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Soil physical properties and cassava yield under different soil cover managements

Propriedades físicas do solo e produtividade de mandioca sob diferentes manejos de coberturas do solo

Amarilis Beraldo RÓS[1]; Andréia Cristina Silva HIRATA[2]

[1] Autor para correspondência. Dr em Agronomia, Agência Paulista de Tecnologia dos Agronegócios, Polo Regional Alta Sorocabana, Rodovia Raposo Tavares, km 561, 19053-205, Presidente Prudente/SP. E-mail.: amarilis@apta.sp.gov.br
[2] Dr em Agronomia, Agência Paulista de Tecnologia dos Agronegócios. E-mail.: andreiacs@apta.sp.gov.br

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Abstract

Plants used as green manure can be managed in different ways. Thus, this study evaluates the impact of managing *Crotalaria ochroleuca* and weeds on cassava yield, soil physical properties and weed management. The treatments consisted of cassava cultivation on four soil cover types: 1 - mowed and incorporated *C. ochroleuca*; 2 - mowed *C. ochroleuca*; 3 - mowed and incorporated weed community; and 4 - weeded control. The incorporation of *C. ochroleuc*a and weeds reduced soil density and increased total soil porosity compared to mowed *C. ochroleuca* and weeded control. There was no difference in soil penetration resistance between the treatments with incorporation of vegetation cover. *C. ochroleuca*, either mowed or incorporated, did not affect weed dry matter density and dry matter accumulation in cassava at 60 days after planting. Commercial yield of cassava did not differ between treatments (averaging 30 t ha^{-1}). The results indicate that managing *C. ochroleuca* or weeds influences soil physical properties, but not necessarily cassava yield.

Additional keywords: *Crotalaria ochroleuca*; *Manihot esculenta* Crantz; penetration resistance; weed community.

Resumo

Plantas utilizadas como adubos verdes podem ser manejadas de diferentes formas. Assim, objetivou-se com este trabalho avaliar o impacto de manejos de *Crotalaria ochroleuca* ou comunidade infestante na produtividade da mandioca, nas propriedades físicas do solo e no manejo de plantas daninhas. Os tratamentos consistiram no cultivo de mandioca sobre quatro manejos de coberturas do solo: 1 - *C. ochroleuca* roçada e incorporada; 2 - *C. ochroleuca* roçada; 3 - comunidade infestante roçada e incorporada, e 4 - testemunha capinada. A incorporação da *C. ochroleuca* e da comunidade infestante reduziu a densidade e aumentou a porosidade total do solo em relação à *C. ochroleuc*a roçada e testemunha capinada. Não houve diferença de resistência à penetração no solo entre os tratamentos com incorporação da cobertura vegetal. A *C. ochroleuca* roçada ou incorporada não interferiu na densidade e no acúmulo de massa seca de plantas daninhas na cultura da mandioca, aos 60 dias após o plantio. A produtividade comercial da mandioca não diferiu entre os tratamentos (média de 30 t ha^{-1}). Os resultados indicam que o manejo da *C. ochroleuca* ou comunidade infestante influencia as propriedades físicas do solo, mas não necessariamente a produtividade da mandioca.

Palavras-chave adicionais: comunidade infestante; *Crotalaria ochroleuca*; *Manihot esculenta* Crantz; resistência à penetração.

Introduction

Cassava (*Manihot esculenta* Crantz) is a species native to Brazil (Valle, 2005). Its roots correspond to the fifth most produced food in the world (International Potato Center, 2010). The crop is cultivated in all Brazilian states (IBGE, 2018), standing out in human and animal food and as raw material in a wide range of industrial products.

Studies have reported that green manure may favor this crop by increasing root yield (Amabile et al., 1994; Pypers et al., 2012). According to Otsubo et al. (2008), in cassava cultivation, the conventional tillage system can be replaced by the practice of minimum cultivation associated with the use of vegetation cover to promote significant increases in crop yield.

Green manure is a conservationist practice in which cover crops are grown and incorporated into the soil or simply bedded. This practice can improve physical (Valicheski et al., 2012; Massad et al., 2014), chemical (Delarmelinda et al., 2010), and biological (Buzinaro et al., 2009; Brito et al., 2016) conditions, increasing yield in successive economic crops (Lazaro et al., 2013; Viola et al., 2013) and controlling spontaneous plants (Queiroz et al., 2010).

