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Effects of Methods of Seedbed Preparation and Organic Amendments on Soil Properties, Growth and Yield of Sunflower (*Helianthus annuus* L.) in a Humid Zone of Nigeria

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Authors' contributions

This work was carried out in collaboration between authors. Author SOA designed the study, wrote the protocol and the first draft of the manuscript. Author TGT managed the literature searches, carried out the field study, soil and plant analysis, and statistical analysis. All authors read and approved the final manuscript.

Research Article

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ABSTRACT

Aims: Field experiments were conducted to evaluate the effects of methods of seedbed preparation via clearing of existing vegetation and organic amendments on some soil properties, growth and yield of sunflower (*Helianthus annuus* L.).
Study Design: The treatments consisted of 2 by 3 factorial combination of bush clearing methods and organic amendments arranged in a split- plot design.
Place and Duration of Study: The experiments were conducted in the late season of 2009 and late season of 2010 at the Teaching and Research Farm of the Federal University of Technology, Akure, Nigeria.
Methodology: The treatments consisted bush clearing methods, manual clearing and herbicide-based zero tillage, were the main plots while organic amendments via application of organic fertilizer and farmyard manure constituted the subplot treatments. Measurements were made on soil properties: physical,(soil moisture contents and temperature), chemical (soil pH, organic matter, N, P, K, Ca, Mg) and biological (bacterial and fungal counts).
Results: The results show that herbicide–based zero tillage plus organic manure

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produced the highest values of soil organic matter (4.2 g kg^{-1} and 4.5 g kg^{-1}) in 2009 and 2010 respectively compared with manual clearing plus organic manure (4.0 g kg^{-1} and 4.2 g kg^{-1}) in 2009 and 2010 respectively. Herbicide–based zero tillage plus organic fertilizer had higher values of organic matter (3.9 g kg^{-1}) in 2009 experiment compared with manual clearing plus organic fertilizer (3.8 g kg^{-1}). In the respective bush clearing methods, application of organic manure increased soil organic matter content. Organic amendments improved the soil micro- environment around the plant compared with unmanured plots with increases the populations of soil bacteria and fungi. Non significant differences were obtained in soil temperatures between bush clearing methods alone and in combination with organic amendments. There were small differences in soil moisture contents between bush clearing methods alone and in combination with manuring. Herbicide-based zero tillage plus organic fertilizer produced values of plant height and stem girth (1.25 m, 2.80 cm and 1.10 m, 2.21cm) which were not significantly different ($P > 0.05$) from values (1.21 m, 2.70 cm and 1.08 m, 2.00 cm) under manual clearing plus organic fertilizer. Although organic amendments improved growth and yield components of sunflower over the unamended, no significant differences ($P > 0.05$) were found for most of the parameters measured. The effects of bush clearing methods were also not significant on growth and yield components of sunflower. Herbicide-based zero tillage plus organic fertilizer produced higher seed yields and is therefore recommended for sunflower production in the study area.
Conclusions: Organic amendments and herbicide–based zero tillage had positive effects on soil and sunflower productivity, this practice is recommended for sunflower production in the study area.

Keywords: Tropics; sunflower; seedbeds; soil; amendment.

1. INTRODUCTION

Sunflower (*Helianthus annuus* L.) belongs to the family Asteraceae. It is an annual crop which was introduced to Nigeria in 1965. It is the world's most important edible oil seed. The seed which can be eaten raw or roasted contains 36 to 45 % oil depending on variety and can be used in salads, cooking, margarine, lubricant, paint vanishes and soap production [29]. The decorticated seed cake is a good source of protein for livestock (35%), especially when made from the whole seed. Non – dehulled or partially dehulled sunflower meal has been substituted successfully for soybean meal in diets for ruminant animals, as well as for swine and poultry feeding.

Although sunflower is known to be drought resistant, water supply is a critical factor for oil formation. Inadequate water supply with or without the use of fertilizers results in reduced seed yield and oil content [13,25,4]. Sunflower has deep tap root system in addition to proliferation of surface lateral roots which make the crop fairly drought resistant [5,25,34,5].Sunflower performs well in both the rainforest and savanna agro - ecologies of Nigeria especially when grown on various seedbed types and manure applications [4]. Fertilizer use in crop production, in particular, organic manures, can influence soil quality, crop growth and yield and chemical and nutritional qualities. However, seedbed preparation may disturb soil structural properties, consequently affecting soil nutrient status and crop productivity.

