academicJournals

Vol. 12(52), pp. 3577-3584, 28 December, 2017
DOI: 10.5897/AJAR2017.12806
Article Number: 320A70055219
ISSN 1991-637X

http://www.academicjournals.org/AJAR

African Journal of Agricultural Research

Full Length Research Paper

Efficacy of the association of cover crops with maize and direct sowing short-term effect on crops' yields in maize-cotton cropping system in Western Burkina Faso

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Received 18 October, 2017; Accepted 29 November, 2017

To improve the productivity and sustainability of cotton and cereals based system, direct sowing under mulch was tested for its efficacy on cotton and maize yields on the research station of Farako-Bâ, in Western Burkina Faso. The experimental design was a complete randomized blocks of Fisher with four replications. Conventional tillage by annual moldboard plowing (T7) was compared with direct sowing under mulch-based cropping system (DMC) using maize association with cover crops defined as: maize without cover crop (T1), maize + *Brachiaria ruziziensis* (T2), maize + *B. ruziziensis* + *Mucuna cochinchinensis* (T3), maize + *B. ruziziensis* + *Panicum maximum* (T4), maize + *B. ruziziensis* + *Stylosanthes hamata* (T5), and maize + *Crotalaria juncea* (T6). Cover crops were planted 21 days after maize emergence between the rows of this main crop. The biomass produced by the cover crops and maize straws were evaluated as well as maize and cotton yields, during the first 6 years of the study, from 2010 to 2015. Results showed that among cover crops, the biomass production was significantly lower with *C. juncea*. The associations of cover crops with maize increased significantly the production of total dry matter compared to plots without cover crops, in the conventional tillage. Association with cover crops did not influence significantly nitrogen, phosphorus and potassium contents of maize and the maize's yields even if the depressive effects were recorded. Compared to the conventional tillage, the DMC appeared also effective on seed cotton yields even without a significant improvement during the 6 first years of the study. These promising results, confirm the feasibility in tropical conditions of DMC which must be continued to better analyze its long-term effects on soil properties.

Key words: Cover crops, mulch-based cropping system (DMC), conventional tillage, biomass, yield.

INTRODUCTION

Conservation agriculture and cropping systems using direct sowing in crop residues mulch are agricultural management practices in full expansion in many regions of the world (Lu et al., 2000; Naudin et al., 2010;

Kulagowski et al., 2016; Nascimento et al., 2016). However, in African countries, these practices are unusual and the majority of cropping systems are characterized by a low productivity, accentuated by climatic variations (Barro et al., 2009; Nielsen and Reenberg, 2010). Conventional tillage, largely practiced, contributes to the degradation of cultivated soil fertility with inappropriate tillage techniques (Schneider et al., 2010; Pedroso et al., 2016). Soil tillage modifies the distribution of crops residues, soil structure and affects consequently the micro-organisms of the soil and therefore, the mineralization of organic matter (Vian et al., 2009; Fernandes de Sousa et al., 2015). Studies have shown that decomposition of organic matter is nearly five times faster under wet and hot conditions in the humid tropics than under temperate conditions (Corbeels et al., 2006; Lal et al., 2007; Wilson, 2015). Soil tillage also affects its physical, chemical and biological properties. The tillage system is considered as the most important soil management system for the sustainability of agroecosystems (Van Eerd et al., 2014; Luoa et al., 2017).

The practice of no-tillage increases the concentration of nutrients in the upper layers of the soil and provide agronomic and environmental benefits (Ducamp et al., 2012; Santos et al., 2014; Marcillo and Miguez, 2017). Luoa et al. (2017) reported that intensification of sustainable agricultural in cultivated lands is a key element of the global response to food security and environmental protection. Studies reported on the advantages of the use of no-tillage systems, particularly, direct sowing mulch-based cropping system (DMC) which is growing in all regions of Brazil, covering 25 million hectares (Nascente et al., 2015). In this system, it is important to assess the contributions of cover crops used in the management of soil fertility (Prabhakara et al., 2015). Using cover crops in the no-tillage system could be an important alternative to increase the sustainability of agricultural systems, which may favor the increasing of soil fertility and restoring considerable amounts of nutrients to crops. The use of cover crops provided a significant increase in the level of nutrients, soil organic matter, cation exchange capacity, and base saturation in the soil (Fernandes de Sousa et al., 2015; Nascente et al., 2015). In addition to reducing nutrient runoff, cover crops, provide protection from raindrop impact and increase soil aggregate stability, decrease wind and water erosion (Zuazo and Pleguezuelo, 2008; Ducamp et al., 2012, Chowaniak et al., 2016; Morton and Abendroth, 2017).

