto sem pastejo; PD 25%, PD 50%, PD 75% - intensidade de pastejo para consumo de 25%; 50% e 75% da massa de forragem disponível) e plantio convencional (PC 50% - intensidade de pastejo para consumo de 50% da massa de forragem disponível). A massa fresca e seca das raízes de mandioca não diferiram entre os tratamentos avaliados, com médias de 31,84 Mg ha^{-1} e 10,88 Mg ha^{-1}, respectivamente. Após 448 dias do plantio da mandioca, a decomposição da palhada não diferiu entre os tratamentos, com média de 53%. O tempo de meia-vida das palhadas foi de 221, 218, 263 e 321 dias para os tratamentos PD 0%, PD 25%, PD 50% e PD 75%, respectivamente. Observou-se melhor qualidade física do solo para o tratamento PD 50%, quando comparado ao PC 50%. As palhadas residuais de pasto anual de capim-marandu não influenciaram a produtividade de raízes tuberosas de mandioca em plantio direto, quando comparada ao plantio convencional, ao mesmo tempo que a intensidade de pastejo de 50%, antes do plantio direto, promoveu melhoria na qualidade física do solo. Pode-se utilizar parte da forragem disponível no pasto para alimentação animal, antes do plantio direto.
Palavras-chave: decomposição, integração-lavoura-pecuária, pasto anual, plantio direto, qualidade física do solo.

INTRODUCTION

The Caiuá Sandstone Formation, found in northwestern Paraná, Brazil, is characterized as a typically cattle-raising region and stands out as one of the biggest cassava producers in Brazil. The municipalities of Paranavaí and Umuarama are the main producers, with around 88.000 cultivated hectares and a production of 2.356.000 tons of roots in the 2017/2018 harvest, mostly intended for the starch industry (SEAB/DERAL 2019).

For cassava farming, the soil is traditionally prepared with one plowing and two harrowings, a practice that may generate problems such as erosion, compaction and nutrient loss (GABRIEL FILHO et al., 2000). These issues may be even bigger in sandy soils such as those in

[1]Researcher, Area of Animal Science, Agronomic Institute of Parana (IAPAR), Rua Amador Aguiar s/nº, Jardim Ipê, PO Box 564, 87701-970, Paranavaí, Paraná, Brazil. E-mail: kfgobbi@iapar.br. *Corresponding author.
[2]Researcher, Area of Crop Science, Agronomic Institute of Parana (IAPAR), Rua Amador Aguiar s/nº, Jardim Ipê, PO Box 564, 87701-970, Paranavaí, Paraná, Brazil. E-mail: takaha@iapar.br.
[3]Researcher, Area of Soil Science, Agronomic Institute of Parana (IAPAR), Rua Amador Aguiar s/nº, Jardim Ipê, PO Box 564, 87701-970, Paranavaí, Paraná, Brazil. E-mail: fidalski@iapar.br.

northwestern Paraná, derived from the Caiuá Sandstone Formation.

Cassava is a crop that renders the soil unprotected for a long period due to some of its characteristics, such as slow initial establishment, large spacing in between plants, and soil revolving at planting and harvest, factors that also lead to losses in the soil by erosion (SOUZA et al., 2006)

Studies with different crops confirm the positive effects of minimum tillage, reduced tillage or no-tillage on the conventional tillage of the soil, especially in association with use of ground cover plants (OTSUBO et al., 2012). On the other hand, some studies have shown that no-tillage can lower cassava yield, and this variability, in different types of soil, contributes to the non-adoption of a conservationism-oriented management for this crop (FIGUEIREDO et al., 2017).

In the Northwest of Paraná, cassava cultivation usually enters the system with the purpose of restoring degraded pastures, and conventional tillage is adopted for plantation establishment. However, in recent years, some producers have been showing interest in adopting no tillage, laying cassava crops over the straw of burndown pasture, in order to reduce implementation costs, as well as provide greater protection to the soil.

The benefits of no-tillage cassava crops to the soil are one of the most efficient conservation practices for erosion control (LIMA et al., 2015), but this type of farming may compromise the physical attributes of the soil, which depend on organic matter (FASINMIRIN and REICHERT, 2011) and are verified through the levels of total organic carbon for the physical quality of soils in the region of the Caiuá Sandstone Formation (FIDALSKI et al., 2007).

In general, producers use high grazing intensities to reduce pasture residues for further burndown, without minding criteria concerning the ideal amount of remnant straw. According to CRUZ et al., (2002), an efficient implementation and management of a no-tillage system requires the minimum amount of straw to be permanently kept at around 6 Mg ha^{-1} of dry mass to cover the soil. On the other hand, some producers have been adopting the practice of establishing pastures in the summer, usually with Brachiaria, for subsequent no-tillage cassava crops in the winter, which thus sets an "annual" pasture that can be briefly used for grazing, but whose main goal is to form straw.