The commonest approach to soil fertility management in Nigeria is through the use of organic manure, but farmers can be discouraged due to associated problems like bulkiness,

cost of transportation and application. Farmers also use mineral fertilizers which greatly increased crop yield. The use of mineral fertilizers is reported to increase yield and in the long term leads to decreasing base saturation and acidification of soil [18] In particular, the use of mineral fertilizers on continuous basis in tropical soil has been associated with reduced crop yield, increased soil acidity and nutrient imbalance [31,1]. In addition to increased soil acidity and nutrient imbalance, high cost of mineral fertilizers and environmental consequences involved in its use have awakened interest in the use of organic manures as nutrient sources. Studies had reported the positive effects of organic manures on soil and crop productivity. Mbah and Mbagwu [23] reported that application of organic manure increased cation exchange capacity (CEC) of soils thus indicating greater nutrient retention capacity of soil.

Lopez et al. [22] identified convetional tillage, zero - tillage and reduced tillage as common tillage practices in sunflower production. Odedina et al. [28], opined that sunflower can be cultivated using several tillage methods including zero-tillage. This study was designed to examine the effect of effects of methods of seedbed preparation via clearing of existing vegetation and organic amendments on soil physical, biological and chemical properties, growth and yield of sunflower in Akure, situated in the humid rainforest zone of Nigeria.

2. MATERIALS AND METHODS

2.1 Experimental Site and Conditions

This study was carried out at the Teaching and Research Farm of the Federal University of Technology, Akure (lat. 7º15', long 5º10') in the tropical rainforest zone of Nigeria. This agroecological zone is characterized by a bimodal rainfall pattern. The rainy season is from March to December with a short dry spell between July and August, while the dry season occurs between December and February. Field experiments were carried out between October and January and April and July of 2009 and 2010, respectively. The sandy loam soil at the site is an Alfisol classified as clayey skeletal Oxic – Palestalf (Soil Survey Staff, 2006). The surface soil (0 – 15 cm) at the experimental sites had the following physical properties: sand 57%, silt 16%, clay 277% and sand 54%, silt 16%, clay 30%, respectively.

2.2 Treatments

For each year's experiment, treatments were 2 by 3 factorial combinations of bush clearing methods and manure application arranged in a split – plot design. The existing vegetation of the site of study were dominated by *Chromolaena odorata*, a broad leaf weed species, and were cleared/removed manually using a hand-held cutlass or via the application of herbicide. The bush clearing methods consisted of clearing of existing vegetation manually using a hand-held cutlass (manual clearing: MC) with the cleared residues were left on the seedbeds, and through application of herbicide to kill existing vegetation (herbicide - based bush clearing method: Herb-Sd). In the herbicide - based seedbed preparation method, the existing vegetation was cleared by spray-application of glyphosate (sarosite: 700g a.i. per litre) at the rate of 200 ml to 20 litres of water (3 l/ha). The bush clearing methods produced No-till seedbeds with minimal soil disturbance. Bush clearing methods constituted the main plot while manure was split within the main plots as subplot and was randomized within the main plot. Manurial treatments consisted of applications of 10 t/ha of farm yard manure, a mixture of partially decomposed cow dung and poultry droppings (obtained from (layers' pen) and organic fertilizer (Sunshine organic fertilizer) (Table 1). In the unmanured control,

neither organic fertilizer nor manure was applied. Treatments were manual clearing alone (MC), manual clearing + organic fertilizer (MC + OF) and manual clearing + organic manure (MC + OM) there was an unamended herbicide – based zero tillage (Herb-Sd), herbicide - based bush clearing method + organic fertilizer (Herb-Sd + OF) and herbicide – based zero tillage + organic manure (Herb-Sd + OM). The plant material from manual clearing with the cutlass simply left on the soil surface where cut.

The site of the experiment (23 x 14 m) was divided into plots of 3 m x 4 m in dimension. There were 1 m guard rows between blocks and 1 m between sections. Sunflower seeds obtained from the University of Agriculture, Abeokuta were planted on the 16th October, 2009 and 24 the April, 2010 respectively at four seeds per hole. Seeds were sown at a spacing of 60 cm and 60 cm manually. Two weeks after planting, the plants were thinned to two plants per stand. Subsequent weeding was carried out at 3 and 7 weeks after treatment application.

