Vol. 14(31), pp. 1421-1431, August, 2019
DOI: 10.5897/AJAR2019.13952
Article Number: BF26EB761731
ISSN: 1991-637X

http://www.academicjournals.org/AJAR

ACADEMIC JOURNALS
expand your knowledge

African Journal of Agricultural Research

Full Length Research Paper

Effect of tillage and mulching on agronomics performances of maize and soil chemical properties in Linsinlin Watershed of Centre of Benin

Akplo Tobi Moriaque[1], Kouelo Alladassi Félix[1]*, Azontonde Hessou Anastase[2], Houngnandan Pascal[1], Benmansour Moncef[3], Rabesiranana Naivo[4] and Mabit Lionel[5]

[1]Laboratory of Soil Microbiology and Microbial Ecology, Faculty of Agronomics Sciences, University of Abomey-Calavi, 01 BP 526 Cotonou, Benin.
[2]Institut National de Recherches Agricoles du Bénin, Benin.
[3]Centre National des Energies, Sciences et Techniques Nucléaires (CNESTEN), Rabat, Marocco.
[4]Institut National des Sciences et Techniques Nucléaires (INSTN), Antananarivo, Madagascar.
[5]SWMCNS, Joint FAO/IAEA, Division of Nuclear Techniques in Food and Agriculture, Vienna-Seibersdorf, Austria.

Received 13 February, 2019; Accepted 19 April, 2019

Soil conservation has become an important aspect in achieving food security. The objective of this study is to assess the effect of two agricultural practices on the agronomic performance of maize and the chemical properties of soil. A field experiment was carried out on loamy-sand soil using Fisher Block design. Tillage systems and mulching significantly affected maize growth and yield components. The interactive effect of tillage and mulching were not significant on growth and yield components of maize. While, the highest growth rate (2.38 cm/day), leaf area (65.70 cm²), collar diameter (1.39 cm), grain yield (4148.71 kg DM ha^{-1}), straw yield (5077.65 kg DM ha^{-1}) and harvested index (40%) were obtained with the treatment combining isohypse ridging and mulch. Tillage increased soil organic matter. Treatment combining isohypse ridging to mulching allowed obtaining the highest level of soil organic matter after trial. The level of nitrogen and available phosphorus did not vary under the treatment. Throughout, this experiment, isohypse ridging under mulching constitute the effective soil conservation practice to combat soil erosion and improve maize productivity on the watershed of Linsinlin in Southern Benin.

Key words: Tillage, mulching, maize yield, soil chemical properties, watershed, Djidja.

INTRODUCTION

In the current context of high population growth and increased pressure on resources, tropical soils are particularly threatened (Kouelo, 2016). Traditional production systems are no longer able to maintain soil

*Corresponding author. E-mail: fkouelo@yahoo.fr.

fertility and production capacity (Séguy, 2006). Chemical and physical degradation affects most of the present agricultural land in Africa (Henao and Baanante, 1999). However, soil productivity is essential for agriculture sustainability, food security and the living conditions of the poor people (OECD, 2009). Continuous land use, near total exports of crop residues through burning, deforestation, and low mineral input are the main causes of declining soil fertility in Africa (Saïdou et al., 2012a).

In Benin, traditional agriculture is characterized by a reduction of the fallow periods without any other measure aimed at restoring nutrients used by previous crops (Saïdou et al., 2009). This form of agriculture is the only one of its kind. The majority of cropping systems used lead to soil degradation (Baco et al., 2011). Thus, food production and the sustainability of production systems are compromised (Egah et al., 2014). In the central agro-ecological zone of Benin, the dynamics of agro-systems and agrarian structures have led to a negative evolution of soil (Agossou and Igué, 2002). Under the effect of population pressure (3.5% as growth rate), fallow practice is greatly reduced or even suppressed in favor of continuous cropping systems, overexploitation of soils without organic or mineral fertilizers. In order to grow, agriculture must learn to save (FAO, 2011). New cropping systems have become necessary to ensure sustainable agricultural production. Conservation tillage (CT) practices (e.g., no-till) have become increasingly common in recent years (Corbell et al., 2006; Ziadi et al., 2014). Considered from the point of view of its function on agricultural production in tropical environments, tillage aims to ensure the establishment of crops and the functioning of the roots, to improve the circulation of water and air in the soil, promote its warming and limit weed infestations and a number of soil-borne bio-aggressors (Roger-Estrade et al., 2011). The literature is unanimous concerning the positive effects of mulch-based systems. Vegetation cover protects the soil surface against the effect of raindrops, increases structural stability, maintains soil moisture, and maintains high soil biological activity (Douzet et al., 2010; Mazarei and Ahangar, 2013). However, opinions remain divergent concerning the effect of tillage. Some authors consider that tillage ensures crop establishment and root functioning, improves the flow of water and air into the soil, and limits infestation (Kurothe et al., 2014). Others consider that tillage limits erosion if it disturbs the least surface residues (Roger-Estrade et al., 2010). Labreuche et al. (2007) consider that plowing is generally considered to be an unfavorable factor for carbon storage and therefore unfavorable for soil organic matter. This multiple role of tillage is often reinforced by the permanent presence of vegetation cover as mulch (Roger-Estrade et al., 2010). The objectives of this study were to determine how the various types of tillage and mulching affect the chemical properties of soil in this region and to use the results to identify sustainable land management practices that would increase production (that is, maize).

MATERIALS AND METHODS

Study area

The experiment was carried out at Linsinlin watershed (latitude 7° 20' 46'' North; longitude 1° 56' 8'' East and altitude 190 m) at Djidja district in Benin from May 29, 2016 to August 31, 2016 (Figure 1). The study area is situated on the Precambrian basement of the Peneplaine Cristalline base rocks as embrechites and granites (Igué, 2000). The soil is locally known as ‘Depleted, Little Ferruginized Tropical Ferruginous Soils’’. The soil texture of Linsinlin watershed is a loamy-sand according USDA textural triangle. These chemical characteristics are 0.11% for total nitrogen, 0.53% for total organic carbon, 72.62 ppm for available phosphorus, 25.94 meq.100 g^{-1} for Exchangeable Cation Capacity, and 5.75 to 5.78 for acidity in average. Linsinlin has a bimodal rainfall distribution with a long rainy season from March to July and a short rainy season from September to November. The annual rainfall of the site is 1200 mm. The average temperature is around 28°C. The average slope is 5% (Kouelo et al., 2015).

