Peruvian Journal of Agronomy
http://revistas.lamolina.edu.pe/index.php/jpagronomy/index

RESEARCH ARTICLE
https://doi.org/10.21704/pja.v6i2.1933

Received for publication: 06 June 2022
Accepted for publication: 31 July 2022
Published: 30 August 2022
ISSN: 2616-4477

Impact of two tillage practices on selected soil properties, growth and yield of maize on an ultisol

Impacto de dos prácticas de labranza en determinadas propiedades del suelo, crecimiento y rendimiento del maíz en un Ultisol de Nigeria

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Abstract

This study investigated the effect of two tillage practices on maize yield and growth, and selected soil properties of an Ultisol of Osun State in Nigeria. This was aimed at selecting an appropriate tillage practice for crop growth and soil maintenance. The study was divided into two experimental plots during the early and late cropping season in 2014. The first plot was manually cleared to have zero tillage while the second plot was plowed twice and harrowed once for conventional tillage. Each plot had three blocks (23.0 m x 2.5 m) with an alley of 1.0 m between blocks and 1.0 m within plots. Three seeds of the test crop were a distance of 75 cm x 50 cm per hill and each plot weeded manually at two weeks intervals till harvest. The selected soil physical and chemical properties and plant growth parameters were collected and determined using standard method after each cropping season. At the end of the experiment zero tillage, had the highest plant height and soil values compared to conventional tillage. Zero tillage also had higher soil chemical values when compared to conventional tillage. The grain yield showed a significant difference between the tillage practices. Zero tillage had a higher yield (1.71 t/ha) when compared with conventional tillage (0.97 t/ha). The study concluded that zero tillage was a better alternative for crop growth and soil maintenance of an Ultisol.

Keywords: *Conventional tillage, Maize crop, plow, harrowed, ultisol.*

Resumen

Este estudio investigó el efecto de dos prácticas de labranza sobre el rendimiento y el crecimiento del maíz, y propiedades seleccionadas del suelo de un Ultisol del estado de Osun en Nigeria. Esto tuvo como objetivo seleccionar una práctica de labranza adecuada para el crecimiento de los cultivos y el mantenimiento del suelo. El estudio se dividió en dos parcelas experimentales durante la temporada de cultivo temprana y tardía en 2014. La primera parcela se desbrozó manualmente para tener labranza cero, mientras que la segunda parcela se aró dos veces y se rastrilló una vez para labranza convencional. Cada parcela tenía tres bloques (23.0 m x 2.5 m) con un callejón de 1.0 m entre bloques y 1.0 m dentro de las parcelas. Tres semillas del cultivo de prueba se colocaron a una distancia de 75 cm x 50 cm por montículo y cada parcela se desyerbó manualmente a intervalos de dos semanas hasta la cosecha. Las propiedades físicas y químicas del suelo seleccionadas y los parámetros de crecimiento de las plantas se recolectaron y determinaron utilizando el método estándar después de cada

How to cite this article:

Oluwatosin Komolafe (2022). Impact of two tillage practices on selected soil properties, growth and yield of maize on an ultisol. *Peruvian Journal of Agronomy, 6*(2), 123-131. https://doi.org/10.21704/pja.v6i2.1933

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temporada de cultivo. Al final del experimento, tuvo los valores más altos de altura de planta y suelo en comparación con la labranza convencional. La labranza cero también tuvo valores químicos del suelo más altos en comparación con la labranza convencional. El rendimiento de grano mostró una diferencia significativa entre las prácticas de labranza. La labranza cero tuvo un mayor rendimiento (1.71 t/ha) en comparación con la labranza convencional (0.97 t/ha). El estudio concluyó que la labranza cero era una mejor alternativa para el crecimiento de los cultivos y el mantenimiento del suelo de un Ultisol.

Palabras clave: L*abranza convencional, cultivo de maíz, arado, grada, ultisol.*

1. INTRODUCTION

Soil nutrient depletion has been an environmental challenge in sub-Saharan Africa for centuries. The depletion of nutrients in these soils is caused by unfavorable changes to its properties. This comportment could be attributed to an inappropriate soil management practices (Alam et al., 2014). Such practices lead to the reduction in organic matter, increase soil acidity and encourage soil erosion. Examples of such practices are inappropriate soil fertility and tillage management practices (Mohanty et al., 2007).