2.3 Determination of Soil Properties

Composite surface (0 – 15 cm soil depth) samples were taken from treatment replicates and were subjected to routine laboratory analysis. Particle size analysis was determined by hydrometer method using 50 g of 2 mm sieved air-dried soil dissolved in water in a 200 ml beaker and poured into sedimentation cylinders. Soil samples were collected from the field using core samplers (8.5cm diameter by 8.5 cm deep) and five samples were collected from each treatment replicate (a total of 15 samples per treatment). Fortnightly starting from 2 weeks after planting (WAP), soil temperature and soil moisture content were monitored. Soil temperature was measured at 3.00pm at 5 cm depth using soil thermometers. Soil moisture content expressed in percentage was determined using gravimetric method (oven-dried soil samples at 105ºC for 24 hours) at soil depth of 10 cm. Composite soil sample was collected, air- dried and sieved using a 2 mm sieve for the determination of pH, organic matter content, nitrogen (N), phosphorous (P), potassium (K), calcium (Ca) and magnesium (Mg). The pH of the soil was determined in 1:1 water suspension by adding 10 ml distilled water to 10 g of soil and read on pH meter. The organic matter content was determined using dichromate oxidation method [39,26]. Total N was determined using micro- Kjeldahl procedure [19] and the available P was extracted using Bray- P- 1 extraction [9] and read on spectrophotometric device. Exchangeable cations K, Ca and Mg were extracted using 1:1 ammonium acetate at pH of 7, K was determined on flame photometer while Ca and Mg were determined using the EDTA filtration method.

2.4 Soil Microbial Population

Fresh and moist soil samples were taken from the treatment plots for microbiological determinations. Measurements of total microbial population were carried out using the standard plate count techniques. Bacterial counts were determined using nutrient agar (NA) while fungi were determined with potato dextrose agar (PDA). One gram (1g) portion of each of the soil samples were aseptically transferred separately into the sterile sample bottles containing 20 ml of sterile distilled water and mixed to form homogeneous suspension. An aliquot (1ml) of the sample suspension was pipette into sterile distilled water and serially diluted to ratio of 10^{-6}. The aseptically pipetted separately into different sterile Petri-dishes and thoroughly mixed with 20 ml of the cool (45ºC) molten agar media (NA & PDA), and the NA plates for were incubated at 37 ± 2ºC for 24 hours while PDA plates were incubated at 27 ± 2ºC for 48 hours. The colonies forming of bacteria and fungi formed were counted.

2.5 Growth and Yield Parameters of Sunflower

Sunflower growth parameters were taken at 50% flowering when much of the growth processes had ceased and thus represented maximum possible value per plant [37] while yield parameters were determined five weeks after spearing (flower opening) as suggested by [29]. The following growth parameters measured included plant height measured as the distance from the ground level to the base of the receptacle when the plants had attained physiological maturity (change in the colour of the backs of the heads from green to lemon yellow). Stem girth was measured using a string wound round the stem just above the ground level and later measuring it out on a ruler.

Leaf area per plant was determined using the non – destructive method of the equation of Reddy et al. (1995)

$$Y = 628 + 0.514nx \quad (1)$$

where, y is the leaf area per plant, x is the leaf area of the specific leaf (for instance 8^{th} leaf), obtained by multiplying the total number of leaves per plant (n) by 0.355 while 'n' is the total number of leaves per plant.

Agronomic characters of root and shoot biomass, plant height, leaf area, number of leaves, yield and yield components were measured. Ten plants were randomly sampled from the middle rows of each plot at 12 weeks after planting (WAP) for the determination of root and shoot dry matter yields for oven-dried fresh biomass at 80ºC for 48 hours. Plant height, number of leaves per plant and stem girth were determined at 12 WAP. Root samples were collected using core samplers d from soil at the base of plant. The roots were separated from soil using moderate jets of water. Harvested heads were threshed and seed yield was taken and expressed in t ha^{-1}.

2.6 Statistical Analysis

Data collected were subjected to analysis of variance (ANOVA) for a split – plot experiment (Genstat, Professional edition). Significant treatment means were separated using the Least Significance Difference (LSD) test at 5% level of probability.

