Scientific Research Publishing

Open Journal of Soil Science, 2021, 11, 352-365
https://www.scirp.org/journal/ojss
ISSN Online: 2162-5379
ISSN Print: 2162-5360

Effects of Direct Sowing under Mulch-Based Cropping System (DMC) on Cotton and Maize Yield and Chemical Characteristics of Ferruginous Soil (Lixisoil) in the South Sudan Area of Burkina Faso

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How to cite this paper: Ouattara, A., Koulibaly, B., Dakouo, D., Coulibaly, K., Bazongo, P., Traore, O. and Nacro, H.B. (2021) Effects of Direct Sowing under Mulch-Based Cropping System (DMC) on Cotton and Maize Yield and Chemical Characteristics of Ferruginous Soil (Lixisoil) in the South Sudan Area of Burkina Faso. *Open Journal of Soil Science*, **11**, 352-365.
https://doi.org/10.4236/ojss.2021.116018

Received: March 23, 2021
Accepted: June 27, 2021
Published: June 30, 2021

Abstract

To better understand the effects of direct sowing under mulch-based cropping system (DMC) in Burkina Faso's cotton production systems, randomized blocks of Fisher experimental design were implemented at Farako-Bâ research station from 2010 to 2019. The study was conducted on lixisoil to evaluate DMC effects on biomass production, crops yields and soil chemical properties in a maize and cotton rotation system associated with cover crop. Conventional tillage and direct seeding without cover crop were compared to DMC under *B. ruziziensis* (GERM. & EVRARD), DMC under *B. ruziziensis* + *M. cochinchinensis* mulch and DMC under *C. juncea* (L.) mulch used in association with maize. Biomass production, crop yields and soil chemistry were evaluated. Results showed that over 10 years, no-till with or without a cover crop provided cotton seed and maize yields that were statistically equivalent to the tillage commonly practiced by farmers. Cover crop has allowed increasing the biomass production compared to Conventional Tillage and Direct Seeding. Maize yield has not varied significantly with the cover crop. After 10 years of maize and cotton rotation, the improvement raised from +27% to +38% for organic matter and from +15% to +29% for nitrogen with DMC including legumes such as *M. cochinchinensis* and *C. juncea* compared to Conventional Tillage on 0 - 5 cm depth. No significant differences were found on soil pH like P_2O_5 and K_2O content. Although DMC with *C. juncea* used as cover crop did not provide the best biomass production, it contributes to increase nitrogen and organic matter and presents better mineral balances in 10 years of rotation. The 5 - 10 cm and 10 - 20 cm were little influenced by DMC systems.

Keywords

Cover Crop, Tillage, Direct Sowing under Mulch-Based Cropping System, Crop Rotations, Soil Characteristic, Leguminous

1. Introduction

To be adopted in terms of inadequate crop systems [1]. Many Conservation agriculture (CA) has long been practiced around the world [2]. In Burkina Faso, as in some sub-Saharan African countries, several studies have been conducted on the socio-economic benefits and positive water balance of CA and have allowed some researchers to recommend this form of agriculture [3]. However, the contribution of CA on physical, chemical and biological characteristics will constitute arguments for better adoption of CA for sustainable production [4] [5]. It's characterized by three principles: minimum tillage, and soil disturbance permanent soil cover and crop rotation and intercropping [5]. CA exists in several forms. From reduced tillage alone or in combination with cover crops, it can ensure sustainable production. In direct sowing under mulch-based cropping system (DMC) which is a form of conservation agriculture, cotton production takes on another dimension because the fiber cannot be associated with biomass production that could influence its quality. In West African cotton systems, soil fertility constitutes a major constraint on ensuring sustainable production [3]. Extension of crop areas is not possible due to over increasing of the human population. The dynamics of agro-systems and soil fertility management in West Africa have led to negative soil evolution. As a result, the acidity, the organic matter and mineral content in soils are below the average recommended levels according to soil chemical interpretation standards [6] [7]. Cropping systems must focus on maintaining or improving the soil organic matter and mineral content and their availability for crops. Factors that contribute to soil degradation include the lack of organic restitution, cropping practices such as annual ploughing of fields [6] [8]. However, DMC application in cotton-based production systems requires an adaptation of the principles in order to ensure cereals and cotton production that meets market standards. Crop residues are insufficient for good soil cover in sub-Saharan Africa [9]. It is important to use cover plants in combination with cereals in a context of cropland scarcity to improve the amount of biomass on plots. In direct sowing under mulch-based cropping system (DMC), cover plants are used based on their highly variable characteristics from one species to another [10].