Tillage practices have been an age long practice in farming. According to Cookson et al. (2008), tillage is a practice used to stir the soil for crop production. It helps to manipulate and loosen the soil for the cultivation. For this reason, its effect on the soil properties and growth of crops has been debated over the years (reference). Tillage impacts the soil chemical, physical and biological properties either positively or negatively. The advantages of proper tillage practice include the stimulation of soil nutrients by incorporating crop residues and pest management, and the seed bed formation. However, inappropriate tillage practices cause soil compaction, increase soil erosion and may lead to loss of soil cover in a long term (Hamza & Anderson, 2005). This indicates that selection of an appropriate tillage practice is essential for reducing soil nutrient depletion and optimum crop productivity.

Tillage is categorized into conventional and zero tillage (or no-till) practices. Conventional tillage involves tillage practices that leave less than 15 % of crop residue on the soil, while zero tillage is the process of retaining most crop residue on the soil surface (Singh et al., 2018). Each has advantages and disadvantages, for instance, conventional tillageloosens the soil, control weeds and integrates organic matter into the soil (Ram et al., 2018). Though its disadvantages include soil erosion, loss of soil cover and disruption of soil microbial activities. In contrast, zero tillage reduces soil disturbance and increases biological activities in the soil (Crittenden et al., 2015). However, its disadvantages include increased use of herbicides, and often it may be inappropriate for all soil types (Soane et al., 2012). Hence, the selection of a suitable tillage system should be based on different factors that include climatic factor and type of crops.

Crops such as maize require a suitable environment to achieve optimum growth and yield. Maize is an important cereal crop that can be cropped and produced all year. This crop also possesses vitamins (such as A and E) and mineral salts (Rouf Shah et al., 2016), therefore, it is ranked as the most important cereal crops, before rice and wheat (FAOSTAT, 2017). In Nigeria, maize could be used as a medicinal and food crop, or even as a raw material in industries, since it could be converted to starch, cornflakes and flour (Ali et al., 2018). The maize has increased its market demand and the need to increase its yield. Nevertheless, in many parts of Africa, its production has been lower than the population growth, hence the need for increased maize production (Santpoort, 2020).

To increase and ensure maximum yield, suitable soil management practices, such as manure application and selection of appropriate tillage, are necessary (Adedokun et al., 2018). Although, many factors such as pest infestation, and post-harvest losses may contribute to low yield, the most important factor is the type of tillage practice on a particular soil type (Aikins & Afuakwa, 2012). According to Rasmussen (1999), different rates of crop productivity could be observed in different soil types depending on the type of tillage practice. However, there is a lack of information on the effect of tillage practices on soil properties and crop responses in different soil types in sub-Saharan Africa. This study aimed to assess the impact of two different tillage practices on the growth of maize and its effects on soil properties of an ultisol. 7º30’0”

2. MATERIALS AND METHODS

The study was carried out at the Teaching and Research Farm, Obafemi Awolowo University, (OAU), Ile-Ife, Osun State, Nigeria in the early (April - July) and late (August - November) seasons of 2014. The research farm was located at latitude 7º30’0” N and longitude 4º30’0” E at an elevation of 268 m above mean sea level. The experimental sites had a rainfall pattern in 2014 that ranged between 26.1 mm and 224.0 mm, and soil temperature ranged between 33.9 ^{0}C and 39.1 ^{0}C (Figure 1 and 2). The site was fallowed for seven years.

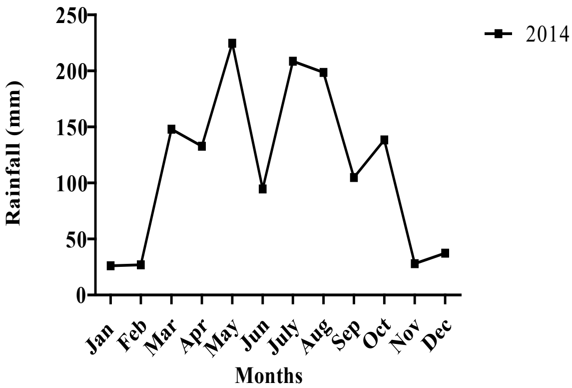

Figure 1: Monthly Rainfall Pattern for the Study Area 2014
Source: OAU Teaching and Research Farm Meteorological Station