3. RESULTS

Table 2 presents the results of soil analyses (physical and chemical properties) before the commencement of the experiments in 2009 and 2010. The soil at the site of the experiment is sandy loam. The soil is low in total nitrogen, available phosphorus and calcium. However the soil organic matter content was high for both seasons. There is variation in soil pH from slightly alkaline in the late season to slightly acidic in the early season.

Table 1. Nutrient composition of the organic manures applied

Treatments	Organic matter (%)	Nitrogen (%)	Phosphorus (%)	Calcium (%)	Magnesium (%)	
Sunshine organic fertilizer	41	0.58	1.72	9.1	3.8	5.3
Farm yard manure	70	0.53	1.40	7.4	2.8	4.0

Table 2. Pre-planting soil physical and chemical properties of site of experiment (2009 and 2010)

Soil properties	2009 experiment	2010 experiment
Sand (%)	58	54
Silt (%)	16	16
Clay (%)	27	30
Textural Class	Sandy loam	Sandy loam
Total Nitrogen (mg/g)	0.20	0.49
Organic matter (mg/g)	3.59	4.36
Available P (mg/kg)	6.04	7.78
Exchangeable K (cmol/kg soil)	0.39	0.60
Exchangeable Ca (cmol/kg soil)	2.32	3.20
Exchangeable Mg (cmol/kg soil)	0.95	1.0
pH (water)	7.34	5.20

3.1 Effect of Bush Clearing Methods on Soil Physical Properties

The effects of the bush clearing methods on soil temperature are presented in Fig. 1. Non significant differences were obtained in soil temperatures between bush clearing methods alone and in combination with farmyard manure and organic fertilizer across all sampling dates (Fig. 1). However, higher soil temperatures (30ºC) were recorded under herbicide-based bush clearing seedbeds compared with clearing using cutlass. In the manured plots, lower soil temperatures (29ºC) were attained over unmanured plots. The effect of bush clearing methods and manure on soil moisture status is shown in Fig. 2. At the beginning of the growing season (September), soil moisture content was higher possibly from the late rains of the second modal rainfall pattern which terminated about November. Non-significant differences in soil moisture contents (0-15 cm depth) were obtained among the treatments across the sampling dates (Fig. 2). In the manured plots, higher soil moisture contents were obtained on most sampling date. There were, however, small differences in soil moisture contents between bush clearing methods alone and in combination with manure.

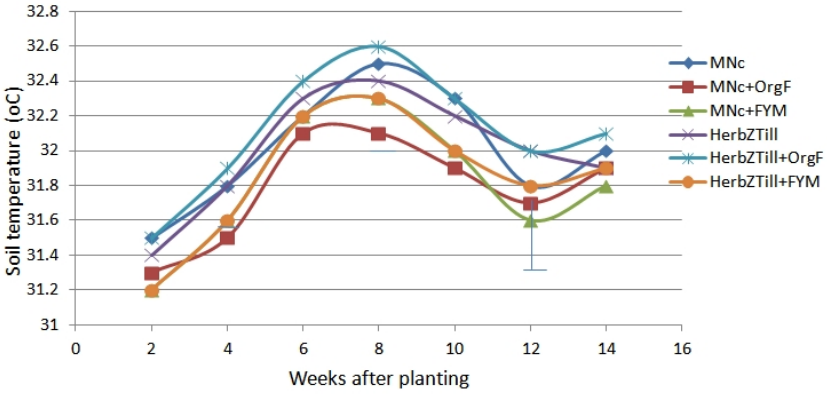

Fig. 1. Effect of bush clearing methods and organic amendment on soil temperature under sunflower

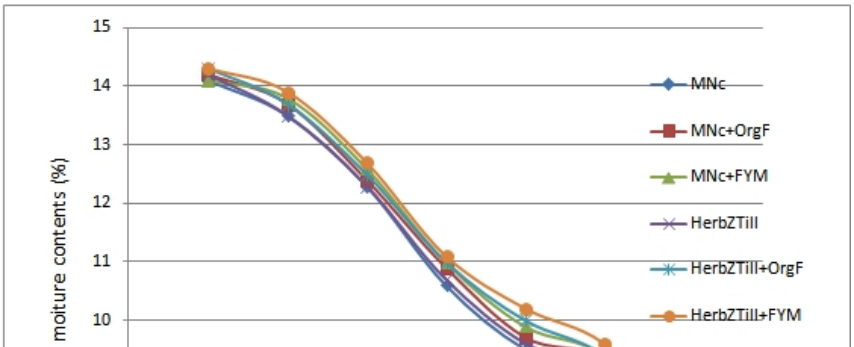

Fig. 2. Effects of bush clearing methods and organic amendment on soil moisture contents under sunflower