Maintaining a mulch over the soil is important for its protection against erosive agents (Panachuki et al., 2011; Tartari et al., 2012), being very indicated in cassava cultivation because of the relatively slow initial growth, i.e., low ground cover, often coinciding with periods of heavy rainfall.

Thus, considering the hypothesis that the use of cover crops increases cassava yield and soil physical properties, this study evaluates the effect of soil cover management on these variables.

Materials and methods

The experiment was carried out in a Red Yellow Argisol with sandy texture. During the cultivation of *C. ochroleuca* and cassava, the weather conditions are presented in Figure 1.

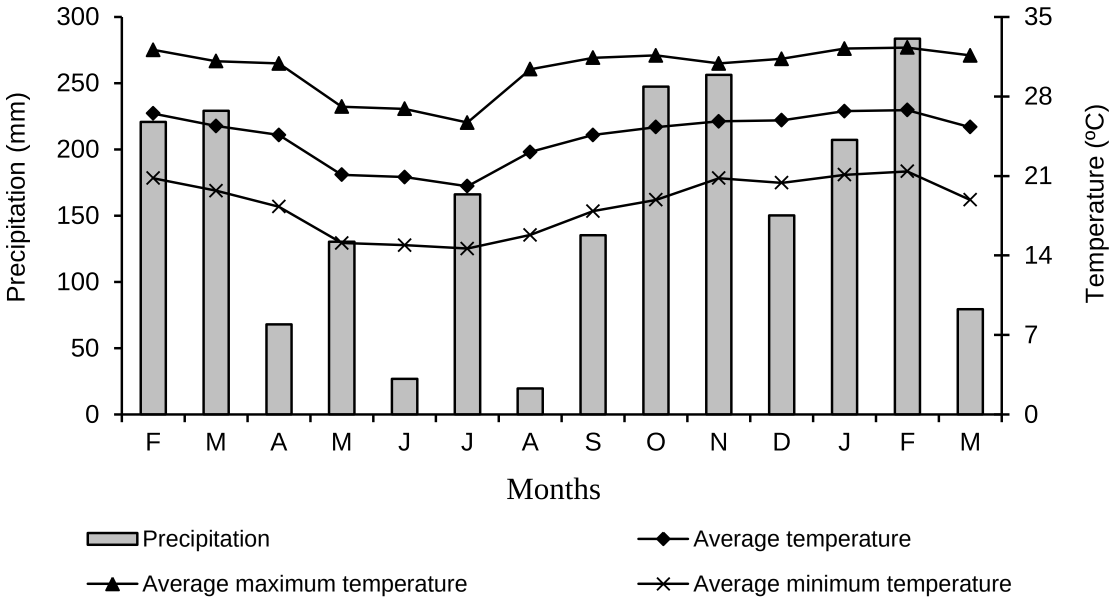

Figure 1 - Pluvial precipitation and average temperatures occurred in the period and place of the experiment.

The soil was sampled in the 0.00-0.20 m depth layer for chemical analysis and soil particle size determination, with the following results: pH (1 mol L^{-1} $CaCl_2$) 5.3; 17.2 mg dm^{-3} P (resin); 13.4 $mmol_c$ dm^{-3} C; 16.8 $mmol_c$ dm^{-3} H+Al; 2.2 $mmol_c$ dm^{-3} K; 13.6 $mmol_c$ dm^{-3} Ca; 3.8 $mmol_c$ dm^{-3} Mg; 53.8% saturation; 920 g kg^{-1} sand; 30 g kg^{-1} silt; and 50 g kg^{-1} clay.

The experimental design was randomized blocks with six replicates. Treatments consisted of cassava cropping in four soil cover types: 1 - mowed and incorporated *Crotalaria ochroleuca*, 2 - mowed *C. ochroleuca*, 3 - mowed and incorporated weed community, 4 - weeded control.

The experimental area was prepared using disc plow and harrow in February 2015. *C. ochroleuca* was sown at a density of 40 kg per hectare (75% germination and 95% purity). Seeds were superficially incorporated into the soil by means of a rake.