The experiment was conducted on two experimental plots. The first plot was manually cleared (zero tillage) while the second plot was plowed twice at 25 cm depth and harrowed once (conventional tillage). Three pre-soil samples were collected and mixed into composite sample for analysis using a soil auger. Each experimental plot had three blocks (23.0 m x 2.5 m) with an alley of 1.0 m between blocks and 1.0 m within plots. Each experimental plot was replicated thrice. Seeds of the test crop maize variety ‘DT-SYN-8W’ were obtained from the Institute of Agricultural Research and Training (IAR and T), Ibadan. All plots were manually weeded using hoe at two weeks intervals till harvest. The test crop was sown at three seeds per hill using 75 cm x 50 cm planting distance. Cow dung compost was applied on each experimental plots at 3 t/ha after two weeks of sowing. Thinning to two seeds per hill was also done after two weeks of sowing. The experiment was laid out in a randomized complete block design (RCBD) with three replications.

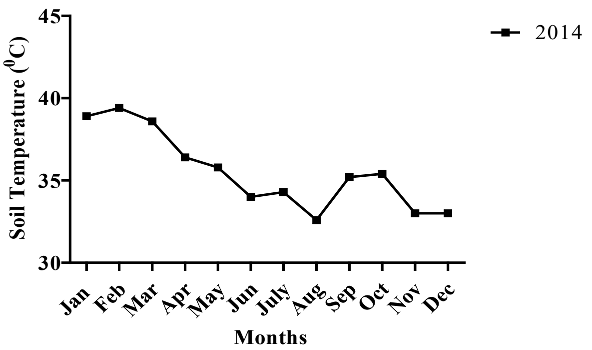

Figure 2: Monthly Soil Temperature of the Area of Study 2013-2014
Source: OAU Teaching and Research Farm Meteorological Station.

During the wet and dry seasons, three post-soil samples per experimental plot were collected before and after each experiment (six samples per season in total). The total of post-soil samples was 6. The depth of soil sampling was 6 inches. These samples were air-dried, crushed, and sieved using a 2 mm mesh before laboratory analysis. Soil The pH of the soil was determined in a 1:1 soil to water suspension using the Dwyer model WPH1 waterproof pH tester (model WPH1 waterproof, Dwyer). The particle size distribution was determined using the hydrometer method (Bouyoucos, 1951). The organic carbon was determined using following the method described by Walkley and

Black method (Walkley & Black, 1934). The exchangeable cations were determined using atomic absorption spectrophotometer (AAS). The bulk density was determined using the core method. Finally, the base saturation was determined according to the equation 1.

$$\text{Base Saturation} = \frac{\text{Exchangeable bases}}{\text{CEC}} \times 100 \qquad \text{eq1}$$

Collection of data on growth parameters commenced at 2 weeks after planting (WAP) and continued till 10 WAP when the maize plant had attained maturity. The growth parameters data collected were plant height, number of leaves, and stem girth using a tape rule, direct counting, and vernier caliper, respectively. The grain yield was determined by shelling a sample of ears (n = 5) from each plot and applying the shelling percentage to the entire experimental plot. The formula used to convert grain yield to grain moisture-standardized yield is shown in equation 2:7.5.

$$\text{Yield (at 12.5\% grain moisture)} = \frac{\text{Grain yield} \times (100 - \text{actual grain moisture \%})}{87.5} \qquad \text{eq2}$$

Data were analyzed using ANOVA (analysis of variance) and their treatment means were adjudged by Duncan's multiple range test ($p < 0.05$) method using SAS 9.0 using the statistical software SAS 9.0, while graphs were plotted using GraphPad Prism 5.

3.1 RESULTS AND DISCUSSION

3.1 Pre-soil Properties

Table 1 shows the soil properties before planting. The pre-soil properties of the experimental site indicated its pH (7.86) was slightly alkaline and its textural class was sandy loam. The organic carbon was high which could be attributed to the soil being fallow for seven years. The base saturation was high while the bulk density was moderate. The carbon and nitrogen ratio and the cation exchange capacity in the soil were also moderate.