MNc: Manual Clearing; MNc+OrgF: Manual Clearing+ Organic Fertilizer; MNc+FYM: Manual Clearing+ Farmyard Manure; Herb-Sd: Herbicide-based clearing Herb-Sd +OrgF: Herbicide-based clearing + Organic Fertilizer; Herb-Sd +FYM: Herbicide-based clearing + Farmyard Manure.

3.2 Effect of Bush Clearing Methods and Organic Amendments on Soil Chemical Properties

The results of the chemical analysis of surface soil (0 – 20 cm) for 2009 and 2010 experiments are shown in Tables 3. Herbicide-based bush clearing method produced higher values of soil organic carbon, nitrogen, phosphorus and magnesium in 2009 experiment while manual clearing recorded higher values of these soil nutrients in 2010. Application of

manure greatly increased pH, soil organic carbon, magnesium, phosphorus and total nitrogen in both 2009 and 2010 experiments. In general, soil nutrient concentrations were higher in manured than unmanured (control) plots. Soil nutrient contents of the manually – cleared plots amended with organic fertilizer or farm yard manure were higher than amended herbicide-based zero tillage plots in 2010. The highest soil nitrogen content was recorded in herbicide–based zero tillage plus organic manure in 2009 while manual clearing plus organic fertilizer recorded the highest nitrogen content in 2010. Application of organic manures improved soil pH, organic matter, phosphorus, magnesium, potassium and calcium contents. Higher values of these parameters were recorded where bush clearing method was combined with application of manure. In particular, higher organic matter contents were produced by herbicide- based zero tillage plus organic manure.

3.3 Effects of Bush Clearing Methods and Organic Amendments on Bacterial and Fungal Populations in Soil

The results of the effects of bush clearing methods and manure application on soil microbial populations in the surface soil (0 - 20 cm) in 2009 and 2010 are shown in Tables 4. Manual clearing produced the highest bacterial population compared to Herbicide – based zero tillage whereas the highest population of fungi was recorded on Herbicides – based zero tillage plots. The effects of bush clearing methods were not significant ($P > 0.05$) on either soil bacteria or fungi populations. There were differences in the population of fungi and bacteria among the treatments. Application of organic manures to the bush clearing methods (manual clearing and herbicide-based) enhanced populations of bacteria and fungi, in particular, bacteria counts were highest under organic manure treatment.

3.4 Effect of Bush Clearing Method and Organic Amendments on Growth Characters of Sunflower

Tables 5 present responses of growth parameters of sunflower to bush clearing methods and organic amendments. The highest values of stem girth and leaf area were recorded for herbicide – based treatments in both experiments. However, there were no significant ($P > 0.05$) differences between the growth parameters in 2010 experiment. Farmyard manure application enhanced sunflower growth in terms of plant height, leaf area, number of leaves and leaf area over unmanured control. Plants in the herbicide treated plots that received organic fertilizers recorded the highest value of stem girth and leaf area in 2009.

3.5 Effects of Bush Clearing Methods and Organic Amendments on Yield Components of Sunflower

The effect of bush clearing methods and organic amendments on yield components of sunflower are presented in Table 6. Herbicide–based bush clearing method produced the highest value of head diameter, seed weight, seed yield, root and shoot biomass in 2009. In 2010, the least values of head diameter and shoot biomass were recorded on herbicide – based bush clearing method. Seldom did differences in values of measured parameters attain significance level between manual clearing and herbicide-based bush clearing method even following organic amendments. However, the highest values of root and shoot biomass, seed weight per plant and total seed yield were obtained from plots amended with organic fertilizers in both experiments. The lowest values of shoot and root biomass were obtained for the un-manured manual clearing and herbicide-based bush clearing plots compared with manured seedbeds.