No research has yet assessed the proper amount of straw to be used that is beneficial to crop development and soil protection, increasing the sustainability of monocrop cassava production systems, or as part of integrated systems for livestock production.

This study aimed to assess cassava productivity (cultivar IPR B 36), in conventional tillage and no-tillage systems on Marandu grass straws, as well as straw decomposition and the physical and chemical attributes of the soil.

MATERIAL AND METHODS

The experiment was conducted at the experimental station of the IAPAR - Agronomic Institute of Parana, located in the city of Paranavaí, from January 2017 to January 2019. The predominant climate type in the region is *Cfa* - subtropical climate (mesothermal), according to Köppen classification, with hot summers, infrequent frost, and rainfall tending to be concentrated in the summer months. The annual average temperature stood at 24 degrees, and the annual average rainfall was 1520 mm (Figure 1).

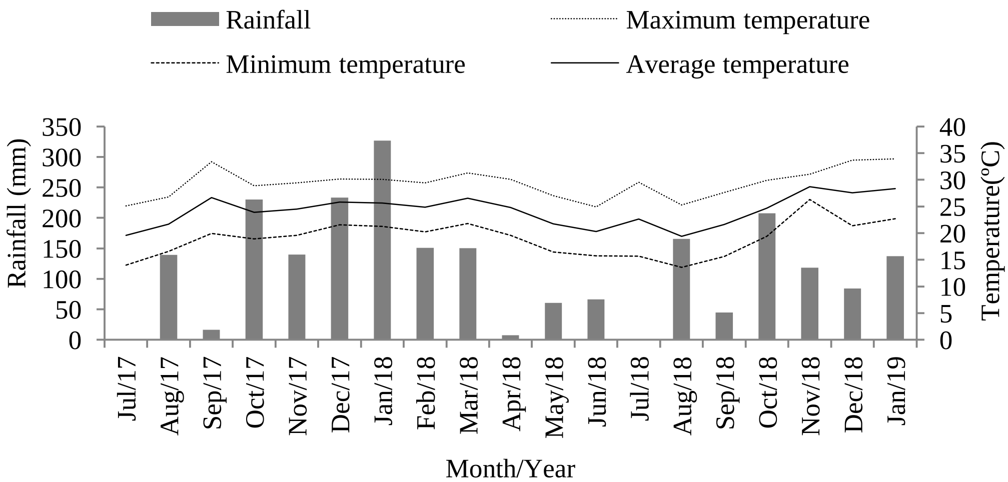

FIGURA 1 - Rainfall, and maximum, average and minimum temperatures during the cassava crop cycle. Source: Meteorological station of IAPAR/Paranavaí.

The soil of the experimental area is classified as Typic Paleudult (Red Argisol Distrofic Latossol), containing 890 g kg^{-1} of sand, 20 g kg^{-1} of silt, and 90 g kg^{-1} of clay in the layer found 0-20 cm deep (MERTEN et al., 2016). Chemical analysis results for the soil before the experiment was implemented, in October 2016, at a depth of 20 cm, presented these values: 24,00 mg dm^{-3} of phosphorus (P); 0.12 $cmol_c$ dm^{-3} of potassium (K^+) (Mehlich^{-1} Extractor); 1.43 cmol$_c$ dm^{-3} of calcium (Ca^{2+}); 0.36 cmol$_c$ dm^{-3} of magnesium (Mg^{2+}) (KCl 1 mol L^{-1} Extractor); 12.07 g dm^{-3} of organic matter (Walkley-Black); pH 4.30 in in calcium chloride solution ($CaCl_2$ 0.01 mol L^{-1}) and 5.60 cmol$_c$ dm^{-3} of cation exchange capacity (CEC) (pH = 7.0).

The experiment was established in an area of annual Marandu grass pasture (*Brachiaria brizantha* cv. Marandu; syn. *Urochloa brizantha* cv. Marandu). In January 2017, the area was conventionally prepared, with one heavy disk harrowing and two leveling disk harrowings, and with correction and fertilization being performed as a function of soil analysis. Afterwards, the Marandu grass was sown with the aid of a hydraulic seeder.

In May 2017, after the Marandu grass was fully established, a uniformization grazing was carried out in the area using crossbred Purunã x Nelore and Purunã x Red Angus heifers.

In July 2017, after the area of the experimental plots was delimited with an electric fence, the treatments were established with the crossbred heifers, using different grazing intensities for the cassava to be planted later. Five groups of animals, with one group per treatment, entered the experimental plots at the same time, only to consume the pasture, with access to water, without being subjected to any type of assessment. A fully randomized design was used, with 5 treatments and 4 repeats, totaling 20 experimental plots (500 m^2), as follows:

- 50% conventional tillage (CT): grazing intensity for intake of 50% of the available forage mass; conventional-tillage cassava.
- 0% no-tillage (NT): no-grazing pasture; no-tillage cassava.
- 25% no-tillage (NT): grazing intensity for intake of 25% of the available forage mass: no-tillage cassava.
- 50% no-tillage (NT): grazing intensity for intake of 50% of the available forage mass; no-tillage cassava.
- 75% no-tillage (NT): grazing intensity for intake of 75% of the available forage mass; no-tillage cassava.