Table 1: Pre-Soil Physical and Chemical Properties

Properties	Values
pH (1 : 1 soil-water)	7.86
Organic Carbon (%)	2.251
Exchangeable Acidity (meq/100 gr)	0.4
C/N	10.61
CEC (meq/100 gr)	21.01
Base saturation (%)	98.13
Bulk density (g/cm^3)	1.55
Sand (%)	79.2
Clay (%)	11.4
Silt (%)	9.4
Textural class	Sandy Loam

3.2 Growth Parameters

The effect of tillage practices on growth of maize and some selected soil properties of an Ultisol were investigated in this study. Figure 3 and Figure 4 show the growth parameters during early and late planting seasons under different tillage practices. All growth parameters were higher under conventional tillage when compared to zero tillage during the early planting season. Conventional tillage when used appropriately is known to increase soil porosity. This ensures a better soil aeration and subsequently leads to better plant growth. This corresponds with the findings of Guan et al. (2015) who observed that conventional tillage practices such as rotary and plow tillage during an early planting season, improved growth parameters such as root length and root weight density when compared to zero tillage. Better performances, however, were observed in zero tillage soils during the late planting season compared to conventional tillage. This could be attributed to improved water retention and increased organic matter observed in soils with zero tillage (Alam et al., 2014)namely, zero tillage (ZT. This agrees with the works of Ram et al., (2018) who also observed increased crop growth in *Triticum aestivum* under zero tillage practice when compared to conventional tillage in long term field experimentation.

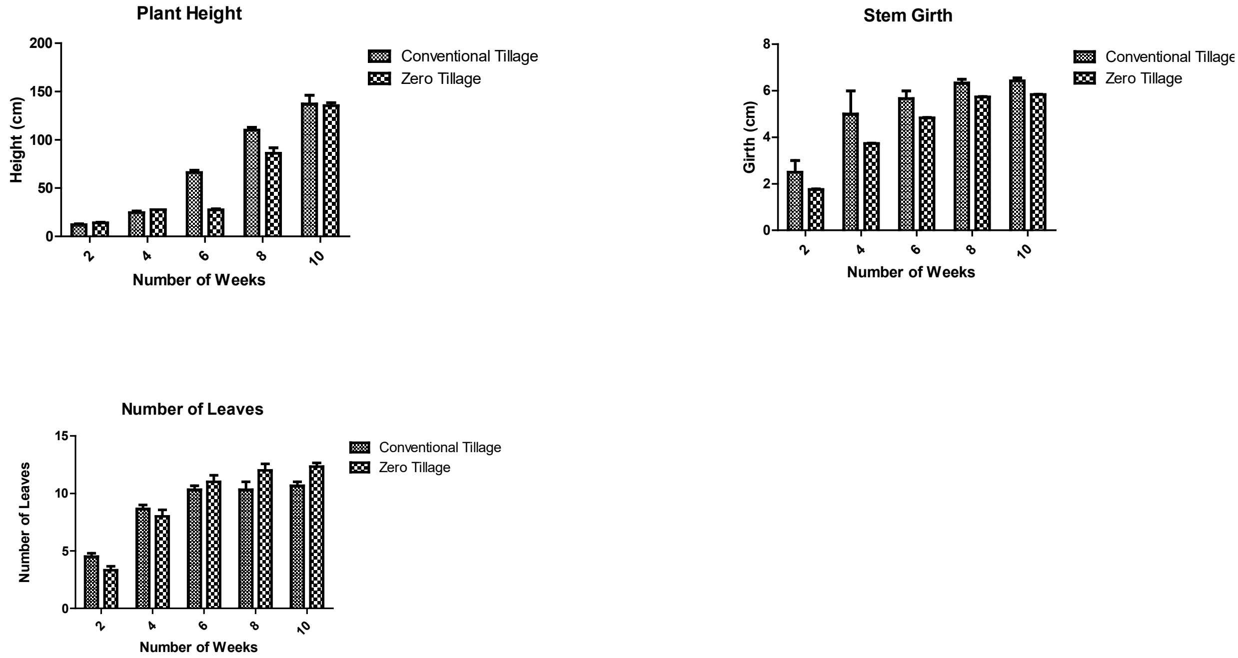

Figure 3: Growth Parameters under Different Tillage Practices during Early Season

