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Effect of tillage on the growth and yield of maize (*Zea mays* L)

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ABSTRACT
As a response to measures that can improve maize yield without increasing the area currently used for cultivation in Nigeria, a field experiment was conducted at the research farm of the Institute of Agricultural Research and Training (IAR&T) Moor Plantation Ibadan to determine the effects of four tillage and cultural weed control method (hoe weeding) on growth and yield of three maize varieties. The tillage methods evaluated are (1) ploughed twice (T_1), (2) ploughed twice, harrowed once (T_2), (3) ploughed twice harrowed once and ridged (T_3), and (4) zero tillage (T_4). The three maize varieties used are (1) Suwan–ISR–Y (Suwan I Striga Resistance-Yellow) (V_1), (2) TZPBSR–W (Tropical Zea mays Population Borer and Streak Resistant–White) (V_2), and (3) DMR–LSR–Y (Downey Mildew Resistant, Late maturing Streak Resistant, Yellow) (V_3). Results showed that T_1 has the highest performance for both maize plant vegetative growth (stem girth, number of leaves and plant height) and maize grain yield, while T_4 has the least. This was more evident at six and eight weeks after planting (WAP) for the vegetative growth, but not at four WAP. Also, TZPB-SR-W showed the most preferable growth and yield of the three maize varieties. The obtained yield with T_1 and TZPB-SR-W is higher than the current average in Nigeria, it discourages traditional ridging, and it practically adapts to low-income local farmers. Rather than the farmers' propensity to recycle their seeds, programs that can encourage the adoption of improved varieties (e.g. TZPB-SR-W) by the maize farmers are essential.

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INTRODUCTION

Maize (*Zea mays* L.) is one of the most important cereal crops worldwide with a remarkable production potential (Nuss & Tanumihardjo, 2010). In Nigeria, it is the second most cultivated crop after cassava, and apart from its economic values, it is also culturally significant (Kling & Edmeades, 1997; Cadoni & Angelucci, 2013). Though Nigeria is one of the highest producers of maize in Africa with high production volumes, its recent average yield of 1.8 MT/Ha is one of the lowest among the top 10 producers in Africa. Thus measures that can improve its yield without increasing the area currently used for cultivation are necessary. Several authors have highlighted the numerous factors that hampered the yield of maize (Iken & Amusa, 2004; Tian et al., 2016). Examples include soil properties, tillage, breed and varieties, seasonal variations, pest and diseases, solar radiation, and other practices such as weed control and irrigation. The major factors of interest for this study are the tillage practices, the seed systems, and the weed control method.

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Tillage is a known and effective farming practice for improving soil tilth and physical properties such as bulk density and porosity. It enhances root penetration, aeration, soil structure, increase soil nutrient use efficiency, as well as decomposition of residue and its availability to plants (Huang et al., 2012; Anjum et al., 2014). However, intensive tillage negatively impacts the ecosystem; it causes environmental noise, air pollution, and increase topsoil erosion, especially with heavy machines (Anjum et al., 2019). Moreover, most subsistence farmers in Nigeria cannot afford it on a commercial scale. Resource conservation technologies are therefore necessary. Decisions on tillage practices by the farmers are in most cases based on how much money the farmer has to spend or the time available in the growing season for land preparation. The influence of tillage is however less considered by most farmers and can be attributed to the knowledge gap and lack of awareness.

Another major limitation to maize yield in Nigeria is the seed systems. There have been advancing researches in identifying several improved varieties, strength, weakness, and use-recommendations (Iken & Amusa, 2004). However, there is slow adoption of hybrid seeds among several local farmers. This is due to farmers' propensity to recycle their seeds, moreover, most key maize-growing states have limited availability of improved open-pollinated maize varieties, and its availability for local farmers is limited. Weeds on the other hand are unwanted plants that struggle for existence in competition with crops. Maize is a competitive crop with weed (Kayode & Ademiluyi, 2004; Jhala et al., 2014), several researchers have reported a yields reduction of up to one tonne per hectare in maize as a result of weed invasion (Steiner & Twomlow, 2003; Lehoczky & Reisinger, 2003), and that to boost maize production, the effect of weeds should be reduced. Among other weed control methods, cultural method (hoe weeding) and chemical method (herbicides) are the most common (Akobundu, 1979; Olatunji et al., 2016). Although hand weeding is economically impractical and time-consuming (Parish, 1990), it remains common, however, the chemical method is not sustainable and not recommendable.

The economic importance of maize necessitates the study of factors that will improve its growth and yield. Thus the objective of this study is to determine the effect of four different tillage practices and cultural weed control method (hoe weeding) on the growth and yield of maize with three different maize varieties.