In the conventional tillage area, the soil was prepared with heavy disk harrow, moldboard plow and leveling disk harrow. In all treatments, after grazing by the animals, the residual forage mass was burn down using 1.44 kg ha^{-1} of glyphosate as active ingredient.

Stem cuttings of cultivar IPR B 36 were planted horizontally and mechanically at a depth of 5-10 cm, on August 15, 2017, using a two-row planter composed of a cutting disc, furrow rod, two discs for opening furrows, press wheel, and cover disk, in a spacing of 90 cm in between rows, and 60 cm in between plants, making up a population of 18,519 plants ha^{-1}. The sampling area of the plots took a space of 48.6 m^2, consisting of 6 useful rows measuring 9 m in length, and 90 plants as total density. Planting did not include fertilization due to the initial levels of phosphorus and potassium. A cover fertilization was performed in November 2017 with 240 Kg ha^{-1} of potassium chloride and 70 Kg ha^{-1} of ammonium sulfate.

In July 2018, the cassava was pruned, and harvest occurred in January 2019. Straw decomposition was assessed in the 0% NT, 25% NT, 50% NT and 75% NT treatments, in which cassava was established through no-tillage over residual straws of Marandu grass.

To assess Marandu grass straw decomposition in the cassava plots established in no-tillage, the litter bag technique was adopted (THOMAS and ASAKAWA, 1993).

Before the Marandu grass was burned down with the glyphosate herbicide, pasture dry matter production was assessed in the plots, using a sampling frame measuring 0,24 m^2. Four samples were taken from each plot. The samples were weighed and dried in an oven at 65 °C for 72 h. The dry samples were put inside nylon bags (30 x 30 cm) with a 2 mm mesh. The amount of sample in the bag was proportional to the pasture dry mass produced per area.

The bags were distributed into the plots on the same day, right after cassava was planted. Eight collection periods were assessed (7, 14, 28, 56, 112, 224 and 448 days after distribution in the field). After each collection, the bags were dried in an oven at 65°C so that the remnant straw was weighed.

Straw decomposition was determined by weight difference, calculating the percentage of the remaining material in the bag, based on the initial total amount. The decomposition constant (k) was determined from this first order equation:

$$A_t = A_0 e^{-kt}$$

in which A_t is the quantity of remaining substrate at any t time; A_0 is the initial quantity of substrate (time zero); k is the decomposition constant.

The half-life time ($t_{1/2}$) of the straw was calculated through the following equation:

$$\ln[(A_0/2)/A_0] = -kt_{1/2},$$

In which $t_{1/2}$ = 0.693 k^{-1} (PAUL and CLARK, 1989).

The determinations obtained from the cassava crop harvest were number of tuberous roots per plant (total number of roots divided by total number of plants in the plot); fresh mass and dry mass of the tuberous roots, and dry mass of the roots (oven at 65°C until constant weight). The dry mass of the roots was obtained by correcting the fresh mass of the roots based on their dry matter percentage.

To assess the physical quality of the soil, samples were taken after grazing and before pasture burndown, before the cassava was pruned, and then again before harvest. Undeformed soil samples were collected using volumetric containers (100 cm^3) from the intermediate layers, at depths of 0-10, 10-20 and 20-40 cm.

In laboratory, the samples were saturated in trays with a water blade above two thirds the height of the cylinders. These samples were subjected to a matric potential of -6 kPa on a tension table and dried in an oven at 105 ºC for 24 h so that water and soil masses could be obtained, and so that the density, macroporosity, microporosity and total porosity of the soil could be calculated through the density of the solid parts of the soil (Teixeira et al., 2017).

Deformed soil samples with six sub-samples were taken to compose a compound sample, before the cassava was harvested, from layers at depths of 0-10, 10-20 and 20-40 cm, and used for determining total organic carbon, by means of the Walkley-Black method (TEIXEIRA et al., 2017).

The data found, which met the statistical assumptions of normality and homocedasticity of the variances, were subjected to analyses of variance and mean comparison tests by the t test, at 5% probability, using SAS Software (SAS INSTITUTE, 1999).

RESULTS AND DISCUSSION

The fresh and dry masses of the cassava roots showed no significant differences among the assessed treatments, with the means being 31.84 mg ha^{-1} and 10.88 mg ha^{-1} (Table 1). Although competition, especially for light, when the cassava starts to grow, was very different comparing treatments, due to the height of residual pastures, this aspect did not happen to influence the yields of tuberous roots.