In the Cotton-4 countries (C4), namely Benin, Burkina Faso, Mali, and Chad, soil tillage and inappropriate management practices cause an accelerated degradation of soil fertility and a decrease of yields which can compromise the cotton production, however, very important in these countries. The rainfall irregularity which characterizes climate changes, involves unfavorable conditions for ploughing, with the consequences of sowing delays, and therefore, a decrease of crops yields (Ouattara et al., 2017). In this context, there is a need to explore DMC for a sustainable alternative of crop production in these countries. Scopel et al. (2005) reported that the amount of crop residues that is retained on the surface as a mulch depends on the residue availability, and hence on crop biomass production, and on the residues destinations. In the cotton growing zones of Burkina Faso, as well as many parts in the tropics, the low amount of crops residues in conventional systems are, in general, burned or removed from the fields for various domestic uses (Ogbodo, 2011; Autfray et al., 2012), while soil surface mulching provides many benefits in no tillage systems (Sombrero and Benito, 2010; Chowaniak et al., 2016).

This study was initiated by the “C4 + Togo” project, in collaboration with Brazil and the C4 countries, to improve the sustainability of cotton sector in Africa. The objective is to quantify the biomass production of cover crops cultivated in association with maize to ensure the DMC. Moreover, the study determines the effects of the DMC technique on the crop’s yields, in a maize and cotton rotation system. It was hypothesized that the introduction of cover crops associated with maize could improve the amount of biomass which is necessary for direct sowing in mulch-based cropping system and increased crops yields.

MATERIALS AND METHODS

The experiment was conducted in Farako-Bâ Research Station (4° 20 W Longitude, 11° 06 N Latitude, 405 m above sea level). The climate is of south-Sudanese type, with a rainy season ranging between May and October, and a dry season, from November to April. During the experiment carried out from 2010 to 2015, the mean annual rainfall was between 831 and 1289 mm, received on 62 to 79 days (Table 1). The rainfall distribution was characterized by frequent dry spells of 10 days or longer in June and July, followed by water excess in August and September.

The experiment was conducted on a tropical ferruginous soil (lixisol), after 4 years of natural fallow. Soil textures were sandy loam (0 to 20 and 20 to 40 cm depths) and clayey (40 to 60 cm), with important percentages of coarse elements unfavorable for moisture and nutrients retention on the surface layers. Soil chemical properties revealed low organic matter contents, total N, available P, and cation exchange capacity, while pH values (5.3 to 5.6) showed high acidity level (Brady and Weil, 2008). The soil hydrological parameters (moisture, bulk density) revealed a good

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Table 1. Sowing dates and rainfall at Farako-Bâ research station, 2010 to 2015.

Parameter	Years					
	2010	2011	2012	2013	2014	2015
Sowing dates of crops	Maize 17/07	Cotton 08/07	Maize 17/07	Cotton 09/07	Maize 26/06	Cotton 4/07
Sowing dates of cover crops	10/08	-	20/08	-	30/07	-
Rainfall (mm)	1289.5	831.0	1089.0	1126.0	1142.9	1050.9
Number of raining days	79	73	51	63	79	65

Table 2. General soil properties at the experiment site, Farako-Bâ station, 2010.

Characteristic	Depths		
	0-20 cm	20-40 cm	40-60 cm
Clay (%)	14.25 ± 0.35	18.63 ± 0.18	28.38 ± 0.18
Silt (%)	29.55 ± 2.02	28.69 ± 1.94	27.63 ± 4.74
Sand (%)	56.45 ± 2.37	52.81 ± 2.11	44.12 ± 4.92
Texture	Sandy loam	Sandy loam	Clayey
C (g kg^{-1})	5.60 ± 0.14	3.98 ± 0.07	3.61 ± 0.09
N (g kg^{-1})	0.43 ± 0.04	0.32 ± 0.07	0.28 ± 0.05
C/N	13.00 ± 0.70	12.50 ± 0.78	13.00 ± 1.43
P total (mg kg^{-1})	104.93 ±1.40	123.94 ± 33.15	171.38 ± 5.63
P available (mg kg^{-1})	6.95 ± 0.03	3.11 ± 0.06	0.67 ± 0.18
K total (mg kg^{-1})	879.76 ± 83.06	1131.06 ± 53.97	1943.49 ± 55.21
K available (mg kg^{-1})	133.87 ± 0.01	101.66 ± 0.00	90.52 ±1.75
CEC (cmol$^+$ kg^{-1})	3.22 ± 0.25	4.32 ± 0.17	7.88 ± 0.62
pH water	5.31 ± 0.15	5.37 ± 0.41	4.94 ± 0.02
Al^{3+} (cmol$^+$ kg^{-1})	0.10 ± 0.03	0.26 ± 0.03	0.42 ± 0.03
H^+ (cmol$^+$ kg^{-1})	0.04 ± 0.01	0.06 ± 0.02	0.04 ± 0.01
Bulk density	1.55 ± 0.01	1.51 ± 0.01	1.49 ± 0.02
Particles density	2.65 ± 0.01	2.68 ± 0.02	2.68 ± 0.02
pF 2.5	15.23 ± 0.09	16.25 ± 0.30	21.29 ± 0.47
pF 3	6.47 ± 0.30	7.82 ± 0.28	13.22 ± 0.12
pF 4.2	3.72 ± 0.74	4.42 ± 0.01	8.73 ± 0.04

Values after the sign ± represent standard deviation of means.

water infiltration within the soil profile. The detailed characteristics of the soil are given in Table 2.