METHODOLOGY

Experimental site and soil analysis

The field experiment was carried out during the rainy season at the research farm of the Institute of Agricultural Research and Training (IAR&T) Moor Plantation Ibadan. It is located on Longitude 03°51E, Latitude 07°23N, and Altitude 650". This region belongs to the humid zone of the rainforest belt in south-western Nigeria. It has a mean temperature of 26°C and a mean annual rainfall of 1220 mm. Before planting, a representative soil sample of the experimental site was obtained, its basic physical and chemical properties were determined following standard laboratory experiment; soil particle size (Bouyoucos, 1962), available P with the Bray 1 method (Bray & Kurtz, 1945), % organic carbon and nitrogen (Walkley & Black, 1934; Bremner & Keeney, 1966).

Treatments and experimental design

The treatment comprised of a factorial combination of four tillage practices and three maize varieties, all subjected to a single weed control method (hoe weeding) (Fig. 1). The four tillage practices include (1) ploughed twice (T_1,), (2) ploughed twice and harrowed one (T_2), (3) ploughed twice, harrowed once and ridged (T_3), and (4) zero tillage (T_4). The three maize varieties considered are (1) Suwan-ISR-Y (V_1), (2) TZPB-SR-W (V_2), and (3) DMR-LSR-Y (V_3). The experiment was laid out as presented in Figure 1 with a net plot size of 80 m × 35 m, following three times replication. The plot size for each treatment was 6.0 m × 6.0 m, with a spacing of about 2m between each plot.

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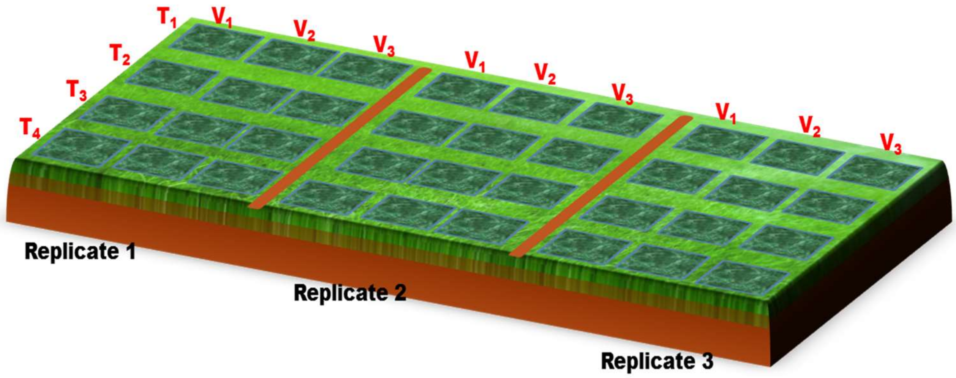

Figure 1: Treatment and experimental layout. T_1, T_2, T_3, and T_4 represents 4 tillage practices (1) ploughed twice, (2) ploughed twice and harrowed one, (3) ploughed twice, harrowed once and ridged, and (4) zero tillage respectively. Also, V_1, V_2, and V_3 represent the 3 different maize varieties (1) Suwan-ISR-Y, (2) TZPB-SR-W, and (3) DMR-LSR-Y respectively.

Planting and Crop Maintenance

Following the experimental layout, as presented in Figure 1, three seeds were planted per hole at a regular row to row spacing and a regular plant to plant spacing (50 × 75 cm). It was later thinned to one plant per stand after two weeks. Hoe weeding was used as a cultural weed control method, regularly done at three weeks interval and weeded three times before the end of the experiment when the crops reached physiological maturity. To simulate the low and/or no fertilizer application by most low-income local farmers (Liverpool-Tasie et al., 2017), nitrogen: phosphorus: potassium (NPK) fertilizer were applied at a rate of 10:10:10 kg ha^{-1}.

Data Collection and Analysis

On each plot, ten maize plants were randomly selected as representative samples to determine the crop growth parameters. The stem girth (cm), number of leaves, and the plants' height (cm) from the ground surface were measured at four, six, and eight weeks after planting (WAP). At maturity, all the maize cobs per plot were carefully harvested manually, shelled, and the grains fresh weights (kg) were determined. The grains were afterwards sun-dried to 10 % moisture content, which were recorded as the dry weights (kg). The crop yields (kg ha^{-1}) for each plot were as well estimated accordingly. The data collected were subjected to Analysis of Variance ANOVA using SPSS. Where there is a significant difference among the treatments, the Duncan Multiple Range Test (DMRT) at a 5 % significant level was used for mean separation.