Experimental design

The effects of tillage and mulching on growth and yield components of maize were evaluated. The experiment was a four replicated experiment arranged to Fisher block design. The experiment comprised 24 plots, each measuring 6 m × 3.5 m. Tillage had three levels: no-tillage (SL), minimum tillage (ML) and isohypse ridging (B). Mulching had two levels: without mulch (0% soil cover rate) and with mulch (50% coverage rate). The treatment was constituted by the combination of the modalities of factors (Table 1). In order to obtain the 50% soil cover rate, 3 t/ha of crop residue was applied two weeks after sowing (Kouelo, 2016). The modalities of these factors are combined to form the installed treatments. A total of six (6) treatments were installed. Maize variety DMR was sown at 50 × 40 cm^2 (for good soil cover). The fertilizer dose recommended was applied: 200 kg of complete NPK (15-15-15). Weeds management was done manually. The harvest of maize was done after 90 days after sowing.

Data collected and treatment

Growth parameters

The growth parameters taken were plant height, dimension of leaves and collar diameter. The measurement of all parameters was performed on 8 plants on four lines selected randomly by experimental unit: height of the maize plant (from 15 to 75th DAS at intervals of 15 days, that is, 15, 30, 45, 60 and 75 Days After Sowing); dimension of leaves (on 75th Days After Sowing); collar diameter (on 60th Days After Sowing). Maize growth speed was estimated fitting linearly maize plant height. Growth speed rate was represented by coefficient a of regression equation. Leaf area was calculated using the method of Ruget et al. (1996). This method uses the number of growing leaves as well as the number and size of full-grown leaves.

Yield components

Maize was harvested from square performance within each plot.

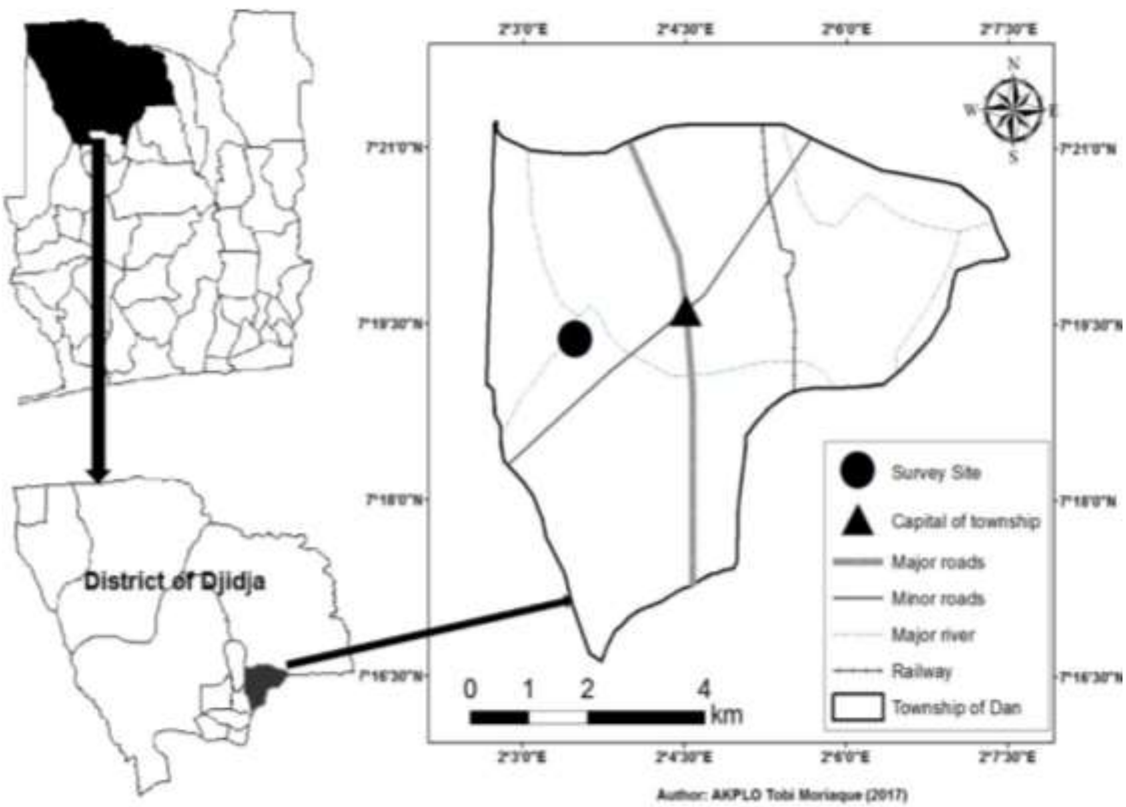

Figure 1. Map showing the study area.

Table 1. Treatment details.

Treatment code	Description
BM50	Isohypse ridging + with mulch
BM0	Isohypse ridging + without mulch
MLM50	Minimum tillage + with mulch
MLM0	Minimum tillage + without mulch
SLM50	No tillage + with mulch
SLM0	No tillage + without mulch

Thus, the harvested effective area per plot was 4 m^2 (2 m × 2 m). The straw and grain were weighed and sub-samples were taken. These samples were dried in an oven at 75°C during 72 h. These dry weights were recorded. Yield calculations were done using the following expressions (Saïdou et al., 2012b):

Dry matter factor (MS) = sample dry weight / sample fresh weight;

Shelling factor (n) = dry weight of grain/ dry weight of cob

Economic yield (kg DM ha^{-1}):

$$EY = \frac{10000 \times P \times MS \times n}{Ea}$$

Biological yield (kg DM ha^{-1}):

$$BY = \frac{10000 \times P \times MS}{Ea}$$

The Harvest Index, HI (Beadle, 1985):

$$HI = \frac{EY}{EY+BY}$$

where economic yield (EY)= weight of seeds; biological yield (BY)= above ground biomass; P= total fresh weight; MS= dry matter factor; n= shelling factor; Ea= effective area (4 m^2).

Chemical properties of soil

Sampling was carried out in the first two soil horizons (0-20 and 20-

40 cm) on each plot at the beginning and at the end of the trial. The samples were air dried and sieved through a 2 mm mesh. Total soil nitrogen content was determined by the Kjeldahl method (Jones et al., 1991). Available phosphorus was estimated using of Bray I method (Bray and Kanz, 1945), soil organic carbon using the method of Walkley and Black (1934).

Statistical analysis

The data collected and the calculated parameters were subjected to a two-way analysis of variance (ANOVA) according to the General Linear Model procedure with SAS 9.2 software. The effects tested are those of tillage, mulching as well as those of their combinations. Means separation was done using the Student-Newman-Keuls test. The threshold of significance used is 5%.

RESULTS

Maize growth

Growth speed

Analysis of the results of the analysis table (Table 2) shows that tillage significantly (p <0.05) influenced growth speed of maize. Indeed, isohypse ridging and minimum tillage had increased maize growth speed by 30 and 14%, respectively compared to no-tillage (Table 3). The effect of mulching was not significant on growth speed. However, mulch practice had increased growth by 6.13% compared to no-mulch. The interactive effect of tillage and mulching were not significant on the growth speed growth. However, on the basis of the values, the treatments can be classified in descending order as follows: SLM0 <SLM50 <MLM0 <MLM50 <BM0 <BM50 (Figure 2).