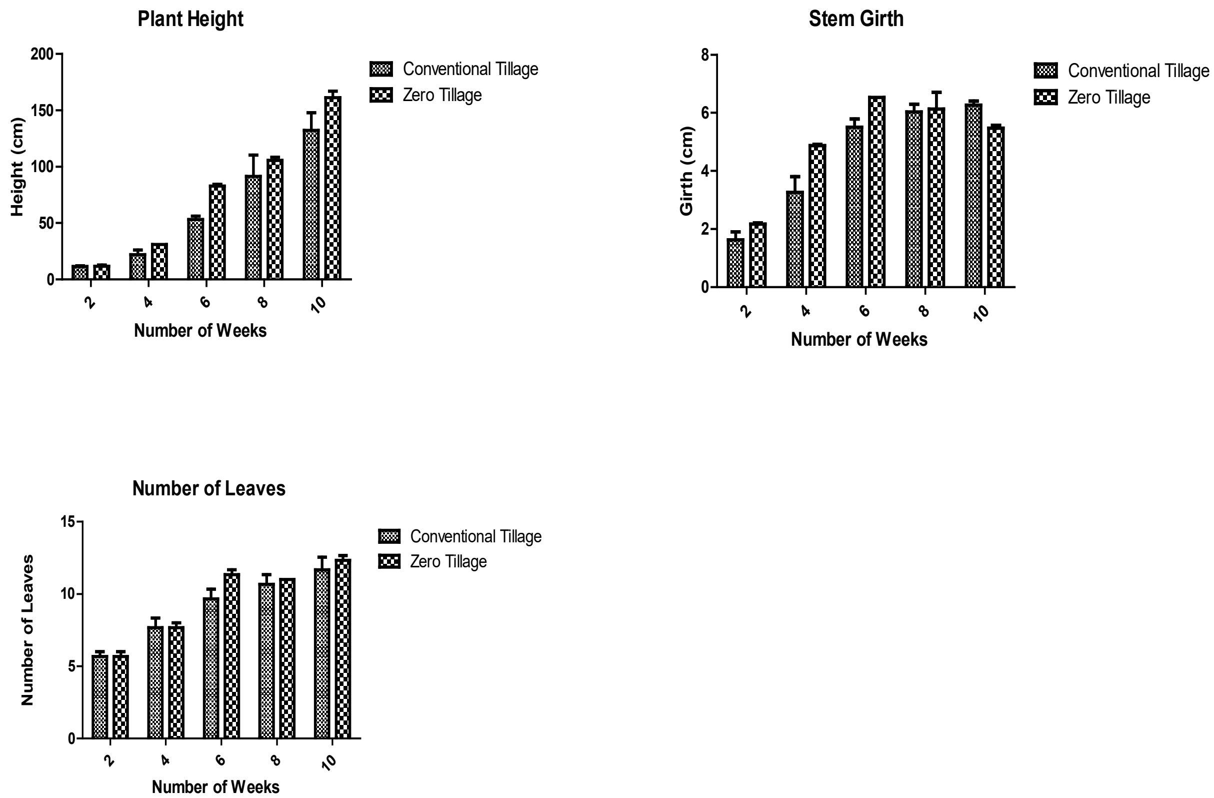

Figure 4: Growth Parameters under Different Tillage Practices during Late Season

3.3 Selected Soil Properties

During the early season (Table 2) conventional tillage had a higher pH (7.7) compared to zero tillage (7.5). However, the study observed that zero tillage (Table 3) had a higher soil pH (1:1 soil to water) compared to conventional tillage. This could be due to an increased crop residue observed in zero tillage soils in comparison to conventional tillage. This agrees with the observations of Lal (1997). After two cropping seasons, he observed that soils with zero tillage had higher pH values when compared to conventional tillage. Cookson et al. (2008) also reported in his study that continuous conventional tillage practice reduces soil pH at a 0 cm to 5 cm depth. At the end of the late season (Table 3), soil organic carbon for zero tillage soils was higher in comparison to conventional tillage. This could be due to the fast decomposition of crop residues observed in conventionally tilled soils. This agrees with the study of Haddaway et al. (2017). He concluded in his study that soils under no-till (zero tillage) had a higher soil organic carbon when compared to intensive tillage (conventional tillage). Mathew et al. (2012) also reported in a two year study, that a higher soil organic carbon was recorded in no-till soils when compared to conventional tillage. This study observed a significant difference between the cation exchangeable acidity for both tillage practices. Cation exchange capacity in conventionally tilled soils was lower (7.39 cmol/kg) compared to zero tillage (8.30 cmol/kg) at the end of the experiment (Table 3). Increased CEC recorded in zero tillage could be due to increased organic matter observed in zero tillage. Increased organic matter is responsible for increased negative charges which results into a higher soil CEC. This agrees with the observations of Thomas et al. (2007) and Dorneles et al. (2015). They stated that zero tillage had values of CEC surpassing recorded values of CT (conventional tillage). The lower bulk density observed in conventional tillage could be ascribed to the continuous use of farm machineries on the soil. This agrees with the work of Osunbitan et al. (2005) who stated that conventionally tilled soils have lower bulk density when compared with zero tillage. However, this study disagrees with Basamba et al. (2006). In his study of the effect tillage practices on soil physical properties of an acid- savanna Oxisol, he recorded a lower bulk density for zero tillage soils when compared with conventionally tilled soils.