RESULTS

Soil Physical and Chemical Properties

Results of the physical and chemical properties of the soil experimental area show that the textural class is sandy-loamy (76.80 % sand, 13.00 % silt, and 10.20 % clay). The pH is slightly acidic (pH of 5.79), with low % Nitrogen (0.07) and % an organic matter of (1.17). The available phosphorus is 4.30 cmolKg^{-1}, while potassium, calcium, magnesium, sodium, and zinc are 0.13, 0.86, 0.72, 0.52, and 8.00 cmolKg^{-1}. Also, the cation exchange capacity is 2.35 cmolKg^{-1}.

Effects of Tillage on Growth Parameters with Maize Varieties

The mean values of the effects of tillage on the growth parameters for the three maize varieties employed are presented in Fig. 2. Fig. 2a shows the stem girth of maize plants at 4, 6, and 8 WAP. Generally, the stem girth size of maize V_2 (TZPB-SR-W) is averagely higher than both Suwan-ISR-Y and DMR-LSR-Y, especially at 6 and 8 WAP. At 4 WAP, stem girth for all the varieties is averagely the same. With the tillage

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practices, all the maize varieties show a similar trend in response to the differences in tillage applications. It shows a decreasing order of $T_1 > T_2 > T_3 > T_4$. This trend is more evident at 6 and 8 WAP. However, at 8 WAP, the highest and lowest stem girth values were both obtained with TZPB-SR-W under T_1 and T_2 respectively. In addition, TZPB-SR-W was significantly different ($p \leq 0.05$) at 6WAP and 8WAP under T_1.