Leaf area

Tillage and mulching significantly (p <0.05) influenced the leaf area. For tillage system, isohypse ridging had increased the leaf area from 110.43 to 74.18 cm² (Table 3). Considering the indeed, mulch practice had allowed an increase of 16% compared to no-mulch. The effect of the combination of tillage system and mulching was not significant on leaf area (p <0.05). Nevertheless, arithmetic differences exist between treatments. Treatment combining isohypse ridging and mulch (BM50) had allowed the highest maize leaf area (120.96 cm²) followed successively by BM0 (99.90 cm²); SLM50 (82.66 cm²); MLM50 (76.10 cm²); MLM0 (74.88 cm²); and SLM0 (65.70 cm²) (Figure 3).

Collar diameter

Isohypse ridging and minimum tillage have significantly increased collar diameter of maize, respectively by 14 and 11% compared to no-tillage (Table 3). Mulching has not significant effect on collar diameter. However, there is little difference between mulch (1.59 cm) and no-mulch (1.54 cm). The interactive effect of tillage system and mulching was not significant. Thus, the highest maize collar diameter was obtained under the treatment combining isohypse ridging with mulch (BM50) (Figure 4).

Maize yield

Grain yield

The results on maize grain yield under different tillage system, mulching levels and these combinations are shown in Table 2. The results show that tillage system and mulching significantly increased the grain yield of maize. Isohypse ridging gave the highest grain yield (3893.11 kg DM ha^{-1}) followed by minimum tillage which increased grain yield by 16% compared to direct tillage. For the mulching factor, the mulch practice allowed an increase of grain yield by 28% compared to the no-mulch-level (Table 3). The interactive effect of tillage system and mulching were not significantly on grain yield (p>0.05). But, an arithmetic difference exists between treatments. Indeed, isohypse ridge combined with the mulch provided the highest grain yield (4148.71 kg DM ha^{-1}) and the lowest grain yield was obtained with the minimum tillage without mulch (Figure 5).

Straw yield

Tillage significantly improved straw yields of maize from 3938.42 to 4972.58 kg DM ha^{-1} (Table 3). Despite of a non-statistical significance of the effect of mulching, the mulch practice increased maize straw yield by 6% compared to no-mulch modality. The maize straw yield was not influenced by the treatments combining tillage system and mulching (p> 0.05). Nevertheless, the treatment combining isohypse ridging with mulch practice (BM50) provided the highest straw yields (5077.65 kg DM ha^{-1}) (Figure 5).

Harvest index

The results (Table 2) showed that tillage system significantly affected the harvest index of maize. Tillage improved the harvest index by 30% (for no-till) to 40% (for ridging), an increase of 10%. Although the effect of mulching was not significant on harvest index, mulch practice provided an increase of 7% compared to no-mulch. The interactive effect of tillage system and mulching were no-significant on the maize harvest index (Table 2). From analyzing of Figure 6, however, the treatment combining isohypse ridging and minimum tillage with mulch (BM50 and MLM50) and isohypse ridging without mulch (BM0) generated the highest

Table 2. Summary of analysis of variance (ANOVA) for various parameters studied in the experiment.

Parameters studied	Growth parameters			Yield components			Chemical properties of soil		
	Growth speed	Leaf area	Collar diameter	Grain	Straw	Harvest index	Available phosphorus	Total nitrogen	Organic carbon
Tillage	0.0056**	<.0001***	0.0104*	0.0158*	0.04362*	0.0729^{ns}	0.329^{ns}	0.31ns	0.01*
Mulching	0.3067^{ns}	0.0013**	0.4127^{ns}	0.0410*	0.6889^{ns}	0.0475*	0.371^{ns}	0.21ns	0.55ns
Tillage vs. Mulching	0.5425^{ns}	0.0713^{ns}	0.6570^{ns}	0.6319^{ns}	0.8814^{ns}	0.2408^{ns}	0.119^{ns}	0.69ns	0.15ns

*Stands for significant at $p \leq 0.05$; **Stands for significant at $p \leq 0.01$; ***Stands for significant at $p \leq 0.001$; ^{ns}No significant.

Table 3. Effect of tillage and mulching on growth parameters and yield component of maize and chemical properties of soil (mean ± standard error).

Factor	Levels	Growth parameters			Yield components			Chemical properties of soil		
		Growth speed (cm/day)	Leaf area (cm^2)	Collar diameter (cm)	Grain (kg DM.ha^{-1})	Straws (kg DM.ha^{-1})	Harvest index	Available Phosphorus (ppm)	Total N (%)	Organic carbon (%)
Tillage	No-tillage	2.46 ± 0.15^{b}	74.18 ± 5.28^{b}	1.43 ± 0.06^{b}	1994.69 ± 251.71^{b}	3938.42 ± 614.58^{b}	0.30 ± 0.04^{b}	17.02 ± 2.23^{a}	0.12 ± 0.003^{a}	0.52 ± 0.03^{b}
	Minimum tillage	2.88 ± 0.13^{ab}	75.49 ± 1.50^{b}	1.60 ± 0.06^{a}	2383.48 ± 402.38^{b}	4434.58 ± 366.02^{b}	0.33 ± 0.03^{b}	14.58 ± 0.98^{a}	0.11 ± 0.01^{a}	0.53 ± 0.03^{b}
	Isohypse ridging	3.23 ± 0.15^{a}	110.43 ± 4.36^{a}	1.67 ± 0.04^{a}	3893.11 ± 572.43^{a}	4972.58 ± 381.91^{a}	0.40 ± 0.03^{a}	14.17 ± 0.79^{a}	0.13 ± 0.01^{a}	0.81 ± 0.1^{a}
Mulching	No-Mulch	2.77 ± 0.18^{a}	80.16 ± 5.21^{b}	1.54 ± 0.06^{a}	2321.24 ± 498.70^{b}	4311.12 ± 530.76^{a}	0.31 ± 0.03^{a}	16.12 ± 1.80^{a}	0.13 ± 0.01^{a}	0.65 ± 0.1^{a}
	With Mulch	2.94 ± 0.09^{a}	93.24 ± 6.09^{a}	1.59 ± 0.04^{a}	3234.18 ± 309.57^{a}	4575.65 ± 344.50^{a}	0.38 ± 0.03^{b}	14.56 ± 0.62^{a}	0.11 ± 0.01^{a}	0.60 ± 0.04^{a}

For each column, the mean followed by the different letter are significantly different.