Plant materials was maize (*Zea mays* L.) and cotton (*Gossypium hirsutum* L.) representing the two main crops in the cotton growing zones of Burkina Faso. Cotton variety used was FK37 with a cycle of 150 days and a potential yield of 3.5 t ha^{-1} of seed cotton. Maize variety SR 21 with 110 days cycle length, and 4.1 t ha^{-1} as potential yield, was also cultivated. In addition to these two crops, the five cover crops used were, *Brachiaria ruziziensis*, *Mucuna cochinchinensis*, *Panicum maximum*, *Crotalaria juncea* and *Stylosanthes hamata*.

This study was conducted in a complete randomized block design, with seven treatments and four replications. The treatments consisted of cover crops associated with maize, followed the next year, by direct sowing of cotton, according to a biennial maize and cotton rotation (Table 3). The experimental unit of 160 m² was a plot consisting of ten 20 m length rows, spaced 0.80 m apart. Each of the four replications was separated by an alley of 2 m, while the total surface of this experiment was 4480 m². In the first year of study carried out in 2010, soil was ploughed using a tractor at an average depth of 25 cm, and then harrowed.

From the second year of study (2011), animal traction was used for ploughing (15 cm depth) only, in conventional tillage plots (T7). The direct sowing was adopted both for maize and cotton, in no-tillage system for the other treatments (T1 to T6). Thus, from the third year of experimentation, direct sowing of maize was done without soil surface mulch after removing the cotton straws. In conventional tillage system, the moldboard plough was used to carry out ploughing in animal draw for soil preparation. Before the direct sowing of crops (maize and cotton), glyphosate (N-phosphonomethyl glycine) non selective herbicides, was used for weeds control at the rate of 720 to 1080 g ha^{-1}. Cotton was directly sown on the biomass produced by maize and the cover crops residues. Cotton and maize were sown in seed holes, drawn aside

Table 3. Treatments used.

Treatment	Years and crops	
	2010, 2012 and 2014	**2011, 2013 and 2015**
T1	Maize	Cotton in DMC*
T2	Maize + *Brachiaria ruziziensis*	Cotton in DMC (maize + *B. ruz*) mulch
T3	Maize + *B. ruz* + *Mucuna cochinchinensis*	Cotton in DMC (maize + *B. ruz* + *M. cochinchinensis*) mulch
T4	Maize + *B. ruz* + *Panicum maximum.*	Cotton in DMC (maize + *B. ruz* + *P. maximum*) mulch
T5	Maize + *B. ruz* + *Stylosanthes hamata*	Cotton in DMC (maize + *B. ruz* + *S. hamata*) mulch
T6	Maize + *Crotalaria juncea*	Cotton in DMC (maize + *C. juncea*) mulch
T7	Maize in conventional tillage (CT)	Cotton in conventional tillage (CT)

DMC*: Direct sowing under mulch-based cropping system.

by 0.40 m, then thinned out 15 days after emergence, at two plants per hole, to obtain a theoretical density of 62,500 plants per hectare. Crops were sown between June 26th and July 17th, depending on years (Table 1). The cover crops *B. ruziziensis*, *M. cochinchinensis*, *P. maximum*, *C. juncea* and *S. hamata* were sown between two rows of maize 0.40 m apart from each other, approximately three weeks after the maize sowing.

In the first year of the study (2010), 6 t ha^{-1} of compost was applied for soil amendment. The average composition of compost was 20.1, 2.2, 1.1, 1.7, 0.3, 2.14, and 0.19% for C, N, P, K, S, Ca, and Mg, respectively. Mineral fertilization of cotton and maize was done using 200 kg ha^{-1} of NPKSB (14-18-18-6S-1B) applied 15 days after emergence and 50 kg ha^{-1} of urea (46% N), at 40 days. Cover crops were not fertilized. Weeds control on the two main crops was done using the herbicides applications (800 g ha^{-1} of diuron for cotton and 1250 g ha^{-1} of pendimethalin for maize) supplemented by mechanical weeding. Cotton protection was ensured by applying the insecticides indoxacarb (150 g ha^{-1}) at 30 and 44 days after emergence, the association of zeta-cypermethrin (12 g ha^{-1}) and profenofos (200 g ha^{-1}) at 58 and 72th days, and cypermethrin (36 g ha^{-1}) associated with acetamiprid (8 g ha^{-1}) at the 86 and 100th days. After maize harvesting, maize straws and cover crops biomass were preserved as surface mulches for soil protection. Thus, in conventional tillage plots (T7), maize straws were completely exported out of the field, as well as the cotton straws removed from all treatments.