Table 3. Effect of bush clearing methods and organic amendments on soil chemical properties under sunflower (*Helianthus annuus* L.) in 2009 (a) and 2010(b)

(a)

Treatment	pH (H_2O)	Organic Matter (mg g^{-1})	Total N (mg g^{-1})	P (mg/kg)	K (cmol/kg)	Ca (cmol /kg)	Mg (cmol/kg)
MC	5.60	3.30	0.17	4.03	0.28	1.80	0.70
MC + OF	5.80	3.80	0.19	5.90	0.35	2.00	1.10
MC + FYM	5.80	4.00	0.21	6.10	0.38	2.30	1.20
Herb-Sd	5.60	3.20	0.18	4.06	0.29	1.80	0.80
Herb-Sd +OF	5.70	3.90	0.20	6.40	0.39	2.20	1.40
Herb-Sd+FYM	5.70	4.20	0.21	6.60	0.43	2.50	1.70
LSD (0.05)	0.23	1.11	0.08	1.24	0.06	0.22	0.07
(b)							
MC	5.15	4.10	0.47	5.00	0.51	2.90	1.11
MC + OF	5.30	4.44	0.59	6.92	0.58	3.62	1.30
MC + FYM	5.05	4.18	0.54	7.89	0.62	3.58	1.35
Herb-Sd	4.97	3.79	0.41	5.28	0.50	2.89	1.00
Herb-Sd +OF	5.06	3.86	0.42	6.78	0.61	3.50	1.28
Herb-Sd+FYM	5.07	4.54	0.52	7.02	0.64	3.68	1.34
LSD (0.05)	0.31	1.04	0.11	1.46	0.09	0.71	0.05

Legend: MC = Manual clearing alone, MC + OF = Manual clearing plus organic fertilizer, MC + FYM =Manual clearing plus organic manure, Herb-Sd = Herbicide – based bush clearing alone, Herb-Sd + OF =Herbicide –based bush clearing plus organic fertilizer, Herb-Sd + FYM =Herbicide –based bush clearing plus organic manure

Table 4. Effect of bush clearing methods and organic amendments on bacterial and fungal populations in soil under sunflower in 2009 (a) and 2010(b)

(a)

Treatments	Bacteria(cfu) (transformed)	Fungi(cfu) (transformed)
Manual Clearing	3.2	2.4
Manual Clearing+ Organic Fertilizer	3.9	2.5
Manual Clearing+ Organic Manure	4.2	2.7
Herbicide-based bush clearing	3.7	2.8
Herbicide-based bush clearing + Organic Fertilizer	4.0	2.3
Herbicide-based bush clearing + Organic Manure	4.1	3.0
LSD (0.05)	0.5	0.2
(b)		
Manual Clearing	3.7	2.8
Manual Clearing+ Organic Fertilizer	4.4	3.0
Manual Clearing+ organic Manure	4.7	3.0
Herbicide-based bush clearing	4.0	2.7
Herbicide-based bush clearing + Organic Fertilizer	4.2	2.9
Herbicide-based bush clearing + Organic Manure	4.4	3.2
LSD (0.05)	0.4	0.1

Table 5. Effects of bush clearing methods and organic amendments on growth characters of sunflower in 2009 (a) and 2010 (b)

(a)

Treatments	Plant height (m)	Leaf area (m^2)	Stem girth (cm)	No. of leaves
Manual Clearing	1.18	0.70	2.30	4.18
Manual Clearing+ Organic Fertilizer	1.21	1.00	2.70	4.31
Manual Clearing+ Organic Manure	1.23	1.20	2.60	4.28
Herbicide- based bush clearing	1.20	0,80	2.50	4.21
Herbicide-based bush clearing + Organic Fertilizer	1.25	1.40	2.80	4.31
Herbicide-based bush clearing + Organic Manure	1.23	1.70	2.60	4.29
LSD	0.07	0.10	0.07	0.17
(b)				
Manual Clearing	1.07	1.25	1.86	4.23
Manual Clearing+ Organic Fertilizer	1.08	1.51	2.00	4.34
Manual Clearing+ Organic Manure	1.09	1.47	2.03	4.48
Herbicide-based bush clearing	0.96	1.28	2.21	4.25
Herbicide-based bush clearing + Organic Fertilizer	1.10	1.56	2.18	4.29
Herbicide-based bush clearing + Organic Manure	1.08	1.54	2.10	4.38
LSD	0.89	0.83	0.73	0.56