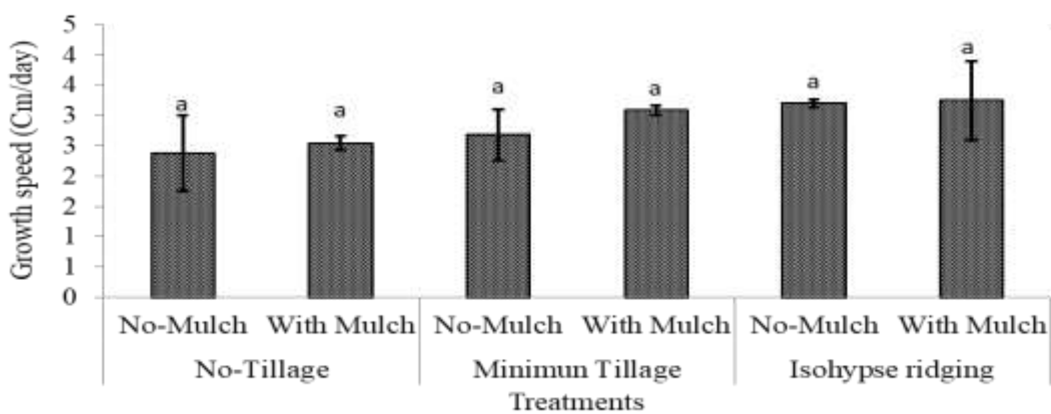

Figure 2. Interactive effect of tillage and mulching on maize growth speed. The error bars correspond to the standard deviation. Different letters indicate statistically significant difference.

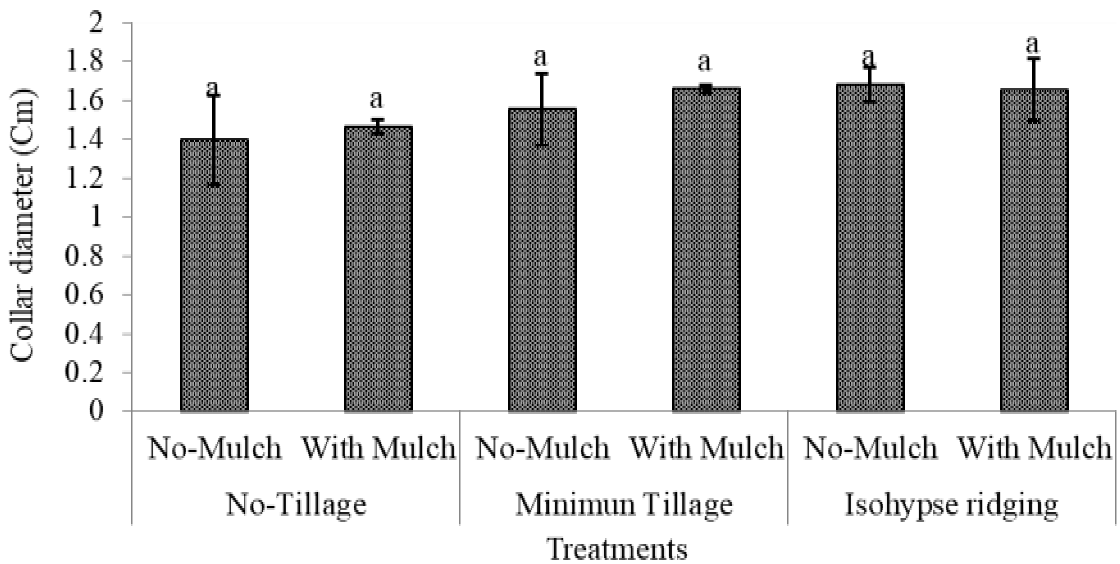

Figure 3. Interactive effect of tillage and mulching on maize collar diameter. The error bars correspond to the standard deviation. Different letters indicate statistically significant difference.

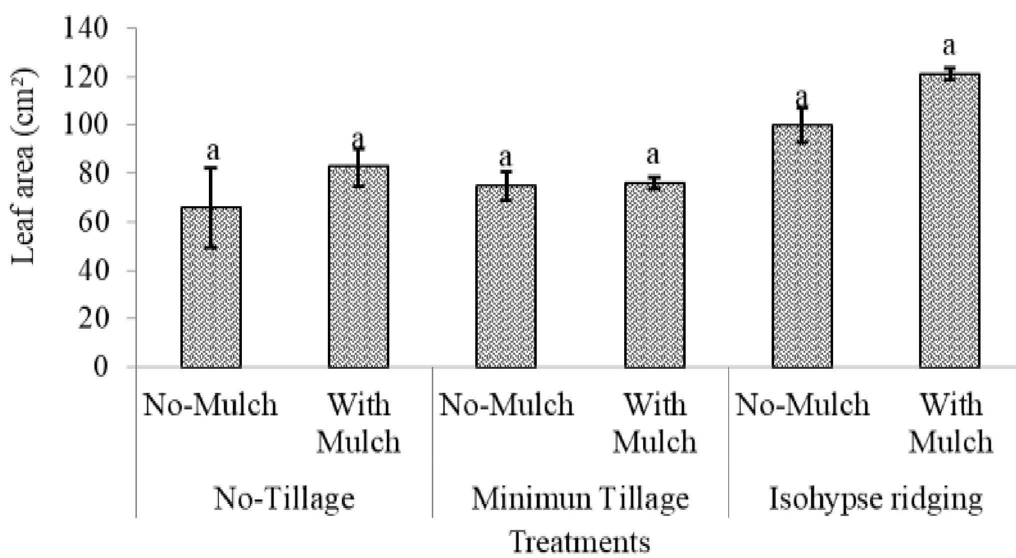

Figure 4. Interactive effect of tillage and mulching on maize leaf area. The error bars correspond to the standard deviation. Different letters indicate statistically significant difference.

harvest index. No-tillage without mulch (SLM0) generated the lowest harvest index, around 15% less than the BM50, MLM50 and BM0.

Chemical properties of soil

Tillage system significantly influenced soil organic carbon ($p<0.05$). The effects of both tillage system and mulching were not significant on total nitrogen and available phosphorus ($p=0.329$ and $p= 0.31$, respectively). In fact, ridging has induced a 36% increase soil organic matter compared to minimum tillage and no-tillage. On the contrary of the case of organic carbon, ridging has decreased available phosphorus content of soil. The highest available phosphorus pool was recorded with direct seeding (17.02 ppm). Total nitrogen has varied little according to the modalities of tillage system. Despite of the not significant effect of the mulching on total nitrogen content, organic carbon content and available phosphorus content of soil, there are arithmetical differences. No-mulch allowed the highest values for the