In the first year of experimentation, leaf samples of maize were collected at 60 days after plants emergence to determine nitrogen, phosphorus and potassium contents. Cotton and maize yields, as well as the dry matter of these two crops, were evaluated on eight central lines (128 m²) of each plot. Determination of the biomass produced by the cover crops (combined with maize) was done from four 1 m² spots in each plot.

Data were collected and subjected to an analysis of variance (ANOVA), using the GENSTAT 9.2 software. Student-Newman-Keuls test was used for means comparison when the analysis of variance reveals significant differences between treatments at 5% significance level.

RESULTS AND DISCUSSION

Contribution of cover crops to biomass production in DMC

The biomass production of cover crops associated with maize varied significantly ($P < 0.05$) according to the type of cover crops (Table 4). Measurements of biomass in 2010, 2012 and 2014 showed that *C. juncea* associated with maize (T6) gave significantly lower biomasses productions. This result confirms that the production of biomass was very dependent on used cover crops reported by various studies (Fageria et al., 2005; Ducamp et al., 2012; Santos et al., 2014). The use of *B. ruziziensis* alone (T2) or associated with *M. cochinchinensis* (T3), *P. maximum* (T4), and *S. hamata* (T5) gave no significant difference in biomass productions (2010 and 2012). However, in 2014, this biomass decreased significantly ($P < 0.05$) with *B. ruziziensis* + *Mucuna cochincinensis* (T3) due to the growing conditions. Santos et al. (2014) reported the interest of covers crops, particularly, grasses with a deep root system and high biomass production, which are essential for nutrient supply in the long term, mainly in the soil surface layers. The lowest biomass productions obtained with *C. juncea* (T6) could be attributed to low densities and vegetative growth of this cover crop which suffer from the competition of maize. Planting two cover crops between main crop (maize) rows, did not improve the biomass amount compared to the use of *B. ruziziensis* alone (T2) which can produce more than 3917 kg ha^{-1} of dry matter. The important biomass production of cover crops can also be affected by environmental conditions, soil fertility and crop management practices (Zuazo and Pleguezuelo, 2008; Basche et al., 2016)

The lowest quantities of total dry matter were produced in the control (T1) and conventional tillage system (T7) plots, without using the cover crops (Table 5). The productions of total dry matter were significantly improved by the associations of cover crops with maize, except *C. juncea* (T6). Using the cover crops, total biomass increase was +13% with *C. juncea* and +63 to +89% with *B. ruziziensis* alone or combined with the other cover crops, which gave better soil covering and the protection from water erosion (Santos et al., 2014; Prabhakara et al., 2015; Alvarez et al., 2017). In addition to the soil protection, the increase in total biomass would induce an improvement of soil organic and biological status (Wilson, 2015). The use of the leguminous *M. cochinchinensis* as cover crop in this study could contribute to nitrogen

Table 4. Productions of dry matter biomass by cover crops associated with maize during 3 years.

Treatment	2010	2012	2014
	kg ha^{-1}		
T1. Maize	-	-	-
T2. Maize + *B. ruziziensis*	3142^{a} ± 770	3442^{a} ± 863	3917^{ab} ± 412
T3. Maize + *B. ruz* + *M. cochinchinensis*	3421^{a} ± 871	3653^{a} ± 879	2500^{bc} ± 610
T4. Maize + *B. ruz* + *P. maximum*	3488^{a} ± 709	3435^{a} ± 1230	5317^{a} ± 1831
T5. Maize + *B. ruz* + *S. hamata*	2454^{a} ± 860	2538^{ab} ± 1118	4483^{a} ± 1502
T6. Maize + *Crotalaria juncea*	833^{b} ± 789	1729^{b} ± 698	1433^{c} ± 402
T7. Maize in conventional tillage (CT)	-	-	-
F	6.681	2.759	6.013
Probability (0.05)	< 0.0001	0.014	0.004

Values followed with the same letter in each column did not differ statistically according to Student-Newman-Keuls test at 5% level of probability. Values after the sign ± represent standard deviation of means.

Table 5. Total biomass production by maize straws and cover crops.