Depending on their characteristics and their development mode, cover crops can influence soil characteristics in different ways. *B. ruziziensis* has high potential to produce above and below ground biomass that can reach deep soil layers. *C. juncea* is a dicotyledon plant with high biomass, which allows mineral elements to be brought up into surface layers. *M. cochinchinensis* is a creeping leguminous with important biomass.

Therefore, it is necessary to identify the contributions of cover plants species, including their potential for producing aerial and underground biomass that may improve soil fertility. In DMC the chemical characteristics of the soil, namely organic matter, nitrogen, phosphorus, and potassium contents, are thought to be partly the result of cover plants and the roots biomass decomposition [11]. The residues degradation in the soil is a function of climate, soil characteristics and residues quality. The degradation rate of mulch depends on the organic matter quality. The quantity and quality of biomass produced varies according to the cover crop species [12]. In the DMC, this degradation constitutes an important source to improve nitrogen, phosphorus and potassium rate of soil. In addition to their biomass production potential, some cover plants are atmospheric nitrogen-fixing. Many cover plants as *Brachiaria* spp., *Panicum* spp., dicotyledon, namely *Crotalaria* spp. *Cajanus* spp. and *Mucuna* spp. are using by the farmers [13]. The objective of this study is to determine the effects of DMC with three specifics covers crops, on the crops yields and chemical characteristics of soil in the South Sudan area of Burkina Faso.

2. Methods

2.1. Study Site

The experimental site was located at Farako Bâ research station in a southwest of Bobo Dioulasso. From 2009 to 2019, the annualmean rainfall was between 744 mm received in 51 days and 1308 mm in 72 days (**Figure 1**). Compared to the mean, 2010, 2013, 2014, 2018, and 2019 rainy seasons recorded an increase from 58 to 239 mm of water. The lowest rainfall was recorded in 2011 and 2017 with 831 and 744.6 mm respectively (**Figure 1**). The soil studied is lixisol characterized by low organic matter (less than 1%), total N (0.043%) and P (104.43 mg·kg^{-1})

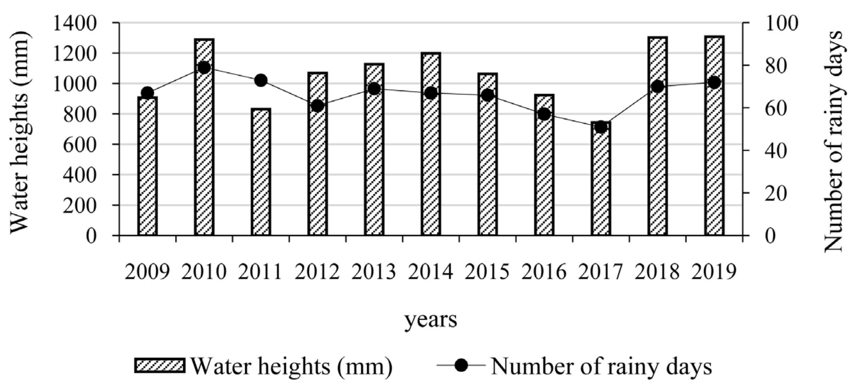

Figure 1. Annual rainfall of Farako-Bâ research station from 2009 to 2019.

content. Texture was sandy in 0 - 40 cm depth and clay in 40 to 60 cm depth. The pH varied from 5.3 to 5.6.

2.2. Plant Materiel

Plant material used included maize (Zea mays L.) variety SR21 with 95 - 110 days of cycle (seeding to maturity) and 5100 kg·ha^{-1} as potential yield and the cotton (*Gossypium hirsutum L.*) FK37 with 120 days of cycle (seeding to boll opening) and 2600 kg·ha^{-1} as potential yield. These varieties are adapted to the local conditions and comely used in Burkina Faso. Three species of cover plants used in pure or in combination with other crops. The biomass of *B. ruziziensis* (GERM. & EVRARD) can reach 6000 to 8000 kg·ha^{-1} under tropical climate. Its fasciculate root system is made up of many roots, dense and constitutes an important source of organic matter both on the surface and in the depth from 1.8 m to 2 m and can help to improve soils [13]. The root system is capable to restructure soil, bring carbon in depth and recycling leached nutrients.

M. cochinchinensis is a leguminous used as green manure and cover plant species, is also grown in combination with cereals to improve biomass. As leguminous, *M. cochinchinensis* fixes atmospheric nitrogen. The *C. juncea* (*L.*) is an annual leguminous up to 4 m long. Its potential biomass can reach 3 to 6 t·ha^{-1} with 3.6% of nitrogen. It can return 100 to 220 units of nitrogen per hectare (Notice: les crotalaires from Institut technique tropical). The maize, cotton and *M. cochinchinensis* seeds were provided by the seed production service at the Farako-Bâ experimental research center. The seeds of *B. ruziziensis* and *C. juncea* were provided by Brazilian Agricultural Research Company, Secretariat of International Relations (Embrapa Cotton).