TABLE 1 - Number of roots per plant, root fresh and dry masses, and cassava root dry matter for no-tillage (NT) (no-grazing pasture (0% NT)) and grazing intensity for intake of 25, 50 and 75% of forage mass (25% NT, 50% NT and 75% NT), and conventional tillage (CT) (50% CT).

Variables	Treatments					CV (%)
	CT 50%	NT 0%	NT 25%	NT 50%	NT 75%	
Number of roots/plant	4.20 a*	4.04 a	3.94 a	4.25 a	3.80 a	14.90
Root fresh mass (Mg ha^{-1})	33.05 a	33.88 a	32.23 a	31.33 a	28.69 a	19.83
Root dry mass (Mg ha^{-1})	11.21 a	11.52 a	10.81 a	10.83 a	10.05 a	20.97
Dry matter (%)	33.74 b	33.95 b	33.55 b	34.52 ab	35.02 a	2.05

*Means followed by the same letter in the row do not differ from each other by the “t” test at 5% probability. CV = coefficient of variation.

Besides the number of studies assessing cassava yield according to different soil tillage systems being small, the results found vary. Some investigations show that no-tillage can lower cassava yield (PEQUENO et al., 2007; LAMIDI, 2016), some others have reported no differences between no-tillage and conventional tillage (OTSUBO et al., 2012), and, in some situations, no-tillage has promoted greater yields than the conventional system has (OTSUBO et al., 2008). This difference observed among studies may have been influenced by different factors, including the type of forage used for forming the straw, as well as the age and management of the pasture, with or without maintenance fertilization, and presence or absence of animals grazing (KLIEMANN et al., 2006; TIMOSSI et al., 2007; CARVALHO et al., 2010).

Otsubo et al. (2012) assessed the effect of different soil tillage systems on the yield of cassava of cultivar IAC 15, in Glória dos Dourados (Mato Grosso do Sul, Brazil), in soil with sandy texture. The authors also found no significant differences as to root fresh mass yield between the conventional tillage and no-tillage treatments over oat straw, with a mean of 52.1 mg ha^{-1}.

In a research conducted in Araruna, northwestern Paraná, same region as that of the present study, Pequeno et al. (2007) observed that the conventional tillage system led to a greater production of aerial parts and tuberous roots for cassava (24.7 mg ha^{-1}) compared to minimum tillage (20.5 mg ha^{-1}) and no-tillage (18.2 mg ha^{-1}). Four agricultural years were assessed, using different annual cover crops before cassava was planted; black oat + forage turnip in the first two years, and millet in the following years. The authors did not inform the amount of residual straw produced, but the different foragers used may have an influence on the divergence of results concerning the present study with Marandu grass.

The conventional tillage of IAC 576-70 table cassava was compared to no-tillage by Devide et al. (2017), in Pindamonhangaba, São Paulo State (Brazil). In the no-tillage system, the authors assessed cassava yield on residues of sorghum, crotalaria, consortium (sorghum and crotalaria), *Brachiaria decumbens* and *B. ruziziensis* crops, through mowing. Yield in no-tillage was 23.9 mg ha^{-1}, 7.0 ha^{-1} smaller than that of conventional tillage. However, the authors stress that the harvest rate was similar among treatments, and no-tillage brought about energy saving in mechanization, as well as the accumulation of quality essential residues for soil conservation.

Lamidi (2016) assessed bitter cassava yield in no-tillage, minimum tillage and conventional tillage, in the state of Osun, Nigeria. The highest cassava yield was found in conventional tillage, 11.2 Mg ha^{-1}, while the lowest one was found in no-tillage, with 9.8 Mg ha^{-1}.

The number of roots per plant was not affected by the assessed treatments either (Table 1), corroborating the results reported by Figueiredo et al. (2014), which did not find any significant difference in the number of roots per cassava plant grown through conventional tillage, minimum tillage and no-tillage. Otsubo et al. (2012), in their turn, observed a higher number of roots per hectare for cassava grown in no-tillage, compared to conventional tillage.

The dry matter content of the roots was significantly greater in the treatment with 75% pasture intake (75% NT), compared to no-tillage without grazing (0% NT), to conventional tillage (50% CT) and to 25% pasture intake (25% NT). However, the 75% pasture intake did not supplant the 50% intake. The smaller amounts of straw had a positive influence on dry matter accumulation. Pequeno et al. (2017) found no significant difference in the dry matter levels of cassava roots comparing conventional tillage, minimum tillage and no-tillage.

The initial forage masses, obtained after Marandu grass grazing by the animals, showed significant differences (P<0.05) among treatments, with a greater amount of dry matter in the 0% NT (9277 Kg ha^{-1} compared to the 50% NT (6110 Kg ha^{-1}) and the 75% NT (6312 Kg ha^{-1}) treatments, without, however, differing from the 25% NT (7913 Kg ha^{-1}). That is because the pasture in 0% NT was not grazed by the animals and because the 25% NT was subjected light grazing. In their turn, the 50% NT and 75% NT treatments did not differ from each other, which may be related to the fact that, under higher grazing intensities, animals consume leaves first, which have a higher nutritional value, leaving only stalks as residues.