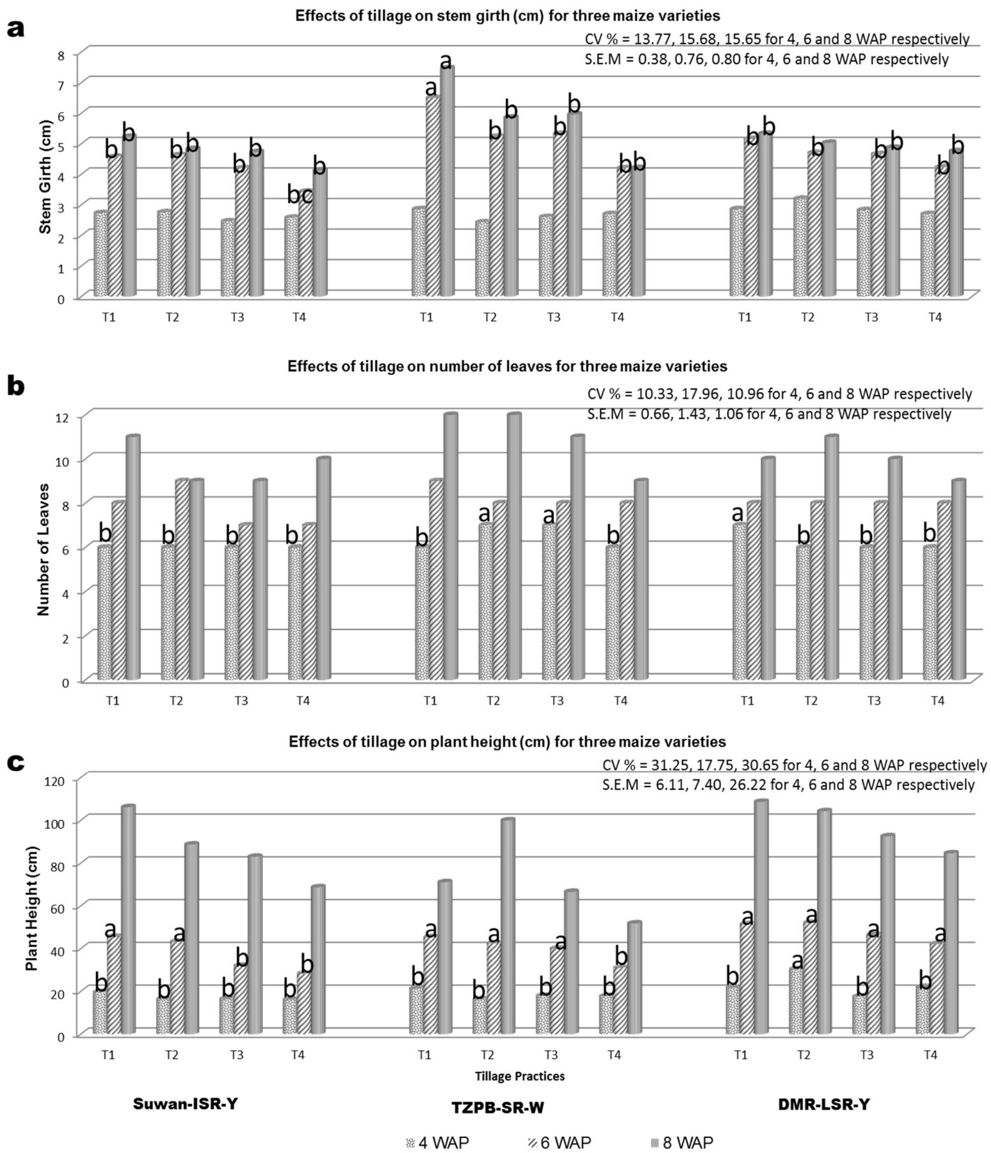

Figure 2: Effects of tillage on growth parameters for three maize varieties (Suwan-ISR-Y; TZPB-SR-W; DMR-LSR-Y). a, b, and c represents the stem girth, number of leaves, and plant height respectively. Means with the same letter are not significantly different (at a 5 % level of significance) according to Duncan Multiple Range Test. CV is the Coefficient of Variation and SEM is the standard error of the mean. T_1= Ploughed Twice, T_2= Ploughed Twice, Harrowed Once, T_3= Ploughed Twice Harrowed Once and Ridged, and T_4= Zero Tillage. WAP= Week after Planting.

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In Fig. 2b, similar to the stem girth, TZPB-SR-W also shows an average high number of leaves than both Suwan-ISR-Y and DMR-LSR-Y. With the tillage practices, only TZPB-SR-W shows a trend of $T_1 = T_2 > T_3 > T_4$ which is most similar to the trend to stem girth. The trend with Suwan-ISR-Y is $T_1 > T_4 > T_3 = T_4$, while DMR-LSR-Y shows a trend of $T_2 > T_1 = T_3 > T_4$. The highest number of leaves was obtained with TZPB-SR-W at 8 WAP for both T_1 and T_2. This was followed by Suwan-ISR-Y under T_1, TZPB-SR-W under T_3, and DMR-LSR-Y under T_2. Almost similar numbers of leaf were obtained at 6 WAP for all the maize varieties and tillage practices except TZPB-SR-W under T_1 and Suwan-ISR-Y under T_2 where the highest leaf numbers were obtained, and Suwan-ISR-Y under both T_3 and T_4 with the lowest number of leaves.

The effects of tillage practices on different varieties of maize with the plant height are shown in Fig. 2c. Unlike other growth parameters, Suwan-ISR.Y and DMR-LSR-Y both show higher height than TZPB-SR-W. At 8 WAP, the highest plant height in descending order was obtained with DMR-LSR-Y under T_1, followed by Suwan-ISR-Y (T_1) and DMR-LSR-Y under T_2. The shortest plant height at 8 WAP in ascending order was observed by TZPB-SR-W under tillage T_4, TZPB-SR-W at T_3, and Suwan-ISR-Y under T_4 tillage practice. An almost similar trend was obtained at 6 WAP. While at 4 WAP, the order of the height was DMR-LSR-Y at T_2 > DMR-LSR-Y T_4 > and DMR-LSR-Y T_1. Plants with the shortest height followed the ascending order of Suwan-ISR-Y at T_4 < Suwan-ISR-Y at T_2 < TZPB-SR-W at T_2. Both Suwan-ISR-Y and DMR-LSR-Y shows a trend of $T_1 > T_2 > T_3 > T_4$, while TZPB-SR-W has a trend of $T_2 > T_1 > T_3 > T_4$.

Effects of Tillage on the Maize Grain Yield (Kg/Ha) with its Varieties

The mean grain yields of the three maize varieties, both fresh and dry, for the 4 tillage practices are presented in Table 2. TZPB-SR-W had the highest yield for fresh weight, while Suwan-ISR-Y was the highest for dry weight. While the least weight for both fresh weight and dry weight was obtained with DMSR-MSR-Y. With the tillage practices, both TZPB-SR-W and DMR-LSR-Y shows a trend of $T_1 > T_2 > T_3 > T_4$ for the fresh weight and dry weight, while the trend observed for Suwan-ISR-Y was $T_1 > T_2 > T_4 > T_3$.

Table 1: Effects of tillage on the yield of three maize varieties (Suwan-ISR-Y; TZPB-SR-W; DMR-LSR-Y).