2.3. Soil Fertilization

Inorganic fertilizer (14 − 18 − 18 + 6S + 1B) were applied in side dressing ten centimeters from the roots and buried at the rate of 44N, 27P, 27K, 9S and 1.5B per hectare on cotton and 74N, 36P, 36K, 12S and 2B per hectare on maize at 15 days after sowing and Urea (46% of N) at 40 days after sowing

Five treatments including three direct sowing under mulch-based cropping system (DMC) with cover plants associated with maize was compared and defined below:

- Conventional Tillage (CT) (annual ploughing): cotton/maize sowing after annual plough;
- Direct Seeding (DS) without cover plant: direct sowing of cotton/maize without mulch;
- DMC/*B. ruziziensis* mulch (DMC 1): direct sowing of cotton under maize and *B. ruziziensis* mulch;
- DMC/*B. ruziziensis* + *M. cochinchinensis* mulch (DMC 2): direct sowing of cotton under maize and *B. ruziziensis* + *M. cochinchinensis* mulch;
- DMC/*C. juncea* mulch (DMC 3): direct sowing of cotton under maize and *C. juncea* mulch.

2.4. Methodological Approach

The approach adopted in this study is to define the possibilities of biomass production with the use of cover plants associated with maize in cotton and maize biennial rotation systems. The growing of maize and cover plants provides a biomass for the direct seeding of the cotton the following campaign. On the course of this study, a randomized block of Fisher experimental design with five treatments and four replications was used for this study. The basic plot consists of 11 lines of 20 m.

Maize, cover crops and cotton residues are kept on the plots. At the head of rotation, maize is combined with cover crops to improve biomass production for use as soil cover. After 15 to 20 days of maize sowing, *B. ruziziensis* and *C. juncea* were sown continuously between the maize rows and *M. cochinchinensis* is sowing in pocket (0.40 m between pockets). Cotton and maize were sown at the same dimensions, *i.e.* 0.80 m between rows and 0.40 m between pocket, giving 62,500 plants ha^{-1} as theoretical density.

NPKSB fertilizer was applied 15 days after emergence and urea at 40 days after emergence. Weed control was carried out if necessary and phytosanitary treatments were carried out using Indoxacarb 150 $g \cdot L^{-1}$, Zeetacypermethryn 12 $g \cdot L^{-1}$ profenfos 200 $g \cdot L^{-1}$ and Acetamiprid 32 $g \cdot L^{-1}$ cypermethrin 144 $g \cdot L^{-1}$ for the three insecticide treatment windows. Maize combined with cover crops was sown in 2010, 2012, 2014, 2016 and 2018, while cotton was sown in 2011, 2013, 2015, 2017 and 2019.

2.5. Data Collection and Analysis

The variables studied consisted of the biomass of maize and cover plant, changes in crop yields, soil acidity (pH), soil organic matter levels, P total and available P, total K and available K. The balances of the chemical parameters were assessed from the initial soil reserves to the implementation of the test and the reserves after 10 years of application of the different systems. The balance sheets reflect the amount between the soil reserves in 2019 and the reserves for the implementation of the study in 2010.

Soil analysis was carried out at the Soil-Water-Plant laboratory at the Farako Bâ research center. The pH water was determined with pH-meter with glass electrode following a 1/2.5 solution ratio. [14] Method was used for organic carbon determination. The organic matter rate is obtained from the formula Carbon rate * 1.724. Total nitrogen was measured by the Kjeldahl method [15]. Total Phosphorus was measured on the condensed mineralization [16]. Assimilable phosphorus was determined by the BRAY 1 method [17]. Total potassium was measured at the flame spectro-photometer from the remnant of the filter from the mineralization of soil test shots.

Data were collected and entered with the Excel 2010 version. XLSTAT 2016 with Fisher test (5%) was used for means separating and standard deviations was calculated with R version 3.6.0 (2019-04-26).

3. Results

3.1. Variations of the Yields of Maize Associated to Cover Crops

Cover crops associated with maize give equivalent maize yields compared to Conventional Tillage (Table 1). The DMC allows an equivalent yield of maize compared to Conventional Tillage and Direct Seeding. Over five years of maize production in rotation with cotton, the average yields ranged from 2791 $kg \cdot ha^{-1}$ (DMC/*B. ruziziensis* + *M. cochinchinensis*) to 3221 $kg \cdot ha^{-1}$ (Conventional Tillage). Maize yields increased regardless of treatments (Table 1).