Treatment	2010	2012	2014
	kg ha^{-1}		
T1. Maize	3932^{b} ± 1142	2258^{d} ± 664	5703^{d} ± 167
T2. Maize + *B. ruziziensis*	6698^{a} ± 704	5981^{a} ± 946	9229^{ab} ± 1030
T3. Maize + *B. ruz* + *M. cochinchinensis*	7314^{a} ± 1121	5551^{ab} ± 344	7786^{bc} ± 575
T4. Maize + *B. ruz* + *P. maximum*	7124^{a} ± 732	6114^{a} ± 518	9965^{a} ± 723
T5. Maize + *B. ruz* + *S. hamata*	6221^{a} ± 1028	5124^{ab} ± 1399	9314^{ab} ± 2221
T6. Maize + *Crotalaria juncea*	4373^{b} ± 1542	4253^{bc} ± 1019	6694^{cd} ± 637
T7. Maize in conventional tillage (CT)	3868^{b} ± 655	3336^{cd} ± 1175	6510^{d} ± 1044
F	8.838	9.607	9.085
Probability (0.05)	<0.0001	<0.0001	<0.0001

Values followed with the same letter in the same column did not differ statistically according to Student-Newman-Keuls test at 5% level of probability. Values after the sign ± represent standard deviation of means.

fixation (Lu et al., 2000; Santos et al., 2014) and can reduce the use of nitrogenous fertilizers of subsequent crops (Tabaldi et al., 2012). The increase of biomass quantities by cover cropping and maintenance of maize straws on the field were favorable to cotton growing in DMC, which main limiting factor in tropical zone, is small amounts of surface residue for soil mulching (Zuazo and Pleguezuelo, 2008; Tabaldi et al., 2012; Prabhakara et al., 2015).

Nitrogen, phosphorus and potassium contents of maize associated with the cover crops

In the first year of experimentation, the use of cover crops associated with maize did not have significant effects on N, P and K contents of maize (Table 5). Cover crops are generally included in cropping systems as nutrient management tools (Ruffo and Bollero, 2003; Busari et al., 2015). According to Loué (1984), maize nutrition was correct for P and K with higher contents than their respective deficiency level of 0.25 and 1.75%. Thus, values of nitrogen were sometimes below the level considered to be adequate (2.75%) by Loué (1984), indicating a nitrogen deficiency on treatments associating maize with *B. ruziziensis* + *P. maximum* (T4) and *B. ruziziensis* + *S. hamata* (T5). Dinnes et al. (2002) and Luoa et al. (2017) reported that for the first several years after conversion to no-tillage, there is competition for nitrogen with soil productivity increases and more nitrogen is stored in the soil in the form of organic matter and humus. These results suggested that the use of cover crops, properly associated with maize may increase biomass production (Fageria et al., 2005) without affecting maize nutrition.

Effects of cover crops association on maize yields

Maize grain yields were not statistically influenced by

Table 6. Nitrogen, phosphorus and potassium contents of maize in 2010.

Treatment	N	P	K
	% Dry matter		
T1. Maize	2.97 ± 0.39	0.49 ± 0.13	2.52 ± 0.30
T2. Maize + *B. ruziziensis*	2.86 ± 0.64	0.38 ± 0.03	2.53 ± 0.01
T3. Maize + *B. ruz* + *M. cochinchinensis*	2.79 ± 0.10	0.38 ±0.05	2.63 ± 0.15
T4. Maize + *B. ruz* + *P. maximum*	2.74 ± 0.03	0.36 ± 0.02	2.73 ± 0.01
T5. Maize + *B. ruz* + *S. hamata*	2.56 ± 0.21	0.34 ± 0.08	2.63 ± 0.45
T6. Maize + *Crotalaria juncea*	3.17 ± 0.43	0.37 ± 0.01	2.84 ± 0.15
T7. Maize in conventional tillage (CT)	2.86 ± 0.21	0.35 ± 0.01	2.63 ± 0.14
F	0.442	1.215	0.500
Probability (0.05)	0.830	0.398	0.792

Values after the sign ± represent standard deviation of means.

Table 7. Yields of maize associated or not with cover crops.

Treatment	2010	2012	2014
	kg ha^{-1}		
T1. Maize	2973^{a} ± 577	2338^{ab} ± 469	3878^{ab} ± 331
T2. Maize + *B. ruziziensis*	2686^{a} ± 887	2441^{ab} ± 781	3782^{ab} ± 572
T3. Maize + *B. ruz* + *M. cochinchinensis*	2622^{a} ± 624	1931^{b} ± 1182	3795^{ab} ± 405
T4. Maize + *B. ruz* + *P. maximum*	2808^{a} ± 497	2527^{ab} ± 575	3362^{b} ± 866
T5. Maize + *B. ruz* + *S. hamata*	2619^{a} ± 590	2406^{ab} ± 109	3770^{ab} ± 582
T6. Maize + *Crotalaria juncea*	2696^{a} ± 528	2462^{ab} ± 658	4106^{ab} ± 113
T7. Maize in conventional tillage (CT)	3039^{a} ± 787	3138^{a} ± 761	4218^{a} ± 702
F	0.230	0.992	0.964
Probability (0.05)	0.962	0.027	0.473

Values followed with the same letter in the same column did not differ statistically according to Student-Newman-Keuls test at 5% level of probability. Values after the sign ± represent standard deviation of means.

