Agriculture, Ecosystems and Environment 165 (2013) 173–183

Contents lists available at SciVerse ScienceDirect

Agriculture, Ecosystems and Environment

journal homepage: www.elsevier.com/locate/agee

Effect of cover plants on soil C and N dynamics in different soil management systems in dwarf cashew culture

Francisco Alisson da S. Xavier[a,*], Stoécio Malta F. Maia[b], Kátia Araújo Ribeiro[c], Eduardo de Sá Mendonça[d], Teógenes Senna de Oliveira[e]

[a] Brazilian Agricultural Research Corporation, Embrapa Cassava & Fruits, Cruz das Almas 44380-000, Bahia, Brazil
[b] Federal Institute of Alagoas, Maceió 57020-600, Alagoas, Brazil
[c] Department of Soil Science, Federal University of Ceará, Campus do PICI, Bloco 807, Fortaleza 60455-760, Ceará, Brazil
[d] Department of Plant Production, Federal University of Espírito Santo, Alegre 29500-000, Espírito Santo, Brazil
[e] Department of Soil Science, Federal University of Viçosa, Viçosa 36570-000, Minas Gerais, Brazil

ARTICLE INFO

Article history:
Received 5 April 2012
Received in revised form 4 December 2012
Accepted 5 December 2012
Available online 19 January 2013

Keywords:
Green manure
Humic substances
Light organic matter
Soil quality

ABSTRACT

Inappropriate soil management practices are one of most important constraints on cashew production in Northeast Brazil. This work aimed to evaluate the changes in soil C and N dynamics caused by different management of cover plants (spontaneous or leguminous) in dwarf cashew culture in Northeast Brazil. The evaluated management systems for control of spontaneous vegetation included: disc harrowing (DH), mechanical mowing (MeM), manual mowing (MaM), leguminous cover crop (LEG), leguminous cover crop + mulch of Carnaúba palm (LEG + m), and application of herbicide (HERB). The floristic composition, plant density, biomass production, and the nutrient content of the spontaneous plants that grew between cashew rows were evaluated. Total soil C and N, mineral- and organic-N, light organic matter fraction, microbial biomass, CO_2-C emission rates and humic substances were determined. HERB treatment promoted a substantial change in the floristic composition of spontaneous species. Richness index was highest in the LEG treatment in the fifth year of the experiment. Dry matter amount of spontaneous plants was quite similar in MeM, MaM, LEG, and LEG + m treatments, with average values of 2245 kg ha^{-1}. DH and HERB treatments reduced dry matter by 69 and 80%, respectively. The MeM system resulted in the highest soil C stock, whereas the DH treatment tended to intensify the mineralization process of soil organic matter due to soil disturbance. LEG treatment resulted in the highest mineral-N contents. Our results suggest that the maintenance of soil organic C levels in DH and MeM treatments is strongly dependent on maintenance of light organic matter levels. Soil from treatments which favored input of organic matter (e.g., LEG, LEG + m and HERB) presented greater C-humic/C-fulvic acids ratio, indicating the predominance of humic acids. Our findings reinforce that cover plants (e.g., spontaneous vegetation and leguminous species) play an important environmental role, contributing to organic matter and nutrient cycling in the soil. Management systems that promote soil covering and the use of leguminous species increased soil organic matter stocks.

1. Introduction

Despite the economic importance of the cashew crop (*Anacardium occidentale* L.) for Northeast Brazil and the continuous growth of cultivated areas, cashew yield has decreased considerably, and Brazilian productivity is currently half of the average world productivity (Crisóstomo et al., 2009). This decrease may be attributed to certain factors such as soil tillage practices, inadequate cropping techniques, deficient pest and disease control, low soil fertility, low genetic potential of plants, and irregular rainfall in the Brazilian Northeast region (Araújo and Silva, 1995).

The average cashew yield per hectare in the Northeast region has remained stable over the past 10 years and rarely exceeds 300 kg ha^{-1} (IBGE, 2011). Such productivity is still very low, considering that proper management can lead to production levels higher than 3000 kg ha^{-1}, according to the Brazilian Agricultural Research Corporation – Embrapa (Embrapa, 2002).