3.2. Variations of Cotton Yields in Systems of Production

Statistical analyses indicate that cotton yields from 2011 to 2019 were not influenced by the treatments applied (Table 2). Compared to Conventional Tillage, DMC did not give significant improvements in cotton yields. Over the five years of cotton production in rotation, average yields ranged from 1191 $kg \cdot ha^{-1}$ (DMC/*B. ruziziensis*) to 1390 $kg \cdot ha^{-1}$ (Conventional Tillage). Overall, trends indicate stability in cotton yields with Conventional Tillage compared to the Direct Seeding and DMC that decline slightly.

Table 1. Evolution of the maize yields from 2010 to 2018 under different treatments.

Treatments	2010	2012	2014	2016	2018	Average
	$kg \cdot ha^{-1}$					
Conv. Tillage	2368 ± 448	2408 ± 444	3921 ± 180	3339 ± 133	4065 ± 105	3221 ± 185
Direct Seeding	1938 ± 305	2026 ± 449	3875 ± 165	3004 ± 790	3649 ± 285	2897 ± 300
DMC/*B. ruz.*	2120 ± 205	2213 ± 382	3775 ± 286	3289 ± 433	3336 ± 326	2945 ± 265
DMC/*B. ruz.* + *Muc.*	2071 ± 346	2302 ± 396	3800 ± 202	2604 ± 381	3172 ± 255	2791 ± 168
DMC/*C. juncea*	2197 ± 417	2325 ± 509	4107 ± 56	3298 ± 530	3269 ± 371	3039 ± 286
F	0.263	0.110	0.467	0.384	1.643	0.431
Probability (0.05)	0.897 (ns)	0.977 (ns)	0.759 (ns)	0.817 (ns)	0.215 (ns)	0.784 (ns)

ns: not significant. DMC: Direct sowing under mulch-based cropping system.

Table 2. Evolution of cotton yields from 2011 to 2019 under different treatments.

Treatments	2011	2013	2015	2017	2019	Average
	$kg \cdot ha^{-1}$					
Conv. Tillage	1361 ± 152	1415 ± 187	1437 ± 211	1165 ± 113	1516 ± 75	1390 ± 76
Direct Seeding	1673 ± 101	1246 ± 203	986 ± 87	975 ± 26	1207 ± 284	1218 ± 115
DMC/*B. ruz.*	1302 ± 86	1204 ± 125	1281 ± 184	985 ± 22	1184 ± 113	1191 ± 86
DMC/*B. ruz.* + *Muc.*	1322 ± 189	1439 ± 29	1131 ± 152	1132 ± 58	1205 ± 124	1250 ± 89
DMC/*C. juncea*	1514 ± 135	1293 ± 42	1007 ± 82	1159 ± 55	1135 ± 104	1230 ± 65
F	1.300	0.566	1.558	2.107	0.910	0.715
Probability (0.05)	0.314 (ns)	0.691 (ns)	0.236 (ns)	0.131 (ns)	0.483 (ns)	0.594 (ns)

ns: non-significant. DMC: Direct sowing under mulch-based cropping system.

3.3. Effects of Direct Sowing under Mulch-Based Cropping System Biomass Production

The average biomass production of maize and total (maize + covers crops) was affected by the compared treatments (Table 3). The maize biomass production varied between 4210 kg·ha^{-1} (DMC/*B. ruziziensis* +*M. cochinchinensis*) and 5497 kg·ha^{-1} (Conventional Tillage) in average (Table 3). The best maize biomass production was obtained with Conventional Tillage. The DMC allows increasing the total biomass compared to Conventional Tillage. The average of total biomass varied between 4746 kg·ha^{-1} (Direct Seeding) and 7413 kg·ha^{-1} (DMC/*B. ruziziensis* + *M. cochinchinensis*). The use of cover plants increased total biomass production. In average, the association of *B. ruziziensis*, *B. ruziziensis* + *M. cochinchinensis* and *C. juncea* contribute to significantly increase the total biomass. A better total biomass production was observed with the association of *B. ruziziensis* + *M. cochinchinensis* cropping with maize (Table 3).

3.4. Effects of 10 Years of Direct Sowing under Mulch-Based Cropping System on Soil Chemicals Characteristics

➢ **Effects of direct sowing under mulch-based cropping system on soil pH**

After 10 years of maize associated to cover crops in rotation with cotton, a little variation in the pH water was observed. The pH was between 5.54 (DMC/*C. juncea* mulch) and 5.69 (Direct seeding). With the Conventional Tillage the pH was 5.60 and 5.62 with DMC/*B. ruziziensis* mulch and 5.63 with DMC/B. *ruziziensis* + *M. cochinchinensis* mulch. Compared to the Conventional Tillage, Direct Seeding and DMC did not cause a significant change of soil pH.

Table 3. Biomass production by maize straws and cover crops (kg·ha^{-1}) from 2010 to 2018 under different treatments.

