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Impact of soil cover systems on soil quality and organic production of yacon

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ABSTRACT

The use of soil cover in vegetables is a widespread practice that provides innumerable advantages to the soil and crop. The objective of this study was to evaluate the soil attributes and the organic production of yacon in different soil cover systems in the Atlantic Forest Biome, Brazil. The experiment was conducted in a randomised complete block design with five replicates. The treatments consisted of seven soil covers: two covers with plastic film, one black and one two-sided white/black, with the white surface facing the atmosphere; a cover with corn straw (30 Mg ha^{-1}); three covers with different levels of coffee husk (1 = 37.5 Mg ha^{-1}; 2 = 75.00 Mg ha^{-1}; and 3 = 112.50 Mg ha^{-1}); and a treatment with no soil cover (NC). During the crop growth cycle, data and soil samples (0–5 cm) were collected monthly, and the following were evaluated: total organic carbon, total nitrogen, potentially mineralisable nitrogen, microbial biomass carbon, C-CO_2 emissions, temperature, moisture, metabolic quotient, and microbial quotient. The dry mass of the spontaneous vegetation was determined at 60, 100, 140, 180, and 210 days after yacon planting. At the end of the growth cycle (210 days after planting), the yield of yacon tuberous roots and the net carbon balance were evaluated. Independent of the cover material, the soil cover systems led to greater stability of soil microbial activity and CO_2 emissions, in addition to greater immobilisation of C in the microbial biomass, promoting a positive C balance in the soil covered with corn straw (10.99 Mg ha^{-1}) and coffee husk at levels 1 (12.88 Mg ha^{-1}), 2 (28.12 Mg ha^{-1}), and 3 (43.28 Mg ha^{-1}). The soil cover reduced temperatures (mean of 6.43%) and greater soil moisture retention capacity (mean of 35%), with the black plastic film being the least efficient. Additionally, the soil covers suppressed spontaneous vegetation, especially the plastic films (100% suppression) and coffee husk at levels 2 (50% suppression) and 3 (74% suppression). These benefits led to higher yields of yacon tuberous roots, most notably the double-sided plastic film cover (31.71 Mg ha^{-1}) and coffee husk at level 2 (28.35 Mg ha^{-1}).

1. Introduction

The tuberous roots of yacon (*Smallanthus sonchifolius*) are a functional food with the highest content of fructooligosaccharides (FOS) in nature (Santana & Cardoso, 2008). These roots can be used to control chronic diseases such as diabetes, blood pressure, and cholesterol levels (Oliveira et al., 2013), and they also have immunostimulatory (Tostes et al., 2014) and prebiotic (Campos et al., 2012) effects.

The increased interest in yacon has generated a demand for technical information regarding its cultivation; however, because it is a little-known crop worldwide, such information remains scarce. Adequate soil management can improve the productive performance of yacon under different edaphoclimatic conditions. Although conventional soil management is still used in the cultivation of vegetables, concern is increasing, especially in tropical regions, regarding high erosivity, including high temperatures, reduced water availability, and rapid soil organic matter decomposition, which increases carbon (C) losses to the atmosphere (Thomazini et al., 2015). It is estimated that 89% of the greenhouse gas mitigation potential of agriculture depends on C sequestration (Smith et al., 2008). In addition, increasing the soil organic C content is an important strategy for managing climate change driven by CO_2 emissions to the atmosphere from agricultural land (Thomazini et al., 2015).

In this context, soil cover strategies, combined with agro-ecological or organic management, are alternatives for soil protection against erosion and reduction of C emissions to the atmosphere (Thomazini et al., 2015; Xavier et al., 2013; Fryrear, 2013). The use of soil cover is an important and widespread alternative in the cultivation of various vegetables, improving production and product quality (Santos et al., 2011). Reports indicate that the use of soil cover is advantageous in carrot (Santos et al., 2011), beet (Sediyama et al., 2011), onion (Santos et al., 2012), cassava (Otsubo et al., 2008), and taro (Oliveira et al.,

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2007), crops that, similarly to yacon, accumulate reserves in underground organs.

Among other benefits to the soil, the cover provides reductions in maximum temperatures and thermal amplitude, greater conservation of water and nutrients, protection against erosive agents, and greater control of spontaneous plants (Silva et al., 2013; Thomazini et al., 2015; Mu et al., 2016). Many materials can be used as soil cover; polyethylene films are the most commonly used, although materials of plant origin such as wood shavings, hulls, and straws may also be used (Sediyama et al., 2011; Santos et al., 2012). However, mixed CO_2 emissions results have been observed in soil covered with these materials (Hu et al., 2016; Mu et al., 2016; Zhao et al., 2016), and information on the effects on soil organic matter is scarce.

Since yacon has been treated as a potato and the use of soil cover in vegetables is a widespread practice that offers innumerable advantages, the objective of this study was to evaluate the soil attributes and the organic production of yacon in different soil cover systems.

2. Materials and methods

2.1. Experimental site

The experiment was performed from April to November 2015 on a family farm in the municipality of Ibatiba, Espírito Santo, Brazil (20° 14′ 02″ S; 41° 30′ 38″ W; 880 m in altitude). Fig. 1 shows the air temperature and precipitation during the experimental period.

The climate of the region is type Aw, with two well defined seasons per year, one hot and rainy, October through March, and the other cold and dry, April through September; the annual precipitation is approximately 1200 mm (Pezzopane et al., 2012).