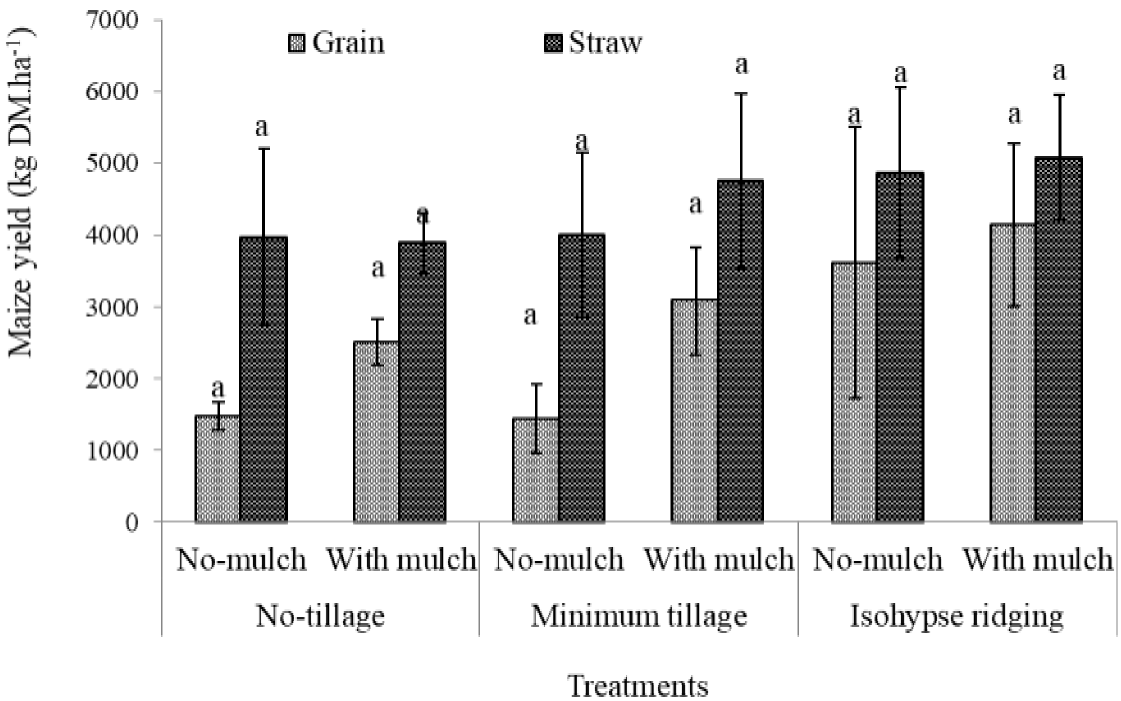

Figure 5. Interactive effect of tillage and mulching on maize yield. The error bars correspond to the standard deviation. For the same parameter, Different letters indicate statistically significant difference.

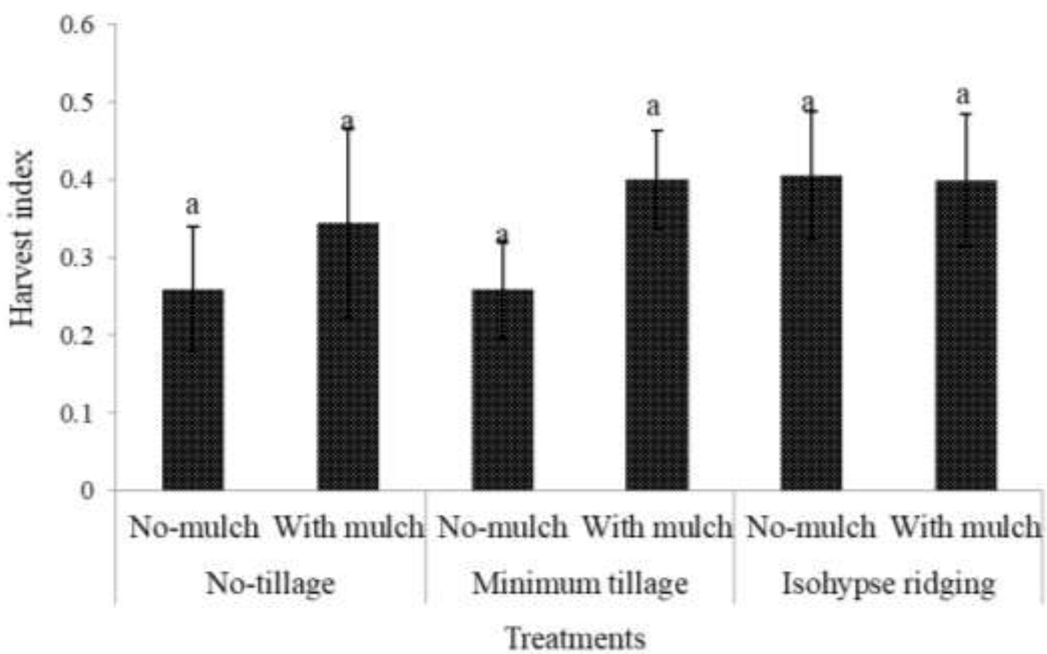

Figure 6. Interactive effect of tillage and mulching on maize harvest index. The error bars correspond to the standard deviation. Different letters indicate statistically significant difference.

three chemical parameters (Table 3). As shown, no-mulching creased by 10, 15 and 8%, respectively, the available phosphorus, total nitrogen and organic carbon content of soil after trial compared to mulch modality (Table 3). The interactive effect of tillage system and mulching were not significant (p> 0.05). However, the statistical classification obtained shows that for total nitrogen and organic carbon content of soil, the BM0