Table 2: Soil Properties during Early Season

Properties	CT	ZT
pH (1 : 1 soil-water)	7.7a	7.5b
Organic Carbon (%)	2.47a	2.01b
Exchangeable Acidity (meq/100 gr)	0.5a	0.5a
CEC (meq/100 gr)	30.83a	15.58b
Base saturation (%)	98.3a	96.8b
Bulk density (g/cm^3)	1.43a	1.47b
Sand (%)	81.2a	78.66b
Clay (%)	8.4b	9.5a
Silt (%)	10.40b	11.83a

Means of the same letter are not significantly different
Legend: CT = Conventional Tillage, ZT = Zero Tillage

Table 3: Soil Properties during Late Season

Properties	CT	ZT
pH (1 : 1 soil-water)	7.63b	7.70a
Organic Carbon (%)	3.06b	3.49a
Exchangeable Acidity (meq/100 gr)	0.93b	1.80a
CEC (meq/100 gr)	7.39b	8.30a
Base saturation (%)	78.30b	87.40a
Bulk density (g/cm^3)	1.35a	1.38b
Sand (%)	85.33b	90.0a
Clay (%)	5.93a	4.60b
Silt (%)	8.73a	5.40b

Means of the same letter are not significantly different
Legend: CT = Conventional Tillage, ZT = Zero Tillage

Base saturation in conventional tillage was lower when compared with zero tillage at the end of the experiment (Table 3). The increased base saturation observed in zero tillage could be due to higher organic matter and base cations present in zero tillage soils. This disagrees with the work of Tarkalson et al. (2006). In a study which spanned a 27 years period, he concluded that base saturation was lower in zero tillage practice when compared to conventional tillage. This study, however, agrees with the reports of Omeke (2017) who stated that conventional tillage lowers the values of base saturation in soils.

Table 4: Mean Grain Yield of Crops Under Conventionally Tilled and No-Till During Early and Late Seasons

Season	CT(t $ha^{-1)}$	ZT
Early	0.79	0.78
Dry	0.97	1.71
Percentage Increase (%)	18%	19.78

Legend: CT = Conventional Tillage, ZT = Zero Tillage

3.4 Grain Yield

A similar yield was observed when conventional tillage was compared to zero tillage during the early season. The yield during the early season indicated no significant difference ($p > 0.05$) between conventional tillage (0.79 t/ha) and zero tillage (0.78 t/ha). However, during the late season, significant difference was observed between both tillage practices. Zero tillage had a higher grain yield with 1.71 t/ha compared to conventional tillage with 0.97 t/ha. It could be attributed to the increased soil organic carbon observed in zero tillage. Zero tillage is known to have a slower organic matter decomposition compared conventional tillage. This could lead to increased yield in subsequent seasons (Cooper et al., 2021).

CONCLUSION

Selected soil physical and chemical properties and plant growth parameters were examined under two tillage practices on an Ultisol. This was in a view of selecting an appropriate tillage practice for continuous cultivation. Soil properties under zero tillage were more improved at the end of the second planting season. The organic carbon and base saturation were higher in zero tillage soils when compared with conventional tillage. However, an increased bulk density was observed in conventionally tilled soils. Although growth parameters were higher in conventional tillage in the first season, it was observed that plant growth under zero tillage during the second season was higher when compared to conventional tillage. This implies that adoption of zero tillage practice would be necessary for crop growth, especially for maize cultivation, zero tillage should be considered as the preferred tillage practice.

Author contributions

Elaboration and execution, development of methodology, conception and design; editing of articles and supervision of the study have involved all authors.

Conflicts of interest

The signing authors of this research work declare that they have no potential conflict of personal or economic interest with other people or organizations that could unduly influence this manuscript.

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