cover crops association in first year (2010), contrary to the third and fifth years (Tables 6 and 7). The best yields were obtained with maize cultivated without cover crops in conventional tillage (T7). Fageria et al. (2005) reported that planting cover crops between main crops can improve soil physical, chemical, and biological properties and consequently lead to improved soil health and yield of principal crops. During the first 6 years of this study, DMC did not show significant increase in maize yields reported by various studies (Scopel et al., 2005; Ducamp et al., 2012; Santos et al., 2014; Luoa et al., 2017). Results showed that cover crops associations led to depressive effects on maize yields mainly due to the competition for water and nutrients of cover crops with maize (Santos et al., 2014; Alvarez et al., 2017). The most significant decreases of maize yields were 13.8 and 38.5%, respectively in 2010 and 2012, with insertion of *B. ruziziensis* + *M. cochinchinensis* (T3) between maize rows. In the experiment, the most severe competition was induced by *M. cochinchinensis* cover cropping invading completely the maize plants whose potentials of production were also reduced. In short term study, after three years experiment, Nkongoloa and Harunab (2015) reported that maize yield was not significantly affected by tillage or cover crop which may have an impact on soybean yield. These results suggested a better choice and management of cover crops in order to avoid adverse effects of cover cropping reported by Dinnes et al. (2002).

Variations of seed cotton yields in DMC

No tillage in DMC (Table 8) did not affect significantly seed cotton yields compared with conventional tillage (T7) using moldboard plough, which is difficult to be done under irregular and unstable climatic conditions (Nielsen and Reenberg, 2010). In 2011, 2013, and 2015, the direct sowing of cotton under maize stems and cover crops biomasses, were as effective on yield conventional tillage system (T7) with annual plough causing soil erosion, compaction, and nutrient depletion (Ouattara et al., 2006;

Table 8. Seed cotton yields variations in conventional tillage and direct sowing with maize as precedent crop.

Treatment	2011	2013	2015
		Kg ha^{-1}	
T1. *DMC maize straws mulch	2214 ± 506	1248 ± 255	1082 ± 140
T2. DMC (maize + *B. ruziziensis)* mulch	2155 ± 264	1195 ± 219	1166 ± 320
T3. DMC (maize + *B. ruz* + *Mucuna c.*) mulch	2045 ± 413	1090 ± 242	1212 ± 234
T4. DMC (maize + *B. ruz* + *Panicum m*) mulch	2202 ± 253	1142 ± 161	1188 ± 286
T5. DMC (maize + *Brach ruz* + *S. hamata*) mulch	2059 ± 391	1204 ± 162	1173 ± 144
T6. DMC (maize + *C. juncea)* mulch	2146 ± 310	1049 ± 140	1015 ± 180
T7. Conventional tillage (CT)	2298 ± 177	1284 ± 334	1336 ± 380
F	0.262	0.616	0.628
Probability (0.05)	0.948	0.715	0.706

*DMC: Direct sowing under mulch-based cropping system. Values after the sign ± represent standard deviation of means.

Basche et al., 2016; Chowaniak et al., 2016; Morton and Abendroth, 2017). This result confirms the importance of DMC which can enhance profitability by lowering machinery and other costs and are more environmentally fit than the moldboard plough (Sombrero and Benito, 2010; Tabaldi et al., 2012; Luoa et al., 2017). Furthermore, yield increases depend on management of cover crops as well as subsequent crops (Fageria et al., 2005). During this study carried out from 2011 to 2015, probably due to climatic variations, the cover crops and no tillage in DMC did not gave the expected increase of crops yield reported by Oliveira et al. (2016). The higher seed cotton yields in 2011 could be attributed to the residual effects of 6 t ha^{-1} of compost previously applied for soil amendment at the beginning of the study in 2010. Long-term research reveals that seven to nine years of continuous no-till produces higher yields than conventionally tilled fields because it takes seven to nine years to improve soil health by getting the microbes and soil fauna back into balance and to start to restore the nutrients lost by tillage (Van Eerd et al., 2014; Kulagowski et al., 2016). The low effectiveness of DMC in improvement of cotton and maize yields, founded in this experiment, seems related to the insufficiency of soil mulching by the residues which are used for the animals feeding. But also, the number of years of experimentation seems insufficient to obtain positive effects of DMC.