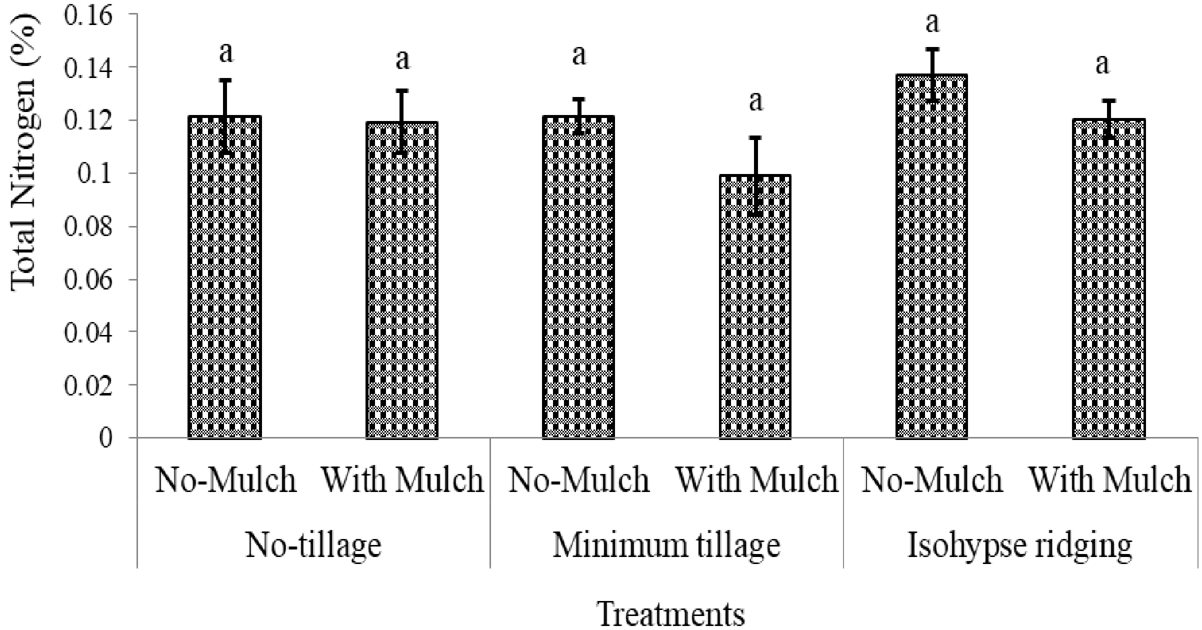

Figure 7. Interactive effect of tillage and mulching on total nitrogen content of the soil. The error bars correspond to the standard deviation. Different letters indicate statistically significant difference.

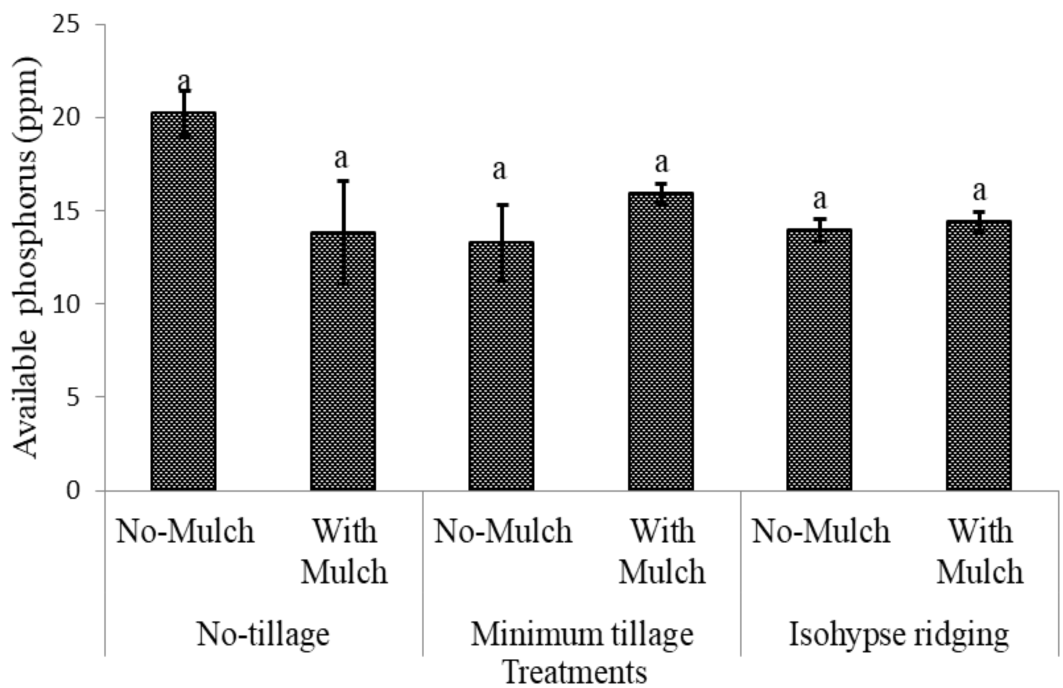

Figure 8. Interactive effect of tillage and mulching on soil available phosphorus pool (The error bars correspond to the standard deviation. Different letters indicate statistically significant difference).

allowed to obtain the high total nitrogen and organic carbon content of soil after trial (Figures 7 and 8). For the available phosphorus, the highest pool was obtained with SLM0 (Figure 9).

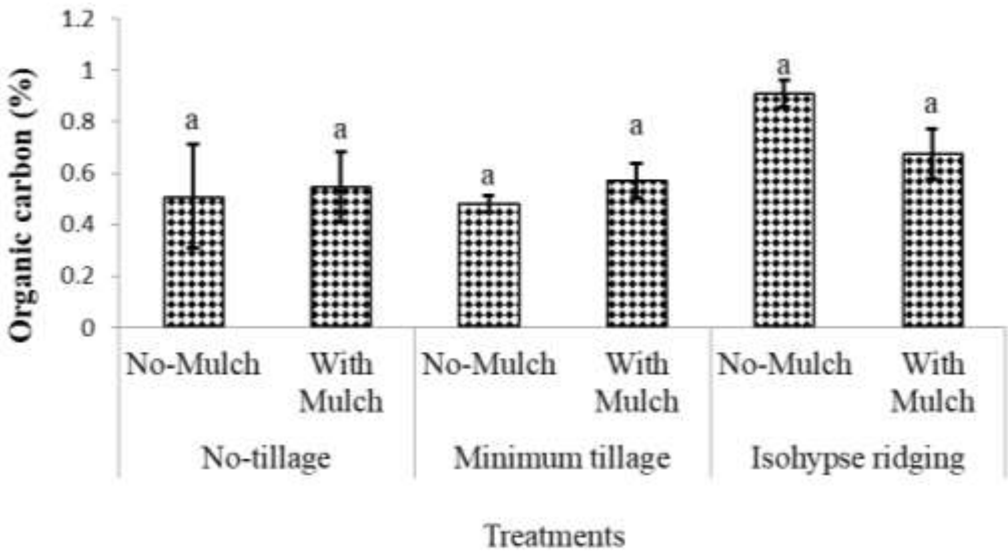

Figure 9. Interactive effect of tillage and mulching on soil carbon organic content. The error bars correspond to the standard deviation. Different letters indicate statistically significant difference.

DISCUSSION

Maize growth

In general, the results of this study have testified to this fact. Indeed, these results show that tillage system and mulching significantly influenced maize growth. Ridging allowed for faster growth, higher leaf area and higher collar diameter. No-tillage allowed slow growth. In fact, under no-tillage, the soil is compact and does not allow good water infiltration and good root development. As opposed to no-tillage, ridging allowed the soil to be aired by the loosening of the humiferous layer, thereby creating an environment favorable to the root activity of maize plants. Similar results were obtained by Abdellaoui et al. (2006), Tomavo (2014), Hountongninou (2016) and Kouelo (2016). These authors related that the growth of maize or wheat was significantly increased by tillage. Tomavo (2014) and Hountongninou (2016) in a study on the effect of tillage, mulching and nitrogen on maize growth in southern Benin showed that flat tillage increased the growth speed, of around 50% compared to no-tillage. Kouelo (2016) obtained the same results on three watersheds in southern Benin. The author concludes that maize grows slowly at no-tillage. The mulch treatments resulted in a significant improvement in maize growth in the study area. The present results confirm those obtained by the authors (Findeling et al., 2003; Diallo et al., 2006; Barthes et al., 2010; Pervaiz, 2009). Researchers agree the role of mulch on the improvement of physical, chemical and biological properties of the soil allows the growth of plants. Indeed, mulch increases soil moisture and nutrients availability to plant roots in turn, leading to higher plant growth.