Table 6. Effects of bush clearing methods and organic amendments on yield components of sunflower in 2009 (a) and 2010 (b)

(a)

Treatments	Root dry weight (g/plant)	Shoot dry weight (g/plant)	Head diameter (cm)	Seed weight (g/plant)	Seed yield (t/ha)
MC	12.10	24.40	13.30	30.20	2.15
MC + OF	13.50	30.60	14.40	34.10	3.37
MC +OM	13.30	29.30	14.10	32.40	3.32
Herb-Sd	12.30	25.60	13.50	30.50	2.54
Herb-Sd + OF	13.80	32.40	14.60	34.60	3.43
Herb-Sd + OM	13.50	31.20	14.30	33.80	3.36
LSD (0.05)	0.34	3.32	0.45	1.15	0.61
MC	10.20	18.58	12.30	12.98	1.08
MC + OF	13.11	29.38	14.53	30.79	2.57
MC + OM	10.71	23.38	13.00	22.67	1.89
Herb-Sd	10.40	20.53	10.35	24.61	2.06
Herb-Sd + OF	11.37	20.58	14.48	31.61	2.63
Herb-Sd + OM	13.30	29.18	12.70	29.25	2.43
LSD (0.05)	7.01	16.40	3.60	17.26	0.53

Legend: MC = Manual clearing alone, MC + OF = Manual clearing plus organic fertilizer, MC + FYM =Manual clearing plus organic manure, Herb-Sd = Herbicide – based bush clearing alone, Herb-Sd + OF =Herbicide –based bush clearing plus organic fertilizer, Herb-Sd + FYM =Herbicide –based bush clearing plus organic manure

4. DISCUSSION

Bush clearing methods involving manual clearing and herbicide-based zero tillage and organic manure and organic fertilizer application affected soil physical, chemical and biological properties, growth and yield of sunflower. The bush clearing methods and organic amendment affected soil temperatures and moisture contents at the different dates after planting sunflower (Fig. 1). In general, moisture content (Fig. 2) increased slightly while temperatures reduced in organically-amended soils. Soil moisture contents improved following decreases in soil temperature in organic-manured plots. These results are consistent with the reports in literature [1,4,7]. These authors reported the effect of manuring on soil moisture conservation and reduction in soil temperature regimes. The lower soil moisture contents observed from unmanured plots have resulted from increased soil moisture evaporation due to high soil temperatures. Seedbed preparation methods adopted in this study brought about least soil disturbance of the soil. This observation is consistent with the recommendation of [30] that simple tillage methods sustain the productivity of tropical soils.

Application of organic manure or organic fertilizer improved soil properties and status of soil nutrients presumably due to their high contents of nitrogen. Organic manure is a source of soil organic carbon, a potentially mineralisable nutrient. It is evident from the study that when fallow vegetation was cleared or cultivated, the pattern of changes in soil conditions varied with methods of seedbed preparation adopted. It was observed that the soil nutrient composition under the various bush clearing methods varied the seedbed management. Herbicide-based zero tillage that higher soil nutrients values might be due to the ability to conserve soil nutrients, favourable temperature and moisture regime, and increased activity of beneficial soil fauna as observed by [30].

In the 2010 experiment, manually-cleared plots had higher soil nutrient contents than the herbicide–based zero tillage. This may be attributed to the faster decomposition of the cleared plant residues while differences in magnitudes of growth and seed yield characters between sowing dates (October-January and April-July) might be due to variations in environmental factors: light intensity, temperature and soil moisture during the seasons, and possibly differences in water and nutrients within soil profile. This agrees with the finding of [24] that N releases associates with climatological characteristics of a region. At the beginning of the April-July sowing season, rainfall is erratic and less, coupled with high soil and air temperatures, which constitutes more stressful environment for sunflower [5].

The pH of surface soil (0 – 15 cm depth) was low, and this was less for herbicide–based zero tillage compared with manually cleared soil. The decline in pH might be attributed to low value of calcium. This was in line with the findings of [3]. The soil at the site of the experiment had low calcium content (Table 2) and improvements in the soil pH, calcium and N in response to application of organic manure were obtained. Nottidge et al. [27] reported that Alfisols are low in organic matter, N, P and exchangeable cations. Despite the relatively high SOM content it is expected that sunflower grown in the study area would still benefit from amendments such as organic manure and organic fertilizer in order to attain optimum productivity.