Devide et al. (2017) compared conventional-tillage cassava, incorporating with plowing and harrowing the residues of sorghum, crotalaria, consortium (sorghum + crotalaria), *Brachiaria decumbens* and *B. ruziziensis* cover crops, with no-tillage system, through mowing. The dry matter input generated for each cover crop did not differ significantly, with values being 3600, 1800, 2400, 2800 and 3400 kg ha^{-1}, respectively. The smaller values for dry matter accumulation, particularly for *Brachiaria*, compared to the no-grazing pasture of the present study (9277 Kg ha^{-1}), may be related with climatic factors, as well as with the seasons for sowing and cutting cover plants. In the study referred to earlier, cover plants were sowed in March and managed (rowing) for cassava to be planted, in July. In the present study, Marandu grass was sowed in January and managed (grazing) before the cassava was planted, in August, resulting in a longer growth period and dry matter accumulation for the grass.

The Marandu grass straw decomposition, assessed when the cassava was cultivated in no-tillage system, showed significant differences among treatments for some assessment periods. However, the very high coefficients of variation (above 30%), observed for the samples collected in some studied periods, contributed to significant differences not being detected among treatments (Table 2). The long cycle of the cassava crop (18 months) may interfere with the variability of the samples, since the bags used for assessing straw decomposition are allocated at different points in the plots, subjected to the often-different effects of the elements.

TABLE 2 - Marandu grass straw decomposition (%) for no-tillage (NT) cassava treatment, with grazing intensity for intake of 0% (no grazing), 25%, 50% and 75% of marandu grass forage mass.

Decomposition period (days)	Treatments				CV (%)
	NT 0%	NT 25%	NT 50%	NT 75%	
7	5.61 a*	6.18 a	8.77 a	6.94 a	32.76
14	7.96 a	7.92 a	8.11 a	7.02 a	19.49
28	6.58 b	8.88 a	7.90 ab	7.46 ab	16.14
56	17.22 a	17.04 a	14.25 a	11.36 a	40.56
112	43.18 a	32.28 ab	34.45 ab	30.48 b	20.09
224	46.07 a	39.92 a	37.63 a	31.96 a	23.09
448	59.93 a	59.00 a	50.16 a	43.56 a	36.89

*Means followed by the same letter in the row did not differ from each other by the t test (5%). CV = coefficient of variation.

A total of 7, 14, 56, 224 and 448 days after the cassava was planted, no significant differences were found among treatments, with the means respectively being 6.88%, 7.75%, 14.97%, 38.90% and 53.16% for Marandu grass straw decomposition (Table 2).

Twenty-eight days after planting, significant differences was found in straw decomposition percentage, which was higher for the 25% NT, in which the animals consumed 25% of the forage mass, compared to the 0% NT, whose initial forage mass was not grazed. However, the 25% NT did not differ from the other treatments (Table 2).

For the cassava crop, whose implementation occurs in the winter, the Marandu grass straw decomposition, in the early periods, is smaller that observed in the summer, when higher temperatures and rainfalls contribute to raising the decomposition rates of vegetal residues (Figure 1). Gobbi et al. 2017 reported an average percentage of Marandu grass straw decomposition (annual pasture) of 36.56% after 56 days, in a soybean integration system, in the Northwest of Paraná, which is more than twice the value found, for the same period, in the present study. This may be related to the soybean crop implementation period, in the beginning of the rainy season, unlike cassava. According to Haag (1985), the release of nutrients from organic matter is low during the dry season, but decomposition speeds up with the start of the rainy days.

The pasture management height, determined by the highest or lowest grazing intensity for forage intake, also affects the amount and quality of residual straw and may influence the establishment of succession planting

(BALBINOT JUNIOR and VEIGA, 2010). Because cassava is a long-cycle crop, residue decomposition increases with time and may vary as a function of the chemical-bromatological composition of the straw. After 112 days, the decomposition percentage of Marandu grass straw was significantly higher for the 0% NT treatment compared to the 75% NT, without differing, however, from the 25% NT and 50% NT treatments (Table 2).

In the 0% NT treatment, whose forage mass was not grazed before burndown for cassava planting, the residual straw had a greater proportion of leaves than the 75% NT treatment did, in which the animals consumed 75% of the available forage, resulting in a residual mass with greater proportion of stems. These morphological differences of the straw contribute to differences in decomposition percentage, since the stems of Marandu grass present a higher proportion of fibrous compounds and lignified tissues (SANTOS et al., 2010), whose rate of decomposition is slower (CORREIA and ANDRADE, 1999).