Maize productivity

Maize productivity was assessed through grain and straw yields and harvest index. Isohypse ridging significantly increased grain and straw yield of maize. This reflects the strong growth favored by ridging compared to no-tillage and minimum tillage. Indeed, the suppression or minimization of the topsoil reversal has significantly reduced the maize productivity components in the watershed of Linsinlin. These results confirm those of Osunbitan et al. (2005) and Kouelo (2016) which attribute this to the formation of crusts and nutrient depletion. Indeed, no-tillage deeply modifies the physical properties (Peigne et al., 2007). The practice of mulch significantly increased maize grain yield and harvest index. The presence of a vegetation cover applied in mulching on the soil preserves the humidity of soil, promoting a microclimate favorable to microbial life, which has the direct consequence of improving the physicochemical properties of the soil. In addition, the mulch cover constitutes a source of organic matter (Pervaiz, 2009). Our results are confirm to those of Barthès et al. (2010) and Badou et al. (2013). Treatments that combine either of the working methods with the practice of mulch (BM50, MLM50 and SLM50) have increased the productivity of maize, respectively compared to the treatments without mulch (BM0, MLM0 and SLM0). Indeed, BM50 combines the beneficial effects of the turning of the soil and those due to the presence of mulching. The effects of non-turning of the soil are attenuated by the presence of mulch. In a no-till situation combined with mulching, the organic matter content of soils (MOS) increases essentially on the surface: West and Post (2002) estimate that 85% of the organic matter accumulates in the first 7 cm. In this regard, Thévenet et al. (2002) stressed the importance of the management (return to soil or removal) of organic residues (quantity, quality and fate). Badou et al. (2013) recommended mulch practice for sustainable land use.

Chemical properties of soil

The results show that the effect of both tillage system and mulching was not significant on the available phosphorus and total nitrogen content of the soil. The effect was significant on soil organic carbon pool. Furthermore, the available phosphorus and total nitrogen pool decreased from no-tillage to ridging and from the no-mulch to with mulch. Hountongninou (2016) reported a decrease in total nitrogen and available phosphorus on flat tillage plots compared to non-tillage plots. The decrease of soil total nitrogen pool could be explained by its high use rate due to the high maize growth on the tilled plots. The reduction of available phosphorus on tilled plots compared to no-tillage plots can be explained by the fact that tillage systems, even in relation to the input of organic matter, promote nutrients depletion, especially phosphorus (Müller et al., 2008). Organic carbon has been increased by ridging and mulching. This can be explained by the fact that a large quantity of organic matter was buried during ridging. Therefore, the presence of mulching constitutes a potential source of soil organic matter. Agricultural practices adopted in agro-systems have positive or negative impacts on soil organic matter content and functions (Aholoukpè, 2013).

Conclusion

Tillage system and mulching, taken separately, significantly affect maize growth and yield. Combined, maize growth and yield is also improved, but the difference is not significant. This improved maize performance has exhausted the nutrient pool of the soil. No-tillage generated the lowest performance, although it was combined with mulching, while mulch-covered logging produced the best maize performance. The soil, poor in organic matter and nutrients, is therefore degraded and consequently exhibits poor physical and chemical properties. The soil would be compact, making it difficult to develop roots and infiltrate rainwater. Regardless of the type of tillage, mulching has improved maize performance. Isohypse ridging and mulching constitute two effective practices for the sustainable use and conservation of agricultural soils in the central agro-ecological zone of Benin.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

REFERENCES

Abdellaoui Z, Fettih S, Zaghouane O (2006). Etude comparative de l'effet du semis direct et du labour conventionnel sur le comportement d'une culture de blé dur en conditions pluviales. Dans: 3èmes Rencontres Méditerranéennes du Semis Direct, Saragosse (Espagne), 23-25 mars 2006.

Agossou V, Igué AM (2002). Caractérisation paysanne et scientifique des sols des sites d'expérimentation agricole de la région centre du Bénin. In: Actes de l'Atelier Scientifique Centre 1, pp. 136–150. Editeurs: Agossou A., Amadji F., Agbo B. et Tandjiékpon A., Dassa Zoumé, Bénin. ISBN 99919-40-12-X.

Aholoukpè HNS (2013). Matière organique du sol et développement du palmier à huile sous différents modes de gestion des feuilles d'élagage. Cas des palmeraies villageoises du département du Plateau au Bénin. Thèse de doctorat du Centre International d'Etudes Supérieures en Sciences Agronomiques (Montpellier/France) et L'Université d'Abomey-Calavi 324p.

Baco MN, Abdoulaye T, Sanogo D, Langyintuo A (2011). Caractérisation des ménages producteurs de maïs en zone de savane sèche au Bénin. Rapport- pays – Enquête-ménage Bénin. IITA Ibadan, Nigeria, 38p.

Badou A, Akondé, PT, Adjanohoun A, Adjé IT, Aïhou K, Igué AM (2013). Effets de differents modes de gestion des résidus de soja sur le rendement du maïs dans deux zones agroecologiques du centre Bénin. Bulletin de la Recherche Agronomique du Bénin, Numéro Spécial Fertilité du maïs Janvier, 2013, pp. 34-38.

Barthès BG, Manlay RJ, Porte O (2010). Effets de l'apport de bois raméal sur la plante et le sol: Revue des Résultats Expérimentaux. Cahiers Agricultures 19(4):280-287

Bray RH, Kurtz LT (1945). Determination of total, organic, and available forms of phosphorus in soils. Soil Science 59:39-45.

Corbell M, Scopel E, Cardoso E, Bernoux M, Douzet JM, Siqueira Neto M (2006). Soil carbon storage potential of direct seeding mulch-based cropping systems in the Cerrados of Brazil. Global Change Biology 12 :1773-1787.

Diallo D, Boli Z, Roose E (2006). Labour ou semis direct dans les écosystèmes soudano–sahéliens (cas du Cameroun et Mali). Actes des journées scientifiques du réseau de chercheurs Erosion et GCES de l'AUEF. Dir. Ratsivalaka S., Serpantié G., De Noni G., Roose E. Actualité scientifique AUEF, Paris: pp 181-188, INRA (Les Colloques N° 65) ed, Paris, 16 mai 1991.

Douzet JM, Scopel E, Muller B, Rakotoarisoa J, Albrecht A, Razafindramanana NC (2010). Effets des systèmes de cultures en semis direct avec couverture végétale sur le ruissellement et l'érosion des cultures pluviales des Hautes Terres de Madagascar. Etude et Gestion des Sols 17(2):131-142.