The soil at the experimental site was classified as Red-Yellow Latosol, with a medium texture (Embrapa, 2014), in a flat relief. A soil sample from the 0–20 cm depth layer was collected for chemical and physical analysis: pH in water 6.15; 12.05 mg dm^{-3} P (Mehlich 1); 48 mg dm^{-3} K; 2.57 cmolc dm^{-3} Ca; 0.96 cmolc dm^{-3} Mg; 0.0 cmolc dm^{-3} Al; 3.69 cmolc dm^{-3} base sum; 3.69 cmolc dm^{-3} effective cation exchange capacity (CEC); 43.96% base saturation; and 65% sand, 5% silt, and 30% clay.

2.2. Experimental design, planting, and crop treatments

The experimental design adopted was randomised blocks with five replications and seven covers as treatments: two plastic films, one black (BB) and the other two-sided white/black (WB), with the white surface facing the atmosphere; corn straw (30 Mg ha^{-1}) (CS); three different levels of coffee husk (CH), CH1 = 37.5 Mg ha^{-1},

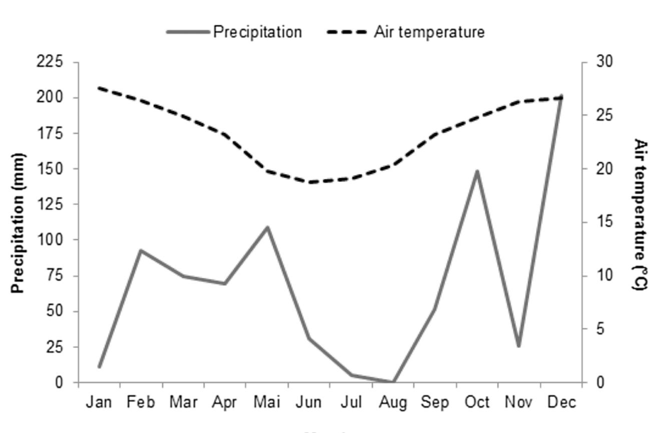

Fig. 1. Monthly precipitation and average air temperature observed from January to December 2015. Source: INCAPER automatic weather station (20°21′25″ S; 41°33′25″ W; 758 m altitude).

CH2 = 75.00 Mg ha^{-1}, and CH3 = 112.50 Mg ha^{-1}; and a treatment with no soil cover (NC). It is noteworthy that three levels of coffee husk were adopted due to the abundance of this residue in the region.

Each experimental plot consisted of 4 rows of 7 plants, with 1.0 m spacing between rows and 0.5 m between plants. The two central rows were used as a working area, except for the plants on the end of each row.

The plastic covers were composed of ElectroPlastic SA® MPP (mulch polypropylene) film. The corn straw and coffee husk used as cover were harvested at the property where the experiment was conducted.

Yacon seedlings were obtained from herbaceous cuttings of approximately 10–15 cm from adult plants, which were placed to root in 600-ml plastic bags. They were irrigated daily to maintain the substrate moisture, and after 60 days, the seedlings were suitable for planting. Those selected for planting were of uniform size.

Soil was prepared by ploughing to 30 cm depth, followed by harrowing. The base fertilisation consisted of 180 g dry mass of plant-cured cattle manure containing the following nutrients: 10.1 g kg^{-1} N, 3.96 g kg^{-1} P, 7.59 g kg^{-1} K, 4.54 g kg^{-1} Ca, and 2.14 g kg^{-1} Mg. During the growth cycle, 30 mm of water per week of supplemental irrigation was applied in the area for the 30 days after the seedlings were transplanted.

2.3. Soil attributes

Data and soil samples (0–5 cm) were collected at 30, 60, 90, 120, 150, 180 and 210 days after yacon planting (DAP) to evaluate total organic carbon (TOC), total nitrogen (TN), potentially mineralisable nitrogen (PMN), microbial biomass carbon (MBC), C-CO_2 emissions, temperature, moisture, metabolic quotient (Qmet), and microbial quotient (Qmic). The soil used for MBC was collected and stored in a refrigerator at 4 °C after passing through a 2-mm sieve, and for TOC, TN, and PMN, the samples were crushed and passed through a 0.212-mm sieve.

The soil TOC was determined by wet oxidation with $K_2Cr_2O_7$ 0.167 mol L^{-1} in the presence of sulfuric acid with external heating (Yeomans & Bremner, 1988). TN was obtained by digestion with sulfuric acid followed by Kjeldahl distillation (Bremner & Mulvaney, 1982; Tedesco et al., 1995). PMN was determined by the anaerobic incubation method developed by Waring & Bremner following Bundy and Meisinger (1994).

C-CO_2 emissions were measured using a LI-8100 portable analyser (Li-Cor, USA) coupled to a dynamic chamber (LI-8100-102), known as a survey chamber, placed on PVC soil collars (10 cm diameter) inserted in the soil (5 cm depth) 40 min before the evaluations. Three measurements with a duration of 1.5 minutes each were taken in each experimental unit. For each C-CO_2 emissions measurement, the soil temperature and moisture were determined using a sensor coupled to a portable reader (Decagon Device).

The MBC content was determined by the irradiation-extraction method as suggested by Ferreira et al. (1999). Qmet was calculated by the ratio between the CO_2 emissions rate of the soil per unit MBC and Qmic by the ratio between MBC and TOC (Ferreira et al., 1999).

2.4. Spontaneous vegetation and yacon yield

At 60, 100, 140, 180, and 210 DAP the dry mass of the spontaneous vegetation was determined in 1 m^2 in the central area of the plots. The dry mass was quantified after drying to constant mass in a forced air oven at 65 ± 2 °C. After each evaluation, the spontaneous vegetation of the whole plot was weeded manually and with the aid of a hoe and left on the ground.

The growth cycle was completed 210 DAP with the flowering of the yacon plants, when the tuberous root yield was determined.