Treatments		Conv. Tillage	Direct Sowing	DMC/*B. ruz*	DMC/*B. ruz* + *M. coch.*	DMC/*C. Juncea*	F	P (0.05)
2010	Maize straw	5444 a	4786 a	4684 a	4257 a	4467 a	2.023	0.150 (ns)
	Cover crops	-	-	2450 a	2751 a	1616 b	8.577	0.010 (s)
2012	Maize straw	5230 a	4948 a	5148 a	4443 a	4473 a	0.329	0.854 (ns)
	Cover crops	-	-	1788 a	1196 a	1497 a	1.369	0.308 (ns)
2014	Maize straw	6510 a	5729 a	5313 a	5104 a	5260 a	2.688	0.078 (ns)
	Cover crops	-	-	3917 a	2733 b	1433 c	33.889	0.000 (s)
2016	Maize straw	5136 a	4157 ab	3755 b	3022 b	3788 b	3.801	0.029 (s)
	Cover crops	-	-	2481 a	3521 a	2009 a	2.322	0.160 (ns)
2018	Maize straw	4897 a	4311 a	4522 a	4458 a	4347 a	0.433	0.782 (ns)
	Cover crops	-	-	2695 ab	3808 a	1712 b	9.112	0.009 (s)
Average	Maize straw	5497 a	4746 ab	4568 b	4210 b	4466 b	3.425	0.040 (s)
	Cover crops	-	-	2666 a	2802 a	1654 b	14.435	0.002 (s)

DMC: Direct sowing under mulch-based cropping system.

➢ **Effects of direct sowing under mulch-based cropping system on soil organic matter**

Statistical analysis shows no significant difference (P > 0.05%) between treatments regardless of the different soil layers (Figure 2). Soil organic matter increase with Direct Seeding and Direct sowing under mulch-based cropping system (DMC) compared to Conventional Tillage. In 10 years on 0 - 5 cm depth, DMC/*B. ruziziensis*, DMC/*B. ruziziensis* + *M. cochinchinensis* and DMC/*C. juncea* gave respectively 27%, 34% and 38% improvement of organic matter compared to Conventional Tillage. Direct Seeding without cover plants gave 33% increase of organic matter compared to Conventional Tillage. On 5 - 10 cm depth, compared to Conventional Tillage, the soil organic matter content improvement was 5%, 14% and 17% respectively with Direct Seeding, DMC/*B. ruziziensis* + *M. cochinchinensis* and DMC/*C. juncea*. On 10 - 20 cm depth, only DMC showed increases of soil organic matter content.

These increases were in order of 23% (DMC/*B. ruziziensis*) and 9% (DMC/*B. ruziziensis* + *M. cochinchinensis* and DMC/*C. juncea*) compared to Conventional Tillage. High soil organic matter was observed with *C. juncea* use as a cover crop on the 0 - 5 cm and 5 - 10 cm depth and with DMC/*B. ruziziensis* on the 10 - 20 cm depth. The organic matter content of soil follows a gradient from the upper (0 - 5 cm) to the deep depth (5 - 10 cm and 10 - 20 cm).

➢ **Effects of direct sowing under mulch-based cropping system on nitrogen (N total)**

The analyses showed N total is equivalent on the different depth and follow a gradient from the upper to the deep depth (Figure 3). Compared to Conventional Tillage, Direct Seeding and DMC have improved total N. These increases are 21% and 3% respectively on the 0 - 5 cm and 5 - 10 cm depth with Direct Seeding compared to Conventional Tillage. With DMC systems increases over Conventional Tillage were in the range of 15% to 29% on the 0 - 5 cm depth, 0% to 9% on the 5 - 10 cm depth and 4% to 19% on the 10 - 20 cm depth. In the DMC systems, the best total N content were observed with treatments containing leguminous as *M. cochinchinensis* and *C. juncea*.

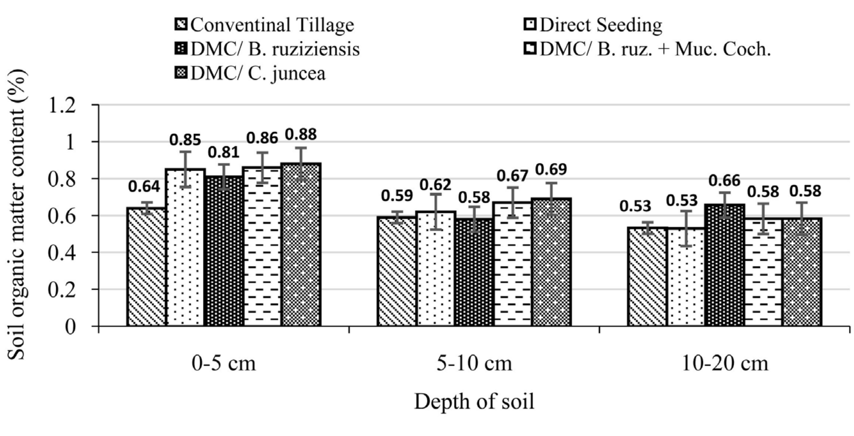

Figure 2. Effects of treatments on soil organic matter (%) in 2019.