After the decomposition constant (k) of the Marandu grass residual straw was determined, the half-life time ($t_{1/2}$) of that straw was calculated, which is the time required for 50% of the biomass to be decomposed. A total of 221, 218, 263 and 321 days were necessary for 50% of the straw to be decomposed in the 0% NT, 25% NT, 50% NT and 75% NT treatments, respectively.

The higher number of days observed for the $t_{1/2}$ of the 75% NT straw may be related to the higher proportion of stems and fewer leaves in the post-grazing forage mass, as well as its higher levels of fibrous compounds, such as cellulose and lignin, which leads to a slower straw decomposition.

Cavalli et al. (2018) assessed the straw residual decomposition of crops (maize, *Brachiaria ruziziensis* and maize/brachiaria consortium) for subsequent soybean planting, in the North of Mato Grosso Estate, Brazil. The brachiaria straw presented the highest decomposition values (85%) throughout the 154-day cycle of the soybean, with a half-life time of 80 days. According to the authors, the maize straw decomposition was smaller (76%), with a half-life time of 165 days, due to its greater C:N ratio, and greater proportion of lignified tissues. As already mentioned, straw decomposition is influenced by type of material, rainfall, temperature, etc., and this may justify the variability of results in different climatic conditions.

Based on the straw decomposition percentage, it was possible to observed that, after 448 days, the straw residual mass present in the experimental plots did not differ (P>0.05) significantly among treatments, with means being 3649, 3378, 3148 and 3565 kg of dry matter per hectare, for the 0% NT, 25% NT, 50% NT and 75% NT treatments, respectively. Considering these similar values for residual straw, as well as the absence of changes in cassava yield among the different assessed treatments, it is possible to state that the annual pasture of Marandu grass can be partially used for grazing and animal feeding, before the burndown and planting of cassava, depending on the initial dry matter production of the pasture.

In the specific case of the present assay, taking into account the recommended amount of residual straw of 6000 Kg ha^{-1} for no-tillage (CRUZ et al., 2002), and the initial dry matter production of Marandu grass around 9000 Kg ha^{-1}, approximately 3000 Kg ha^{-1} of pasture dry mass could be used by the animals, before burndown for cassava planting. The 25% NT (7913 Kg ha^{-1}), 50% NT (6110 Kg ha^{-1}) and 75% NT (6312 Kg ha^{-1}) allowed obtaining the adequate amount of residual straw, after grazing by the animals. This amount of forage would be enough to feed around 11 animal units (AU) for approximately 30 days.

The temporal assessment of the physical attributes of the soil allowed characterizing its physical quality over the 18 months, between planting, after the cassava branches were pruned, and before the roots were harvested. Smaller soil density values were found before the cassava was planted, 0-10 cm deep, in the 0% NT treatment compared to the 50% CT treatment, as well as 10-20 cm deep, comparing the 25% NT with the 50% NT and the 75% NT (Table 3).

After branch pruning, no differences in soil density were found among treatments. With the resumption of vegetative development in the aerial part and in the bulkiest cassava roots, soil density before harvest was lower in the 50% NT treatment, at the depth of 0-10 cm, compared to the 0% NT and 25% NT treatments. At the depth of 10-20 cm, density was also lower in the 50% NT compared to the 50% CT, 25% NT and 75% NT treatments. A straw effect on soil decompaction similar to the 0-10 and 10-20 cm layers was found by Fidalski and Alves (2015).

TABLE 3 - Soil density in three seasons and three soil layers for no-tillage (NT) (no-grazing pasture (0% NT) and grazing intensity for intake of 25%, 50% and 75% of forage mass (25% NT, 50% NT and 75% NT), and conventional tillage (CT) (grazing intensity for intake of 50% of forage mass; 50% CT).

Soil layer (cm)	Treatments					Mean	CV (%)
	CT 50%	NT 0%	NT 25%	NT 50%	NT 75%		
	---------- kg dm^{-1} ----------						
	Before cassava planting (May/2017)						
0 - 10	1.71 a*	1.60 b	1.65 ab	1.66 ab	1.67 ab	1.66	3.15
10 - 20	1.73 a	1.72 ab	1.69 b	1.73 a	1.76 a	1.72	1.35
20 - 40	1.76 a	1.79 a	1.78 a	1.78 a	1.73 a	1.77	2.46
	After cassava branch pruning (August/2018)						
0 - 10	1.71 a	1.66 a	1.74 a	1.70 a	1.66 a	1.69	3.55
10 - 20	1.80 a	1.72 a	1.79 a	1.79 a	1.70 a	1.76	4.52
20 - 40	1.83 a	1.81 a	1.82 a	1.77 a	1.81 a	1.81	2.47
	Before cassava root harvest (January/2019)						
0 - 10	1.63 ab	1.64 a	1.64 a	1.58 b	1.63 ab	1.62	2.23
10 - 20	1.77 a	1.74 ab	1.76 a	1.68 b	1.76 a	1.74	2.36
20 - 40	1.79 a	1.78 a	1.76 a	1.76 a	1.78 a	1.77	1.83

*Means followed by the same letter in the row do not differ from each other by the t test at 5% probability. CV = coefficient of variation.