Conclusion

This study pointed out the benefit of cover crops insertion between the main crops to improve biomass production which is necessary to undertake direct sowing under mulch-based cropping system. The association of various cover crops with maize did not influence maize plants nutrition in the first year of experimentation, but this practice could affect the maize yields compared to conventional tillage. Generally, even if the DMC did not produce improvements in cotton and maize yields, these practices appeared as effective as conventional tillage system which is more expensive for the requirement of soil plowing. These first results, suggested a better use of cover crops to avoid the risks of competition with the principal crop. Analyses of specific impact of each cover crop were needed to improve management of cover crops for appropriate recommendations to farmers regarding the diversification of agricultural productions. In addition, this study revealed a potential to be explored by direct sowing under mulch-based cropping system. Therefore, the DMC effects on soil properties, especially on soil hydrology and nutrients cycling, need to be determined for environmental sustainability of the production system in continuation of the study.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

ACKNOWLEDGEMENTS

The authors would like to thank the Brazilian Cooperation Agency through the “C4 +Togo” project, which is at the origin of this study and the Cotton Interprofessional Association of Burkina Faso (AICB), for its financial contribution.

REFERENCES

Alvarez R, Steinbach HS, De Paepe JL (2017). Cover crop effects on soils and subsequent crops in the pampas: A meta-analysis. Soil Till. Res. 170:53-65.

Autfray P, Sissoko F, Falconnier G, Ba A, Dugue P (2012). Usages des résidus de récolte et gestion intégrée de la fertilité des sols dans les systèmes de polyculture élevage : étude de cas au Mali-Sud. Cah. Agric. 21:225-234.

Basche AD, Archontoulis SV, Kaspar TC, Jaynes DB, Timothy B, Parkin TB, Miguez FE (2016). Simulating long-term impacts of cover crops and climate change on crop production and environmental outcomes in the Midwestern United States. Agric. Ecosyst. Environ. 218:95-106.

Barro A, Zougmoré R, Sédogo MP (2009). Evaluation de la faisabilité de trois types de travail du sol : application du modèle Sarra dans le Plateau central au Burkina Faso. Sécheresse 20(4):338-345.

Brady NC, Weil RR (2008). The Nature and Properties of Soils. 14 ed., Pearson-Prentice Hall, Upper Saddle River: NJ; 990p.

Busari MA, Kukal SS, Kaur A, Bhatt R, Dulazi AA (2015). Conservation tillage impacts on soil, crop and the environment. Int. Soil Water Conserv. Res. 3:119-129.

Chowaniak M, Klima K, Niemiec M (2016). Impact of slope gradient, tillage system, and plant cover on soil losses of calcium and magnesium. J. Elementol. 21(2):361-372.

Corbeels M, Scopel E, Cardoso A, Bernoux M, Douzet JM, Neto MS (2006). Soil carbon storage potential of direct seeding mulch-based cropping systems in the Cerrados of Brazil. Glob. Change Biol. 12:1773-1787.

Dinnes DL, Karlen DL, Jaynes DB, Kaspar TC, Hatfield JL, Colvin TS, Cambardella CA (2002). Nitrogen management strategies to reduce nitrate leaching in tile-drained Midwestern soils. Agron. J. 94:153-171.

Ducamp F, Arriaga FJ, Balkcom KS, Prior SA, Van Santen E, Mitchell CC (2012). Cover crop biomass harvest influences cotton nitrogen utilization and productivity. Int. J. Agron. 12 p. Article ID 420624

Fageria NK, Baligar VC, Bailey BA (2005). Role of cover crops in improving soil and row crop productivity. Comm. Soil Sci. Plant Anal. 36:2733-2757.

Kulagowski R, Riggi L, Chailleux A (2016). Short-term effects of conversion to direct seeding mulch-based cropping systems on macro-fauna and weed dynamics. J. Crop Improv. 30(1):65-83.

Fernandes de Sousa R, Brasil EPF, Célio de Figueiredo C, Leandro WM (2015). Soil organic matter fractions in preserved and disturbed wetlands of the cerrado biome. Rev. Bras. Cienc. Solo 39(1):222-231.

Lal R, FolIett RF, Stewart BA, KimbIe JM (2007). Soil carbon sequestration to mitigate climate change and advance food security. Soil Sci. 172(12):913-956.

Loué A (1984). Méthode de contrôle de la nutrition minérale du maïs. In l'analyse végétale dans le contrôle de l'alimentation des plantes tempérées et tropicales, (ed) Martin-Prevel P, Gagnard J, Gautier P, Paris: Éditions Tec & Doc – Lavoisier pp. 598-631.

Lu Y, Bradley WK, Teasdale JR, Abdul-Baki AA (2000). Cover crops in sustainable food production. J. Food Rev. Int. 16(2):121-157.

Luoa Z, Wanga E, Xinga H, Smitha C, Wangb G, Cresswella H (2017). Opportunities for enhancing yield and soil carbon sequestration while reducing N_2O emissions in rainfed cropping systems. Agric. For. Meteor. 232:400-410.

Ogbodo EN (2011). Effect of crop residue on Soil Chemical Properties and Rice Yield on an Ultisol at Abakaliki, Southeastern Nigeria. World J. Agric. Sci. 7(1):13-18.

Marcillo GS, Miguez FE (2017). Corn yield response to winter cover crops: An updated meta-analysis. J. Soil Water Conserv. 72(3):226-239.