The weed community and *C. ochroleuca* (1.6 m height and 7 t ha^{-1} dry weight) were mowed at 80 days after sowing the legume. All treatments, with the exception of unincorporated *C. ochroleuca*, were harrowed at 0.25 m depth.

Cassava was planted 15 days after the management of *C. ochroleuca* (on May) and weeds. Moreover, 0.2-m-long cuttings were obtained from the middle third of stems of 10-months-old table cassava cultivar IAC 576-70. Stem cuttings were planted at 0.1 m depth. At 7 days after planting, before the emergence of cassava plants, herbicide glyphosate (1,440 g a.i. ha^{-1}) was applied to control weeds that emerged in the period.

The experimental unit consisted of an area of 50.4 m^2, with eight rows containing 10 plants each, using a spacing of 0.7 m between plants and 0.9 m between rows. The useful area consisted of the six central rows of each plot, except for the end plants. In the control treatment, weeds were eliminated by hand at 70, 90, and 154 days after cassava planting.

Soil physical properties evaluated were soil density (SD), total porosity (TP), and soil penetration resistance (PR). To determine SD and TP, undisturbed samples were collected in each plot at 60 days after cassava planting (DAP), in the middle portion of 0.0-0.1; 0.1-0.2; and 0.2-0.3 m depth layers. Collections were performed between plant rows.

Soil density (SD) was determined by the volumetric ring method, in which the weight of the dry soil sample at 105 ºC is linked to the sum of the volumes occupied by the particles and pores. Total porosity (TP), in turn, was obtained through the relationship between soil density and particle density, the latter being calculated by the volumetric balloon method according to Claessen (1997).

Soil penetration resistance (PR) was determined by the use of an impact penetrometer at 60 (June) and 305 (May) DAP. Three PR measurements were obtained in each experimental plot, from which mean values were calculated. We evaluated the number of impacts every 0.05 m in the 0,00-0.30 m depth layer. The data obtained for the number of impacts per dm were transformed into soil penetration resistance using the equation presented by Stolf (1991). Results were presented as mean values for each 0.05 m depth. Penetration resistance (PR) data were analyzed using an average value at each depth. Mean standard error was used to evaluate each sampled depth.

From 60 DAP, plant height (measured from ground level to apical shoot) data were collected every 35 days, with the last evaluation being performed at 305 DAP. Plants were harvested at 310 DAP, when the total and commercial yields and the total and commercial number of roots were evaluated. Total yield and total number of roots considered all roots with diameter and length equal to or greater than 0.03 m and 0.10 m, respectively. For commercial yield and number of commercial roots, roots with diameter and length equal to or greater than 0.04 m and 0.15 m, respectively, were considered. The following were also evaluated: individual fresh weight, diameter, root length, length/diameter ratio, and dry weight of commercial roots.

At 70 days after cassava planting, the weed community was sampled by means of a square of 0.5 m^2, thrown at random between cassava rows. The weeds contained in the square were identified, quantified, and the shoot dry weight determined in a forced-air circulation oven at 65 ºC until constant weight.

The obtained data were submitted to analysis of variance and the means adjusted to polynomial regression equations. The criterion for choosing the model was the significance by the F test and the highest values of the coefficient of determination (R^2). A 5% probability of error was adopted.

Results and discussion

For the soil physical attributes density and total porosity, there was no interaction between soil management and the depths analyzed. There was no difference between depths, only managements presented significant differences (Table 1).

Table 1 - Density (SD) and total porosity (TP) of the soil at 60 days after planting of cassava in soil cover under different managements, at layer 0,00 - 0.30 m.

Treatment	SD (kg dm^{-3})	TP (cm^3 cm^{-3})
Mowed and incorporated *Crotalaria ochroleuca*	1.54 B	41.3 A
Mowed *Crotalaria ochroleuca*	1.65 A	37.3 B
Weeded control	1.65 A	37.1 B
Mowed and incorporated weed community	1.54 B	41.5 A
CV (%)	4.17	7.41

Means followed by equal letters in the columns did not differ significantly by the Tukey test (p> 0.05).