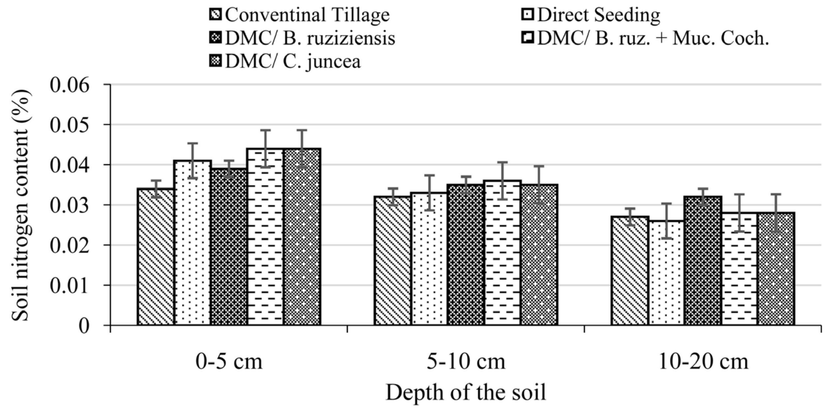

Figure 3. Effects of treatments on soil nitrogen content (%) in 2019.

➢ **Effects of direct sowing under mulch-based cropping system on P total, P assimilable, K total and K available**

The analyses of variance revealed no significant differences between DMC, Direct Seeding and Conventional Tillage for P total and P assimilable levels regardless of soil depth (**Table 4**). On the 0 - 5 cm, 5 - 10 cm and 10 - 20 cm depth, Conventional Tillage gave higher total P than those of Direct Seeding and DMC. On other hand, we notice on 0 - 5 cm depth, high levels of assimilable P with DMC/*B. ruziziensis* + *M. Cochinchinensis* and DMC*/C. juncea*. On the 0 - 5 cm, 5 - 10 cm and 10 - 20 cm depth considered, total K and available K were statistically equivalent. On 0 - 5 cm, availability K was improved with Direct Seeding and DMC system compared to Conventional Tillage (**Table 5**).

➢ **Soil chemicals characteristics reviews over 10 years of operation (0 - 5 cm)**

Over 10 years of crop rotations (maize-cotton) the pH of soil has changed slightly, depending on the treatments (**Figure 4(a)**). Soil pH balances variation between 2010 and 2019 indicate a decrease of pH on the upper depth (0 - 5 cm) with Conventional Tillage as well as Direct Seeding alone and DMC/*B. ruziziensis* and DMC/*B. ruziziensis* + *M. cochinchinensis*. pH balance was from −0.055 to −02 units. On the other hand, with *C. juncea* use as a cover crop in the DMC system, the soil acidity balance shows an increase of one unit towards neutrality.

As for organic matter contents, only DMC/*B. ruziziensis* associated with *M. cochinchinensis* and DMC/*C. juncea* provided stability or a little increase of +0.054% (DMC/*B. ruziziensis* + *M. cochinchinensis*) and +0.90% (DMC/*C. juncea*) (**Figure 4(b)**).

The total N decreased with Conventional Tillage, Direct Seeding and DMC/*B. ruziziensis*, *DMC/B. ruziziensis* + *M. cochinchinensis* and DMC/*C. juncea*. Leguminous cover crops use (*M. cochinchinensis* and *C. juncea*) did not give nitrogen positive balance. Total P balance show 11.53; 12.54 and 37.91 $mg \cdot kg^{-1}$ improvements respectively with DMC/B. ruziziensis, DMC/*C. juncea* and Conventional Tillage. However, total P improvements were not inducing any improvement of availability P (**Figure 4(c)**).