Organically amended plots showed increases in organic carbon, and N compared to unmanured plots, based on the fact that organic manures are sources of N and carbon to soil. The increases on the contents of soil nutrients to manured plots is consistent with the

findings of [12,21,8]. These authors obtained increases in the contents of soil organic carbon, organic matter, N and exchangeable cations following livestock manure application. Soil microbial population increased under organic and organic fertilizer application compared to control plots. Addition of organic manures are known to increase the population and activity of microbial populations. Bolton et al. [10] reported increases in microbial counts in response to fertilization. In general, bacterial population was higher than fungal population in the top soil (0-20 cm). This agrees with the findings of [32], who reported that cattle manure application promoted the growth of bacteria and not fungi. This was partially attributed to changes in soil pH in the manure - treated plots. Frostegard et al. [17] and [33] showed that increased soil pH in the acidic range caused a shift towards dominance of the bacterial community while fungal communities were unaffected.

The increases in bacterial population might be due to increase in soil organic carbon following manure application. This agrees with the findings of [16] that livestock or green manuring on organic farms provided a greater input of organic carbon, resulting in increases in soil bacterial populations. In this study, the enhanced biological activities in the manure treated plots are evidenced by relatively high carbon content. Organic manuring promoted microbial activities which can accelerate breakdown of organic substances from the added manure. This findings corroborate previous studies which showed that incorporation of organic manure increased activity, diversity and densities of soil microbes bacteria [15,20].

In this study, it was observed that application of manure in combination with bush clearing improved sunflower growth and yield characters over manual clearing alone. This observation could be attributed to the favourable soil nutrient status created by the use of farmyard manure and organic fertilizer. Irrespective of bush clearing methods, organic manuring improved soil nutrient status, the growth and yield of sunflower.

Sunflower growth and yield characters differed with type of bush clearing methods adopted. Herbicide – based zero tillage plus farmyard manure was the most productive in terms of soil fertility and sunflower performance. The treatment improved soil nutrients status and microbial population compared with herbicide - based zero tillage plus organic fertilizer and manual clearing plus organic fertilizer. Application of herbicide-based zero tillage plus organic fertilizer recorded the highest sunflower yield in terms of head diameter, seed yield and seed weight compared with herbicide–based zero tillage plus farmyard manure application. This confirmed previous studies by Agele et al. [4] that sunflower performance was not limited by nutrient availability and that the crop is hardy to both soil moisture and nutrient status ([6].Bush clearing–manure combination improved soil chemical and biological conditions and had additive effects on growth and yield of sunflower in this study. Herbicide–based zero tillage combined with organic fertilizer application in the 2009 and 2010 experiments respectively, produced 3.43 and 2.63 $t.ha^{-1}$ and 3.37 and 2.57 $t.ha^{-1}$ seed yield under manual clearing plus organic fertilizer.

5. CONCLUSION

Bush clearing methods involving manual clearing and herbicide–based zero tillage and organic manure and organic fertilizer application affected soil quality (physical, chemical and biological properties) parameters and the growth and yield of sunflower in this study. The results showed that herbicide–based bush clearing method was the most productive in terms of soil properties; this treatment produced increased carbon and soil microbial populations. Organic manure and organic fertilizer application improved soil nutrient status presumably due to the high contents of organic matter and other nutrients. Organic amendments and

herbicide–based zero tillage had positive effects on soil and sunflower productivity. Improvements in growth and yield parameters of sunflower were obtained from organic manure-amended herbicide–based bush clearing method compared with organically amended manually cleared plots. Manuring was favourable for soil productivity, the short term changes reported is closely related to the key contribution of manure in terms of nutrients. Since herbicide–based bush clearing method plus organic fertilizer produced higher seed yields in both experiments this practice is recommended for sunflower production in the study area. The results supported earlier reports from the literature on the benefits of herbicide-based bush clearing method to crop productivity (expanded hectarage and increased yield). However, organic manure use along with herbicide-based bush clearing can contribute to improvements in soil health across time in addition to reduced costs of fertilizers. The results of this study may impact sunflower production in Nigeria where sunflower is not currently widely grown. The results also emphasize the inclusion of sunflower into the Nigerian cropping system.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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