* Corresponding author at: Brazilian Agricultural Research Corporation, Embrapa Cassava & Fruits, Rua Embrapa s/n, PO Box 007, 44380-000 Cruz das Almas, Bahia, Brazil. Tel.: +55 75 33128045; fax: +55 75 33128096.
E-mail addresses: alisson.xavier@embrapa.br, alixavi@gmail.com (F.A.S. Xavier), stoecio@hotmail.com (S.M.F. Maia), esmjplia@gmail.com (E. de Sá Mendonça), teo@ufv.br (T. Senna de Oliveira).

0167-8809/$ – see front matter
http://dx.doi.org/10.1016/j.agee.2012.12.003

Cashews can be grown in several types of soil, but they are preferably grown in sandy loam textured soils, which typically have a number of limitations for plant development, including low natural fertility, extremely low organic matter contents, and low cation exchange capacity (Embrapa, 2002). Therefore, adopting adequate management practices can result in increases of the production potential in both the short and long term.

Studies conducted in the Northeast of Brazil in cashew cropping areas have shown that use of green manure through cover crop management (e.g., mainly leguminous species) is an efficient strategy for increasing soil fertility by increasing available soil nutrient contents, enhancing soil structure, preventing soil erosion, and promoting weed suppression (Oliveira et al., 1998, 2000; Embrapa, 2002). Maia et al. (2004) found that managing cover crops in cashew cultivation provided a suitable option for green fertilization, and that these cover crops promoted soil covering and accumulation of K, Ca, and Mg in the soil. The most common species used as cover crops are: *Crotalaria juncea* L., *Mucuna aterrima* P.&T., *Canavalia ensiformis* D.C., *Cajanus cajan* L., *Dolichos lablab* L., *Pennisetum glaucum* R.Br, *Clitoria ternatea*, L. (Oliveira et al., 2000; Chaves and Calegari, 2001). Notwithstanding, studies evaluating the benefits of cover crops to the soil and to the environment are still scarce in Northeast Brazil.In Northeast Brazil, soil management in cashew cropping is performed differently depending on the level of mechanization available. Large farms (extensive farms) tend to use disc harrowing, mechanic mowing or herbicide application to control spontaneous plants. Because of low financial capital, small farms tend to use tractors or chemical inputs (e.g., herbicides), and manual mowing is commonly adopted. Although the use of leguminous species as cover crops can be a highly recommended practice due to its benefits to the soil, it is still poorly adopted among cashew farmers. Among other advantages, such practice increases organic matter to the soil and promotes biological nitrogen fixation (Torres et al., 2008; Silva et al., 2009; Silva Araújo et al., 2011).

In cashew cropping, the removal of all organic residues under tree canopies, including spontaneous plants, is commonly performed with the goal of facilitating the harvest of cashew nuts. This practice promotes the reduction of soil organic matter (SOM) levels through removal of organic residues and gradually removes the upper soil horizon where the fine root system is abundant. No conclusive studies have determined whether these effects result in a decrease in productivity. This practice differs when herbicides are applied; in this case, organic residues are kept under the tree canopy (Ribeiro et al., 2007). The influence of the maintenance of these residues on soil fertility and cashew trees remains poorly understood. Overall, a diversity of management systems in the Brazilian Northeast region may theoretically affect the dynamics of cover plants and SOM in different ways.

Because of its close relationship with different soil functions SOM is the most frequently reported attribute chosen as an indicator of soil quality (Reeves, 1997; Melero et al., 2009). Thus, increasing soil C and N stocks and reducing soil C losses by improved soil management are important strategies for sustainable development. Reduction of soil disturbance associated with greater organic residue cycling tends to increase SOM levels and directly affect different SOM pools (Corbeels et al., 2006; Sainju et al., 2008).

Based on the hypothesis that less intensive management practices associated with continuous organic matter input lead to improvement of soil quality through the increase of C and N storage, we aimed to evaluate the effect of six different management systems for weed control on the soil organic C and N dynamics in an Arenic Kandiustults cultivated with dwarf cashew in Northeastern Brazil.

Table 1
Selected soil physical and chemical properties of an Arenic Kandiustults cultivated with dwarf cashew in the experimental station of Pacajus, Brazil.