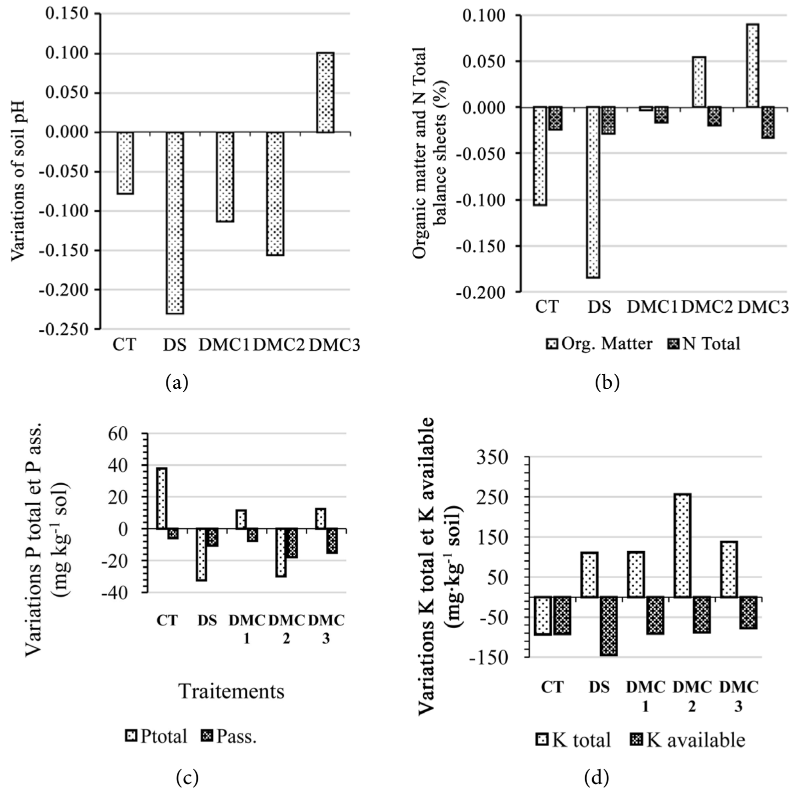

Figure 4. Soil chemicals characteristics from 2010 to 2019. Legend: CT: Conventional Tillage; DS: Direct Seeding; DMC 1: DMC/*B. ruz*iziensis; DMC 2: DMC/*B. ruziziensis* + *M. cochinchinensis*; DMC 3: DMC/*C. juncea*. (a) Soil pH balance (0 - 5 cm); (b) Organic matter and N Total balance (0 - 5 cm); (c) P Total and P ass balance sheets. (0 - 5 cm); (d) K Total and K available balance (0 - 5 cm).

Table 4. Effects of treatments on total P and assimilable P in soil (2019).

Treatments	0 - 5 cm		5 - 10 cm		10 - 20 cm	
	P total	P ass.	P total	P ass.	P total	P ass.
	mg·kg^{-1} of soil					
Conv. tillage	150.94 ± 34	12.17 ± 4	154.61 ± 36	11.91 ± 2	144.61 ± 34	7.27 ± 1
Direct Sowing	101.15 ± 11	12.01 ± 2	98.45 ± 4	10.49 ± 3	120.86 ± 30	7.10 ± 1
DMC/B. ruz.	124.17 ± 29	10.88 ± 1	120.86 ± 27	5.13 ± 1	119.11 ± 26	5.43 ± 1
DMC/B. ruz.+ Muc.	104.68 ± 10	14.43 ± 4	92.88 ± 5	9.81 ± 2	100.18 ± 9	6.21 ± 1
DMC/*C. juncea*	135.44 ± 28	14.66 ± 2	127.46 ± 34	9.14 ± 2	117.46 ± 30	5.57 ± 1
F	0.736	0.315	0.959	1.678	0.34	0.51
P (0.05)	0.582 (ns)	0.863 (ns)	0.458 (ns)	0.207 (ns)	0.847 (ns)	0.730 (ns)

DMC: Direct sowing under mulch-based cropping system.

Total K balances indicate improvements with Direct Seeding, DMC/*B. ruziziensis*, DMC/*B. ruziziensis* + *M. cochinchinensis* and DMC/*C. juncea* compared to Conventional Tillage. These total K positives balances did not induce an improvement of his availability in soil (Figure 4(d)).

Table 5. Effects of treatments on total K and available K in soil (2019).

Treatments	0 - 5 cm		5 - 10 cm		10 - 20 cm	
	K total	K available.	K total	K available.	K total	K available.
	mg·kg^{-1} of soil					
Conv. tillage	1988 ± 273	89 ± 12	1733 ± 160	99 ± 4	2002 ± 194	75 ± 2
Direct Sowing	1867 ± 139	131 ± 21	1878 ± 200	103 ± 3	2050 ± 191	77 ± 9
DMC/B. ruz.	1685 ± 99	146 ± 9	2090 ± 328	82 ± 1	1990 ± 113	70 ± 2
DMC/B. ruz. + Muc.	1966 ± 332	128 ± 14	1976 ± 284	1001 ± 2	1733 ± 134	68 ± 6
DMC/*C. juncea*	1709 ± 64	141 ± 20	1736 ± 91	82 ± 3	2076 ± 162	69 ± 3
F	0.458	1.982	0.455	0.31	0.718	0.637
P (0.05)	0.766 (ns)	0.149 (ns)	0.767 (ns)	0.867 (ns)	0.593 (ns)	0.644 (ns)

DMC: Direct sowing under mulch-based cropping system.