The areas incorporated with *C. ochroleuca* and weed community showed lower values of soil density (1.54 Mg m^{-3}) compared to unincorporated *C. ochroleuca* and weeded control. Studies have shown that soils under no-tillage present higher soil density due to their nonrevolving and the movement of agricultural machines and implements (Stone & Silveira, 2001). The presence of incorporated cover plants may also have contributed to the lower soil density in these treatments. Importantly, unlike the *C. ochroleuca* treatment without incorporation, an additional harrowing operation was performed on the weeded control at the time of the evaluation, at 60 DAP. Nevertheless, the soil density was similar between these managements (1.65 Mg m^{-3}). Almeida et al. (2008) reported that the use of green manure species *Pennisetum americanum* L., *Crotalaria juncea* L., and *Cajanus cajan* L. promoted similar soil density in no-till or conventional-till (incorporated) areas, indicating that nonrevolving the soil by plowing did not increase density.

Silva et al. (2005) observed similar values for soil density, ranging from 1.35 to 1.67 Mg m^{-3}, with no difference between no-tillage and conventional tillage up to a depth of 17.5 cm.

Total porosity was similar to soil density between treatments (Table 1), which was also observed by Stone & Silveira (2001), being consistent due to the correlation between these soil properties. The increase in soil porosity values improves the soil structure, being one of the benefits of using green manure (Wutke et al., 2010). In the present study, the incorporation of green manure favored this soil physical property. According to Von Osterroht (2002), the use of green manure improves soil physical properties due to increased organic matter contents.

In the evaluation performed at 60 DAP, there was an increase in the PR value due to the increase in soil depth (Figure 2). The use of a plowing harrow in the weeded treatment and those with incorporated crotalaria and weeds resulted in lower penetration resistance in these treatments compared to mowed unincorporated *C. ochroleuca*. De Rossi et al. (2007) also observed that in the treatment with mowed black oats there was greater mechanical resistance, followed by the treatment with oat incorporation in the soil. In that study, the treatment that resulted in the least resistance was uncovered soil.

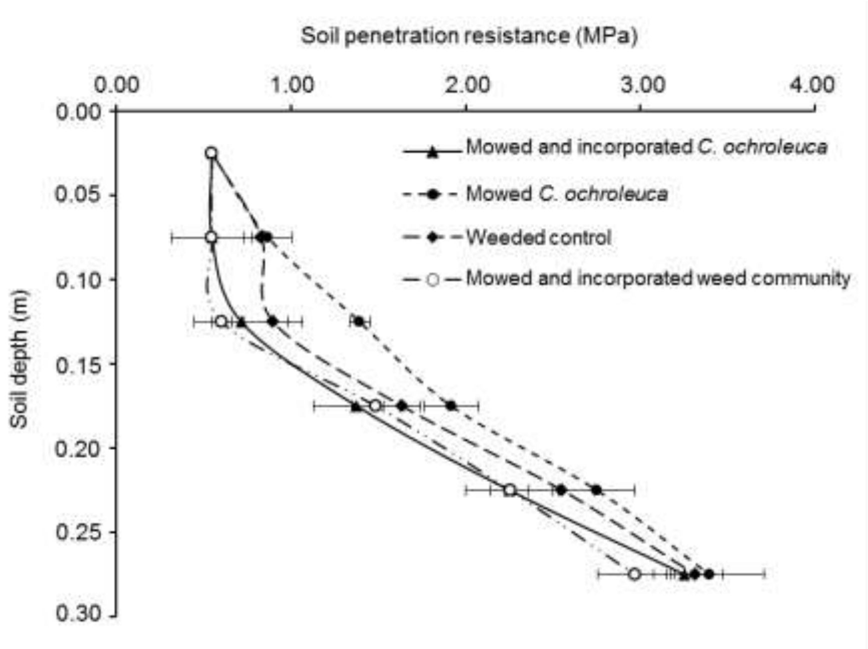

Figure 2 - Soil penetration resistance at 60 days after planting of cassava in soil cover under different managements.

There was no difference in PR between the treatments in which the vegetation was incorporated. The treatment that came closest to the results of mowed and unincorporated *C. ochroleuca* was the weeded control, since there was no incorporation of plant mass in the soil. These data are related to the results for soil density and porosity, where there was higher density and lower porosity for unincorporated *C. ochroleuca*. At depths greater than 0.25 m, as far as the soil was revolved, the treatments did not differ from each other.