Maize varieties	Tillage practice	Fresh grain weight (kg)	Dry grain weight (kg)	Grain yield (MTha^{-1})
Suwan-ISR-Y	T_1	4755.6	622.2	1.32
	T_2	4622.2	444.4	1.28
	T_3	1466.7	170.8	0.41
	T_4	1644.4	177.8	0.46
TZPB-SR-W	T_1	7555.6	577.8	2.10
	T_2	6800.0	533.3	1.89
	T_3	5200.0	530.3	1.44
	T_4	2800.0	266.7	0.78
DMR-LSR-Y	T_1	4311.1	488.9	1.20
	T_2	3200.0	365.6	0.89
	T_3	3111.1	355.6	0.86
	T_4	1333.3	133.3	0.37
CV %		36.75	5.15	
S.E.M		0.32	0.01	

Means with the same letter are not significantly different (at a 5 % level of significance) according to Duncan Multiple Range Test. T_1= Ploughed Twice, T_2= Ploughed Twice, Harrowed Once, T_3= Ploughed Twice Harrowed Once and Ridged, and T_4= Zero

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Tillage. CV is the Coefficient of Variation and SEM is the standard error of the mean.

DISCUSSION

Soil Physical and Chemical Properties

Maize performs best on well-drained, aerated, warm, deep, and soft loam having adequate organic matter content and rich in nutrients (Oguntoyinbo, 1981). Although the obtained soil physical and chemical properties of the experimental soil vary in comparison to previous related studies, however, it suggests suitable for maize cultivation (Agbede, 2006; Nwachuku & Loganathan, 2008; Ayodele & Omotoso, 2008; Oyedele et al., 2009). The pH is higher than values obtained by (Adegaye et al., 2019), likewise is the high available P. However, the values of % OM, total N, K^+, Na^+, Ca^{2+}, and Mg^{2+} are low. The soil nutrient is, therefore, necessary to be improved. This can be enhanced by the reincorporation of soil residue back to the soil (Janzen, 2005), especially by low-income farmers with no means of efficient fertilization. On the other hand, the soil textural class is suitable for maize cultivation, though it is a permanent physical property (Adesipo et al., 2020), its distribution on the site can be influenced by manipulating the soil.

Effects of Tillage on Growth Parameters and Yield with Maize Varieties

Except for the plant height where DMR-LSR-Y has the highest value followed by Suwan-ISR-Y, the stem girth and leaf number of TZPB-SR-W was the highest. In terms of the tillage practice, the most similar trend could be observed about the maize varieties and the employed tillage practice beyond 4 WAP. For the plant stem girth, several leaves, and the plant height, T_1 which is ploughed twice was mostly the highest, followed by T_2 and T_3 while T_4 (zero tillage) has the lowest values. This is also true concerning the weight (both fresh and dry) of the harvested maize, and the observation was the same for all the varieties, especially beyond 4 WAP. These obtained poor responses under zero tillage in almost all the growth parameters are an indication for poor growth which influences yield. Also, the highest value gotten in ploughed twice in most of the growth parameters is a pointer to good conformation and high yield. This is because there was adequate room for photosynthesis, proper nutrient and water utilization, and the ability of the plant to bear maize cob at a proper level above the ground without lodging, thereby preventing rodents, disease and insect attacks. This best performance under ploughed twice also agrees with the recommendations from related previous studies that “there is no need for excessive soil manipulation for maize production”. Zero tillage is not encouraging; however, the tillage operation should be minimal (Duiker et al., 2006). Moreover, minimal tillage practice minimizes production cost, especially for low-income farmers, and it assures efficient yield. (Osunbitan et al., 2005) indicated that soil bulk density decreases with the degree of soil manipulation during tillage practices with no-tillage having the highest and ploughed harrowed having the least. They stated further that the effects of the degree of soil manipulation on hydraulic conductivity, soil bulk density, soil strength, and penetration consequently affects crop productivity (Kayode & Ademiluyi, 2004). To this extent, (Couper, 1995) stated that care must be taken in soil manipulation since tropical soils are physically fragile, generally low in fertility, and easily eroded when cleared of natural vegetation.

CONCLUSION AND RECOMMENDATIONS

With the result obtained from the growth and yield performances of the three varieties of maize under different tillage and cultural weed control method, it can be concluded that ploughed twice is the best tillage method coupled with TZPB-SR-Was it best favours both the growth and yield of maize. It generates a yield of 2.10 $MTha^{-1}$, which is above the recent average of 1.8 $MTha^{-1}$, in Nigeria, moreover, its less tillage demands practically adapts to low-income local farmers. The results also suggest that the common practice of ridging by most local farmers seems not to be an appropriate technology and generate optimum yield. However, no-tillage is not favourable for maize cultivation. In addition, differences in improved seed should be adequately considered,

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and the availability of this seed needs to be assured by the government, while the farmers show interest and readiness to adopt.

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Declaration of competing interest
The authors declare that they have no conflict of interest.

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