The macroporosity in the 0-10 cm layer had an ephemeral effect before cassava planting, presenting a higher value in the 0% NT than in the 50% CT and in the 50% NT treatments (Table 4). In the 10-20 cm layer, before the crop was planted, macroporosity was greater in the 25% NT treatment than in the 50% CT and 75% NT treatments. At this depth, after branch pruning, macroporosity was greater in the 75% NT than in the 25% NT. Before the cassava roots were harvested, the 50% NT treatment presented greater macroporosity than the 50% CT and 75% NT treatments. The effect of no-tillage on reducing soil macroporosity in no-tillage system for cassava over pasture was observed in similar layer and soil (AZEVEDO et al., 2014).

Total porosity before cassava planting at the depth of 0-10 cm in the 0% NT treatment was greater than in the 50% CT and in the 75% NT treatments (Table 5). In that period, 10-20 cm deep, the greatest total porosities were observed in the 50% CT, 0% NT and 25% NT treatments compared to the 75% NT treatment. Before the cassava tuberous roots were harvest 10-20 cm deep, the 50% NT treatment presented greater total porosity compared to the 50% CT, 25% NT and 75% NT treatments. Figueiredo et al. (2017), assessing cassava crop in conventional tillage, minimum tillage or no-tillage, observed higher values for macroporosity and total porosity in the 10-20 cm layer for no-tillage. At the depths of 0-10 and 20-30 cm, in their turn, conventional tillage showed higher macroporosity values.

TABLE 4 - Soil macroporosity in three seasons and three soil layers for no-tillage (NT) (no-grazing pasture (0% NT) and grazing intensity for intake of 25%, 50% and 75% of forage mass (25% NT, 50% NT and 75% NT), and conventional tillage (CT) (grazing intensity for intake of 50% of forage mass; 50% CT).

Soil layer (cm)	Treatments					Mean	CV (%)
	CT 50%	NT 0%	NT 25%	NT 50%	NT 75%		
	kg dm^{-1}						
	Before cassava planting (May/2017)						
0 - 10	0.20 b*	0.26 a	0.23 ab	0.22 b	0.23 ab	0.22	10.93
10 - 20	0.18 bc	0.20 ab	0.21 a	0.20 ab	0.16 c	0.19	10.21
20 - 40	0.14 a	0.11 a	0.12 a	0.13 a	0.15 a	0.13	18.94
	After cassava branch pruning (August/2018)						
0 - 10	0.17 a	0.20 a	0.15 a	0.18 a	0.20 a	0.18	20.35
10 - 20	0.10 ab	0.12 ab	0.09 b	0.10 ab	0.13 a	0.11	22.03
20 - 40	0.08 a	0.09 a	0.09 a	0.07 a	0.08 a	0.08	31.88
	Before cassava root harvest (January/2019)						
0 - 10	0.22 a	0.22 a	0.23 a	0.25 a	0.22 a	0.23	10.94
10 - 20	0.14 b	0.15 ab	0.16 ab	0.19 a	0.13 b	0.15	19.43
20 - 40	0.09 a	0.11 a	0.12 a	0.10 a	0.10 a	0.11	20.28

*Means followed by the same letter in the row do not differ from each other by the t test at 5% probability. CV = coefficient of variation.

Soil density, macroporosity and total porosity did not differ in the assessed periods and treatments at the depth of 20-40 cm (Tables 3, 4 and 5). These results allow inferring that the animals trampling on the Marandu grass did not compromise the physical quality of this soil layer, as observed in other studies with brachiaria, considering different grazing heights (FIDASKI and ALVES, 2015).

TABLE 5 - Total soil porosity in three seasons and three soil layers for no-tillage (NT) (no-grazing pasture (0% NT) and grazing intensity for intake of 25%, 50% and 75% of forage mass (25% NT, 50% NT and 75% NT), and conventional tillage (CT) (grazing intensity for intake of 50% of forage mass; 50% CT).