At 305 DAP, in the 0-0.15 m layer, the incorporation of plant mass generally promoted lower PR compared to the treatments without incorporation (Figure 3). It is noteworthy that PR was lower in the treatment with incorporated weed community compared to incorporated *C. ochroleuca*. One possible explanation is the slower degradation of grasses (of which part of the weed community was composed) compared to legumes such as *C. ochroleuca*.

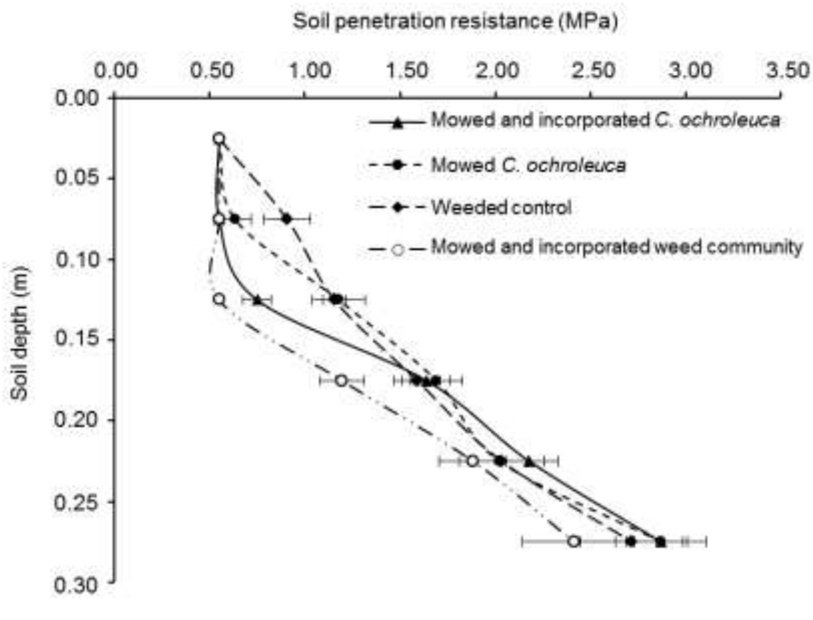

Figure 3 - Soil penetration resistance at 305 days after planting of cassava in soil cover under different managements.

The weed community was evaluated on the eve of cassava planting. In areas where crotalaria was not cultivated, the weed community was composed of *Gnaphalium spicatum* (33 plants m^{-1}); *Digitaria horizontalis* (17.6 plants m^{-1}); *Brachiaria decumbens* (11 plants m^{-1}); *Cyperus* sp. (11 plants m^{-1}); *Bidens pilosa* (2.2 plants m^{-1}); *Euphorbia heterophylla* (2.2 plants m^{-1}); *Portulaca oleracea* (2.2 plants m^{-1}); *Sida* sp. (2.2 plants m^{-1}); and Commeliana *benghalensis* (2.2 plants m^{-1}).

In the evaluation of the weed community at 70 DAP, the predominant species was *D. horizontalis* (Table 2), which presented high density in the area, except for the weeded treatment, where *Ganaphalium spicatum* was the predominant species. This is explained because in the weeded treatment there was no multiplication of *D. horizontalis* before cassava planting, resulting in a lower potential for competition with *G. spicatum*, which emerged more abundantly in this treatment. Even with *C. ochroleuca* treatments before management, *D. horizontalis* (6.6 plants m^{-1}), *C. benghalensis* (8.8 plants m^{-1}), and *E. heterophylla* (2.2 plants m^{-1}) infestations were quantified in areas with *C. ochroleuca* coverage.

Table 2 - Species, dry mass and weed density in cassava cultivated under different soil cover managements, evaluated at 70 days after planting the crop.

Weed species	Mowed and incorporated *Crotalaria ochroleuca*	Mowed *Crotalaria ochroleuca*	Weeded control	Mowed and incorporated weed community
		Plants m^{-2}		
Digitaria horizontalis	216.7	223.6	9.25	263.0
Commelina benghalensis	6.9	2.8	1.9	1.9
Euphorbia heterophylla	1.4	8.3	-	3.7
Brachiaria decumbens	13.9	5.6	20.4	9.3
Cyperus sp	2.8	1.4	3.7	-
Gnaphalium spicatum	8.3	-	63	35.2
Portulaca oleracea	2.8	-	7.4	3.7
Total density	252.8a	241.7a	105.65a	316.8a
Total dry mass	94.1a	37.8a	35.8a	96.2a

Means followed by equal letters in the lines did not differ significantly by the Tukey's test ($p > 0.05$).