Soil properties	Soil layers (cm)				
	0–23	23–70	70–95	95–150	150–200
Fine sand ($g\,kg^{-1}$)	300	350	260	190	260
Coarse sand ($g\,kg^{-1}$)	630	570	530	530	450
Silt ($g\,kg^{-1}$)	40	30	60	60	70
Clay ($g\,kg^{-1}$)	30	50	150	220	230
pH H_2O	4.70	4.40	4.60	4.40	4.40
Ca^{2+} ($cmol_c\,kg^{-1}$)[a]	0.40	0.30	0.70	0.60	0.50
Mg^{2+} ($cmol_c\,kg^{-1}$)[a]	0.40	0.30	0.70	0.50	0.50
Al^{3+} ($cmol_c\,kg^{-1}$)[a]	0.20	0.30	0.45	1.00	1.05
Na^+ ($cmol_c\,kg^{-1}$)[b]	0.05	0.07	0.06	0.04	0.03
K^+ ($cmol_c\,kg^{-1}$)[b]	0.06	0.07	0.21	0.20	0.05
Available P ($mg\,kg^{-1}$)[b]	3.00	1.00	1.00	1.00	1.00
$H^+ + Al^{3+}$ ($cmol_c\,kg^{-1}$)[c]	0.99	0.99	1.48	1.81	1.65
CEC ($cmol_c\,kg^{-1}$)[d]	1.90	1.73	3.15	3.15	2.73
Base saturation (%)	48	43	53	42	39
Aluminum saturation (%)	18	29	21	43	49
Total organic C ($g\,kg^{-1}$)[e]	3.60	2.58	1.92	2.22	1.26

[a] 1 M KCl extraction (Embrapa, 2009).
[b] Mehlich 1 (Embrapa, 2009).
[c] 0.5 M CaAc pH 7.0 extraction (Embrapa, 2009).
[d] Cation exchange capacity [$CEC = \sum Ca^{2+} + Mg^{2+} + Na^+ + K^+ + (H^+ + Al^{3+})$].
[e] Sulfur acid oxidation (Yeomans and Bremner, 1988).

2. Materials and methods

2.1. Location and characterization of the experimental area

This study was conducted in the experimental station of the National Research Center for Tropical Agroindustry of the Brazilian Agricultural Research Corporation (EMBRAPA/CNPAT), which was located in the municipality of Pacajús, state of Ceará, coordinates 4°30′S and 38°30′W. The mean temperature of the region ranges from 26 to 28 °C, and the annual rainfall is 930 mm, with a dry season that lasts 4–5 months (August–December) and a rainy season that lasts from January to July. The soil of the experimental area is a sandy loam Arenic Kandiustults (Ribeiro et al., 2007). Selected soil chemical and physical properties are presented in Table 1.

The experiment began in 1997 in an area of approximately 2 ha, where dwarf cashew (*A. occidentale*) seedlings of clone CCP 76 were planted in 7 m × 7 m space. Each experimental plot was composed of 16 plants and an area of 441 m^2.

Soil fertilization was performed annually, applied in the canopy projection and incorporated at 5 cm depth. The doses applied were based on the growth stage requirements of the cashew crop, as articulated by Embrapa (2002) and Crisóstomo et al. (2009). From the second to the fourth year of the experiment, 178 g of N, 300 g of P_2O_5, and 100 g of K_2O were applied. In the fifth year 140 g of N, 100 g of P_2O_5, and 120 g of K_2O were applied. Finally, in the last year, the formulation was changed to 200 g of N, 300 g of P_2O_5, and 180 g of K_2O. Fertilization was generally performed in February and March, or at the beginning of the rainy season.

Six treatments for the control of spontaneous plants were applied between cashew rows. The disc harrowing (DH) treatment consisted of the grinding of spontaneous plants with grids of 10-harrow discs of 60 cm of diameter coupled to the wheel of a farming tractor and incorporation of these plants at 15–20 cm depth. Mechanical mowing (MeM) consisted of the use of a mechanical mower coupled to a wheel farming tractor, whereby spontaneous plants were mowed and left under the soil surface. Manual mowing (MaM) consisted of the mowing by hand-hoeing of spontaneous plants close to the stem base and the integration of residues under the soil surface. Leguminous cover cropping (LEG) consisted of the planting of leguminous species between cashew rows, with the goal of achieving soil covering and fixation of atmospheric N. The