Morton LW, Abendroth LJ (2017). Crops, climate, culture, and change. J. Soil Water Conserv. 72(3):47-52.

Nascente AS, Stone LF, Crusciol CAC (2015). Soil chemical properties affected by cover crops under no-tillage system. Rev. Ceres Viçosa 62(4):401-409.

Nascimento EC, Matos TS, Genuncio GC, Amaral Sobrinho NMB, Everaldo Zonta E (2016). Characterization of family organic production in peri-urban regions. Afr. J. Agric. Res. 11(18):1629-1637.

Naudin K, Gozé E, Balarabe O, Giller KE, Scopel E (2010). Impact of no tillage and mulching practices on cotton production in North Cameroon: A multi-locational on-farm assessment. Soil Till. Res. 108(1-2):68-76.

Nielsen JO, Reenberg A (2010). Cultural barriers to climate change adaptation: A case study from Northern Burkina Faso. Glob. Environ. Change 20:142-152.

Nkongoloa NV, Harunab SI (2015). Effect of Tillage and Cover Crop on Corn and Soybean Yields in a Silt Loam Soil. Proced. Environ. Sci. P 29.

Oliveira RA, Brunetto G, Loss A, Gatiboni LC, Kürtz C, Júnior VM, Lovato PE, Oliveira BS, Souza M, Comin JJ (2016). Cover crops effects on soil chemical properties and onion yield. Rev. Bras. Ciênc. Solo 40:23.

Ouattara B, Ouattara K, Serpentié G, Mando A, Sédogo MP, Bationo A (2006). Intensity cultivation induced effects on soil organic carbon dynamic in the western cotton area of Burkina Faso. Nutr. Cycl. Agroecosyst. 76:331-339.

Ouattara K, Serme I, Bongoungou S, Zombre P (2017). Soil and water conservation, and soil fertility management effects on rain water productivity of maize hybrid in Burkina Faso. Afr. J. Agric. Res. 12(12):1014-1021.

Pedroso AJS, Ruivo MLP, Piccinin JL, Okumura RS, Birani SM, Júnior MLS, Silva de Melo V, Costa AR, Albuquerque MPF (2016). Chemical attributes of Oxisol under different tillage systems in Northeast of Pará. Afr. J. Agric. Res. 11(49):4947-4952.

Prabhakara K, Hively WD, McCarty GW (2015). Evaluating the relationship between biomass, percent groundcover and remote sensing indices across six winter cover crop fields in Maryland, United States. Int. J. Appl. Earth Observ. Geoinf. 39:88-102.

Ruffo ML, Bollero GA (2003). Modeling rye and hairy vetch residue decomposition as a function of degree days and decomposition days. Agron. J. 95:900-907.

Sombrero A, Benito A (2010). Carbon accumulation in soil. Ten-year study of conservation tillage and crop rotation in a semi-arid area of Castile-Leon, Spain. Soil Till. Res. 107:64-70.

Santos IL, Caixeta CF, Cortês de Sousa AAT, Figueiredo CC, Ramos MLG, Carvalho AM (2014). Cover plants and mineral nitrogen: effects on organic matter fractions in an oxisol under no-tillage In the Cerrado. R. Bras. Cienc. Solo 38:1874-1881.

Schneider F, Kallis G, Martinez-Alier J (2010). Crisis or opportunity? Economic degrowth for social equity and ecological sustainability. Introduction to this special issue. J. Clean. Prod. 18:511-518.

Scopel E, Findeling A, Guerra EC, Corbeels M (2005). Impact of direct sowing mulch-based cropping systems on soil carbon, soil erosion and maize yield. Agron. Sustain. Dev. 25:425-432.

Tabaldi LA, VieiraI MC, ZárateI NAH, da Silva LR, Farias WL, Pilecco GM, Formagio ASN, Gassi RP, Padovan MP (2012). Cover crops and their effects on the biomass yield of *Serjania marginata* plants. Ciênc. Rural Santa Maria 42(4):614-620.

Van Eerd LL, Congreves KA, Hayes A, Verhallen A, Hooker DC (2014). Long-term tillage and crop rotation effects on soil quality, organic carbon and total nitrogen. Can. J. Soil Sci. 94:303-315.

Vian JF, Peigné J, Chaussod R, Roger-Estrade J (2009). Effets du mode de travail du sol sur les microorganismes à l'échelle du profil cultural. Étude et Gestion des Sols 16(3/4):355-364.

Wilson CB (2015). Long-term Impacts of conservation management practices on soil carbon storage, stability, and utilization under cotton production in West Tennessee. "Master's Thesis, University of Tennessee. http://trace.tennessee.edu/utk_gradthes/3555

Zuazo VHD, Pleguezuelo CRR (2008). Soil-erosion and runoff prevention by plant covers: A review. Agron. Sustain. Dev. 28(1):65-86.