There was no difference between treatments for weed density and dry weight. These plants, associated with the high seed bank of the area and the rapid decomposition of *C. ochroleuca*, contributed to the equalization of results. According to Erasmo et al. (2004), there was a gradual reduction in weed emergence after cutting *C. ochroleuca* until 60 days after its management. In that study, however, the legume was sown in November, while in the present essay the sowing was done in February, which reduced its growth potential due to the photoperiod.

Regarding the growth of cassava plants, there was interaction between height and evaluation time (Figure 4).

The difference in plant height in the different treatments was widened with increasing days after planting. Incorporated *C. ochroleuca*, mowed *C. ochroleuca*, incorporated weed community, and weeded control presented a height of 2.54, 2.43, 2.31, and 2.23 m, respectively, at 305 DAP. Thus, *C. ochroleuca* contributed to plant growth. A possible justification for the height difference between treatments with and without green manure is related to improvements in soil fertility because legumes have the ability to fix nitrogen and produce residues rich in this nutrient (Giller, 2001). It is also noteworthy that although nitrogen is important for cassava cultivation, this crop is more limited by potassium (Howeler, 2002), and green manures quickly release this nutrient when added to the soil (Partey et al., 2011).

Total yield and number of commercial roots showed significant differences between treatments (Table 3). Management with incorporated *C. ochroleuca* promoted higher total yield than that with incorporated weed community. The other treatments did not differ from each other. Amabile et al. (1994) also compared cassava root yields in areas previously cultivated with green manure, and differences in cassava yield as a function of green manure management occurred only for some of the species used as green manure.

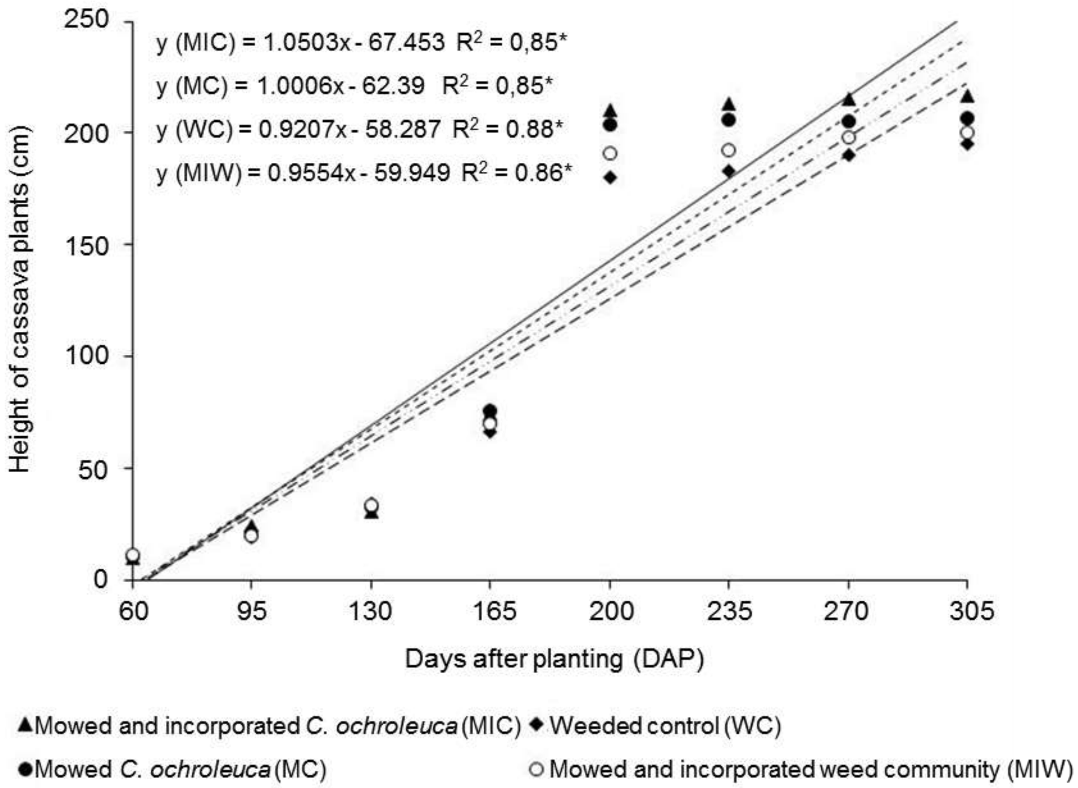

Figure 4 - Height of cassava plants cultivated in different soil cover managements, evaluated at different periods after planting the crop. * Significant at 5% probability by the F test.