Egah J, Baco MN, Lokossou RS, Moutouama FT, Akponikpè PBI, Fatondji D, Djènontin AJ, Tossou CR, Sokpon N (2014). Incidence économique des techniques exogènes de conservation de l'eau et des sols au Bénin. Bulletin de la Recherche Agronomique du Bénin (BRAB), n°75 1:57.

FAO (2011). Produire plus avec moins: Guide à l'intention des décideurs sur l'intensification durable de l'agriculture paysanne. Rome 2011. 101p.

Findeling A, Ruy S, Scopel E (2003). Modeling the effects of a partial residue mulch on runoff using a physically based approach. Journal of Hydrology 275:49-66.

Henao J, Baanante C (1999). Estimating rates of nutrient depletion in soils of agricultural lands of Africa. ISBN 0–88090–125–X (paperback). 87p.

Hountongninou A (2016). Effet du travail de sol, du mulching et de l'azote sur la productivité du maïs (Zea mays L.) sur un sol ferrallitique dégradé au sud du Bénin. Mémoire de Master, FSA–UAC. 96p.

Igué AM (2000). The use of a soil and terrain data base for land evaluation procedures: Case study of Central Benin. PhD thesis, University of Hohenheim, Germany, 235 p. ISSN 0942–0754.

Jones Jr JB, Wolf B, Mills HA (1991). Methods of Elemental Analysis (Chapter 4) pp. 27-38. In: Plant Analysis Handbook. Micro–Macro Publishing, Inc. 183 Paradise Blvd., Suite 108, Athens, Georgia.

Kouelo AF, Houngnandan P, Azontondé HA, Benmansour M, Rabesiranana N, Mabit L (2015). Assessment of the level of soil degradation in three watersheds affected by intensive farming practices in Benin. Journal of Experimental Biology and Agricultural Sciences 3(6):529-540.

Kouelo AF (2016). Effets des pratiques culturales sur la dégradation du sol au niveau des trois bassins versants du sud Bénin. Thèse de Doctorat en Sciences Agronomiques, Universités d'Abomey–Calavi, Bénin, 239 p.

Kurothe RS, Kumar G, Singh R, Singh HB, Tiwari SP, Vishwakarma AK, Sena DR Pande VC (2014). Effect of tillage and cropping systems on runoff, soil loss and crop yields under semiarid rainfed agriculture in India. Soil and Tillage Research 140:126-134.

Labreuche J, Le Souder C, Castillon P, Ouvry JF, Real B, Germon JC, de Tourdonnet S (2007). Evaluation des impacts environnementaux des Techniques Culturales Sans Labour en France. ADEME-ARVALIS Institut du végétal-INRA-APCA-AREAS-ITB-CETIOMIFVV. 400p.

Mazarei M, Ahangar AG (2013) The Effects of Tillage and Geographic Factors on Soil Erosion: A Review. International Journal of Agriculture and Crop Sciences 6:1 024.

Müller M, Schafflützel R, Chervet A, Sturny WG, Zihlmann U, Weissopf P (2008). Teneurs en phosphore et en potassium après 11 ans de semis direct ou de labour. Revue Suisse d'Agriculture 40p.

Osunbitan JA, Oyédélé D J, Adélaku KO (2005). Tillage effects on bulk density, hydraulic conductivity and strength of a loamy sand soil in southwestern Nigeria. Soil and Tillage Research 82:57-64.

Pervaiz MA, Iqbal M, Shahzad K, A–UL–Hassan (2009). Effect of Mulch on Soil Physical Properties and N, P, K Concentration in Maize (Zea mays L) Shoots under Two Tillage Systems. International Journal of Biological and Chemical Sciences 11(2):119-124.

Roger–Estrade J, Adamiade V, Arrouays D, Baranger E, Bartoli M, Boizard H, Chaplain V (2011). Dégradation physique des sols agricoles et forestiers liée au tassement: principaux résultats du projet GESSOL–ADD DST. Etude et Gestion des Sols 18(3):187-189.

Roger–Estrade J, Anger C, Bertrand M, Richard G (2010). Tillage and soil ecology: Partners for a sustainable agriculture. Soil and Tillage Research 111:33-40.

Ruget F, Bonhomme R, Chartier M (1996). Estimation simple de la surface foliaire des plantes de maïs en croissance. Agronomie: Agriculture and Environment 10p.

Saïdou A, Balogoun I, Koné B, Gnanglé CP, Aho N (2012b). Effet d'un système agroforestier à karité (*Vitellaria paradoxa* c.f. gaertn) sur le sol et le potentiel de production du maïs (Zea maize) en zone Soudanienne du Bénin. International Journal of Biological and Chemical Sciences, pp. 2066-2082.

Saïdou A, Kossou D, Acakpo C, Richards P, Kuyper TW (2012a). Effects of farmers' practices of fertilizer application and land use types on subsequent maize yield and nutrient uptake in central Benin. International Journal of Biological and Chemical Sciences 6(1):365-378.

Saïdou A, Kossou D, Azontondé A, Hougni DGJM (2009). Effet de la nature de la jachère sur la colonisation de la culture subséquente par les champignons endomycorhiziens: cas du système 'jachère' manioc sur sols ferrugineux tropicaux du Bénin, International Journal of Biological and Chemical Sciences 3(3):587-589.

Séguy L (2006). Le semis direct sur couverture végétale permanente (SCV): une solution alternative aux systèmes de culture conventionnels dans les pays du Sud. Dossier AFD 2006, Paris France. 68p.

Thévenet G, Mary B, Wylleman R (2002). Stockage du carbone et techniques de travail du sol en milieu tempéré : bilan de 30 années d'expérimentation en grandes cultures. C.R. Acad. Agric. France, juin 2002.

Tomavo FC (2014). Effet du travail du sol, du mulching et de la fertilisation azotée sur la productivité du maïs (Zea mays L.) et la dynamique de la matière organique du sol au Sud- Bénin. Thèse de Master en Sciences Agronomiques/Faculté des Sciences Agronomiques d'Abomey- Calavi/ Bénin 55p.

Walkley A, Black I A (1934). An examination of the Degtjareff method for determining soil organic matter and a proposed chromic acid titration method. Soil Science 37:29-38.

West TO, Post WM (2002). Soil organic carbon sequestration rates by tillage and crop rotation: a global data analysis. Soil Science Society of America Journal 66:1930-1946.

Ziadi N, Angers DA, Gagnon B, Lalande R, Morel C, Rochette P, Chantigny MH (2014). Le travail du sol et la fertilisation synthétique à long terme affectent le fonctionnement du sol et les rendements des cultures dans une rotation maïs-soya dans l'est canadien. Canadian Journal of Soil Science 94:365-376.