Soil layer (cm)	Treatments					Mean	CV (%)
	CT 50%	NT 0%	NT 25%	NT 50%	NT 75%		
	kg dm^{-1}						
Before cassava planting (May/2017)							
0 - 10	0.36 b*	0.40 a	0.38 ab	0.38 ab	0.37 b	0.38	4.70
10 - 20	0.35 ab	0.35 ab	0.37 a	0.35 bc	0.34 c	0.35	2.67
20 - 40	0.34 a	0.33 a	0.33 a	0.33 a	0.35 a	0.33	5.44
After cassava branch pruning (August/2018)							
0 - 10	0.36 a	0.37 a	0.35 a	0.36 a	0.37 a	0.36	6.02
10 - 20	0.32 a	0.36 a	0.32 a	0.33 a	0.36 a	0.34	9.16
20 - 40	0.31 a	0.32 a	0.32 a	0.34 a	0.32 a	0.32	5.52
Before cassava root harvest (January/2019)							
0 - 10	0.39 a	0.38 a	0.39 a	0.41 a	0.39 a	0.39	4.03
10 - 20	0.34 b	0.35 ab	0.34 b	0.36 a	0.34 b	0.34	4.39
20 - 40	0.32 a	0.33 a	0.34 a	0.34 a	0.33 a	0.33	4.14

*Means followed by the same letter in the row do not differ from each other by the t test at 5% probability. CV = coefficient of variation.

The physical quality of this soil, taking into account the changes in physical attributes over the 18 months of the cassava crop, allows inferring that there were improvements in the soil profile as the amount of straw provided by the treatments reduced, between the cassava planting and harvest in the 0-10 layers (0% NT to 50% NT), expressed by soil density, and 10-20 cm (25% NT to 50% NT), expressed by soil density, macroporosity and total porosity (Tables 3, 4 and 5). This improvement in soil physical quality at the 10-20 cm depth corroborates the improvements found in integrated crop-livestock system and in the soil of the Caiuá Sandstone Formation, in the Northwest of Paraná (FIDALSKI, 2015).

The soil layer between 10 and 20 cm deep corresponds to the transition between the superficial horizon A, with granular structure at 0-10 cm, and horizon Bt, with textural gradient by the duplication of clay content in relation to horizon A. This may mean that there was a biological decompaction of the soil, bringing about better physical conditions for the development of cassava tuberous roots (GABRIEL FILHO et al., 2003).

Total organic carbon levels did not differ statistically between conventional tillage (50% CT) and no-tillage (0%, 25%, 50% and 75% NT) at depths of 0-10, 10-20 and 20-40 cm (Table 6). This means that the higher physical quality of this soil, found for the 50% NT treatment compared to the 50% CT, was not influenced by the levels of total organic carbon, neither by straw decomposition, and did not compromise the yielding of cassava roots (Table 1). The effect of organic carbon content on the physical quality of soils in the Caiuá Sandstone Formation area, in northwestern Paraná, depends on a longer time than the cultivation period of the annual pasture, as found by Fidalski et al., 2007. The higher accumulation rates and the higher carbon stocks in the soil occur in systems with permanent grazing (SALTON et al., 2011).

TABLE 6 - Total organic carbon levels in the soil before the harvest of cassava tuberous roots in three soil layers for no-tillage (NT) [no-grazing pasture (0% NT) and grazing intensity for intake of 25%, 50% and 75% of forage mass (25% NT, 50% NT and 75% NT), and conventional tillage (CT) (grazing intensity for intake of 50% of forage mass; 50% CT)].

Soil layer (cm)	Treatments					Mean	CV (%)
	CT 50%	NT 0%	NT 25%	NT 50%	NT 75%		
	g kg^{-1}						
0 - 10	6.19 a*	5.84 a	5.58 a	5.85 a	6.48 a	5.99	12.23
10 - 20	4.42 a	4.53 a	4.05 a	4.27 a	4.91 a	4.44	12.81
20 - 40	3.18 a	3.59 a	3.60 a	3.54 a	3.20 a	3.42	11.39

*Means followed by the same letter in the row do not differ from each other by the t test at 5% probability. CV = coefficient of variation.

In light of the results found in the present study, it was possible to observe that the different amounts of straw, obtained after annual Marandu grass grazing, did not compromise the cassava yield in no-tillage, compared to conventional tillage, while it had beneficial effects on the physical quality of the soil.

However, the diverging results found in studies on no-tillage cassava crops show that doubts remain as to the effects of soil tillage system on cassava yield. This influences decision making by producers when it comes to the cropping system to be adopted. The difference in no-tillage cassava yield may be related to variations in the edaphoclimatic conditions where the assessments were carried out. In the same way, forage type, age, management with or without animals grazing, influences straw formation before cassava planting. It is possible to assume that the age of the pasture (annual or perennial) used for composing the straw will also affect the development and yield of cassava in no-tillage. In this case, not only due to differences in the amount and quality of the produced aerial part, which affects the decomposition of residual straw, but also due to the amount of underground biomass formed by the roots of the grass. Further studies are necessary to assess different types of pasture, with different ages, correlating cassava yield and soil physical attributes, thus allowing a more informed recommendation for producers.

CONCLUSIONS

The residual straws of annual Marandu grass pasture did not influence the yield of cassava tuberous roots in no-tillage, compared to conventional tillage, while the 50% grazing intensity, before no-tillage, improved the physical quality of the soil. Planting cassava on annual Marandu grass straw can be an option for producers, which could even use part of the forage available in the pasture to feed animals, before no-tillage.

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