4. Discussion

During the 10 years of crop rotation, the effect of direct Seeding with or without a cover plant on cotton and maize yields of Direct Seeding was statistically equivalent to conventional tillage. The use of *B. ruziziensis*, *B. ruziziensis* + *M. cochinchinensis* and *C. juncea* as cover crops associated with maize did not influence the maize yields. After 10 years cultivation, including 5 years of cotton cultivation, the cotton yields indicate that Direct Seeding, direct sowing under mulch-based cropping system were equivalent to Conventional Tillage. These results confirm [9] [10] [18] who found an equivalence between Direct Seeding and Conventional Tillage after 5 years or 20 years of direct sowing under mulch-based cropping system. Biomass production has been significantly improved by cover crops. This ensured fairly good soil coverage during direct seeding in a mulch-based cropping system. [19] estimated that with DMC, biomass production of at least 6000 kg·ha^{-1} are required to ensure good soil cover and according to [3], 2 t·ha^{-1} of biomass are required to improve soil water balances compared to Conventional Tillage. *B. ruziziensis* has ensured high of biomass and amount better when associated with *M. Cochinchinensis*. The contribution of *C. juncea*-biomass productionwas lower than *B. ruziziensis and B. ruziziensis with M. cochinchinensis*.

With the DMC, soil acidity varied very little compared to Direct Seeding and Conventional Tillage. The balance sheets indicate general decline of pH with the Conventional Tillage, Direct Seeding and DMC/*B. ruziziensis*, DMC/*B. ruziziensis* + *M. cochinchinensis*. With *C. juncea* as a cover crop in DMC, the increase of pH to neutral pH has been observed.

In 2019, organic matter was relatively higher with DMC tested compared to Direct Seeding without cover crop and Conventional Tillage on 0 - 5 cm and 10 - 20 cm depth. The increasing of organic matter with DMC is attributed to cover crops degradation. These results confirm studies of [4] [20] that obtained same trends in tropical climate conditions. The accumulation of organic matter in the

0 - 5 cm depth compared to the 5 - 10 cm and 10 - 20 cm depth is due to more pronounced accumulation and degrading in the tropical area of residues and a higher root density in this depth. Conventional Tillage contributes to create conditions for a rapid decomposition of soil organic matter. The higher organic matter was recorded with the use of *C. juncea* as a cover crop because the decomposition of *C. juncea* residue was slow compared to *B. ruziziensis* and *M. cochinchinensis* residues. The contribution of leguminous cover crops was only in the first 10 centimeters of soil depth. The leguminous used as cover crops, namely *M. cochinchinensis* and *C. juncea*, has led to increases soil nitrogen content, particularly on the 0 - 5 cm and 5 - 10 cm depth. This is related to the atmospheric nitrogen-fixing characteristics of leguminous cover crops used. These results are similar to those of [21] which featured leguminous cover crops with a strong root system that could improve nitrogen levels on different depth of soil. *B. ruziziensis*, which has a powerful root system fasciculate in association with *M. cochinchinensis*, has contributed to better colonization of depth through its important and fasciculate root system that can reach in deep depth. The high levels of total P and assimilable P with Conventional Tillage are partly related to the faster of organic matter degrading in tropical climate area. Conventional Tillage creates the conditions for substrate mineralization by soil micro-organisms. The results of [22] indicate a significant reduction in organic matter under continuous ploughing related to the mineralization process.

5. Conclusion

Cover cropping systems are effective because they ensure stability and durability of crop production. Frequent ploughing is not the same solution, especially under conditions of climate change that prevent good crop establishment. Soil acidity under both conventional tillage and DMC systems showed little variation. The DMC systems improved total soil K levels while reducing available K losses. *B. ruziziensis*, alone or in combination with *M. cochinchinensis* and *C. juncea*, contributed effectively to biomass production. These cover crops have stabilized or improved soil organic matter levels. These cover crops have stabilized or improved soil organic matter levels. The contribution of the leguminous (*M. cochinchinensis* and *C. juncea*) was weakly perceived on the soil nitrogen content in the upper layers. DMC appears to be an applicable practice in cotton-based production systems in the southern Sudanese zone of Burkina Faso. However, its adoption requires a slight adaptation of the production method. *B. ruziziensis* alone or in combination with *M. cochinchinensis* ensures good biomass production. The adoption of DMC requires support from the government and open collaboration between the actors concerned such as producers, breeders and local authorities.

Acknowledgements

The authors express their gratitude to Cotton 4 + Togo Project and the Inter-professional Cotton Association in Burkina Faso (AICB) for funding this study.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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