Table 3 - Yield and production components of cassava cultivated under different soil cover managements.

Treatment	Total yield (t ha^{-1})	Commercial yield (t ha^{-1})	Total number of roots (x 1000 ha^{-1})	Number of commercial roots (x 1000 ha^{-1})
Mowed and incorporated *Crotalaria ochroleuca*	33.62 A	30.91 A	90.2 A	66.6 AB
Mowed *Crotalaria ochroleuca*	31.01 AB	28.50 A	90.7 A	70.1 A
Weeded control	32.94 AB	30.54 A	83.3 A	57.5 B
Mowed and incorporated weed community	27.47 B	25.97 A	76.5 A	54.7 B
CV (%)	8.49	8.79	13.4	12.4

Means followed by equal letters in the columns did not differ significantly by the Tukey test (p> 0.05).

Commercial yields, however, did not differ significantly from each other, with an average value of 28.98 t ha^{-1}. The total number of roots did not differ between treatments, with an average value of 7.92 roots ha^{-1}. Gabriel Filho et al. (2000) found no differences in root yield between tillage systems (minimum and conventional) and between the types of cover crops used. According to the authors, the absence of significant response to the use of minimum tillage and cover crops is possibly due to the good soil physical characteristics, with high natural fertility and no water deficiency. In the present study there was also no water deficit in the period (Figure 1), which may have contributed to the similarity between treatments.

The number of commercial roots varied, and the management with mowed *C. ochroleuca* favored a higher number of roots compared to the weeded control and incorporated weed community.

Cassava plants in the weeded area produced roots with higher average fresh weight, while in incorporated *C. ochroleuca* areas the average root fresh weight was lower than that found in weeded treatments and in those with incorporated weed community. This is related to the higher number of commercial roots produced by the plants in the area with incorporated *C. ochroleuca*, with no difference in commercial yield between treatments.

In the treatment with mowed *C. ochroleuca*, cassava plants produced shorter roots compared to those produced in the weeded treatment and those with incorporated weed community (Table 4). The higher soil density and lower soil porosity of this treatment (mowed *C. ochroleuca*) may explain the lower root depth.

Table 4 - Characteristics of cassava roots cultivated under different soil cover managements.

Treatment	Length (cm)	Diameter (cm)	Length/Diameter ($cm\ cm^{-1}$)	Fresh mass (g)	Dry mass (%)
Mowed and incorporated *Crotalaria ochroleuca*	27.37 AB	5.28 A	5.21 A	455.21 BC	38.12 A
Mowed *Crotalaria ochroleuca*	25.63 B	5.38 A	4.79 A	411.21 C	37.99 A
Weeded control	28.87 A	5.35 A	5.40 A	530.07 A	37.15 A
Mowed and incorporated weed community	28.79 A	5.38 A	5.37 A	475.36 B	37.24 A
CV (%)	3.43	7.41	6.81	4.30	3.21

Means followed by equal letters in the columns did not differ significantly by the Tukey test (p> 0.05).

There was no difference between treatments for the variables mean root diameter, root length/diameter ratio, and root dry weight (Table 4).

Amabile et al. (1994) found a difference in cassava yield as a function of the plant species used for green manure, in which spontaneous vegetation promoted higher yield than important plant species routinely used as green manure.

Conclusions

The incorporation of *C. ochroleuca* and weed community reduced penetration resistance, increased porosity, and reduced soil density in relation to mowed *C. ochroleuca* and uncovered soil.

Neither mowed nor incorporated *C. ochroleuca* affected weed dry matter density and accumulation in cassava at 60 days after planting.

Commercial cassava yield did not differ between treatments.

Incorporated *C. ochroleuca* promoted an increase in the number of roots compared to the weeded treatment and those with incorporated weed community.

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