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ECONOMIC ASSESSMENT OF TILLAGE PRACTICES ON PRODUCTIVITY OF COWPEA IN ILE IFE, NIGERIA

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Abstract

Tillage is one of the major threats to soil health which often results into soil physical degradation if not properly manage. Zero tillage was an alternative option from both economic point of view and environmental protection of our invaluable soil resources. The goal of the present scientific paper is to evaluate the response of different tillage systems and evapotranspiration on productivity of cowpea (*Vignaunguiculata*)*in Nigeria. The research was conducted in Obafemi Awolowo University, Ile-Ife Osun State, Nigeria. The research used replicated randomized complete block design with treatments consisting of Zero-tillage (ZT), Reduced tillage (RT), Conventional tillage + Mulch (CT + ML) and Conventional tillage (CT). Exchangeable cations (Ca^{2+}, Mg^{2+}, K^+ and Na^+) were extracted with neutral solution of 1.0 M NH_4OA_C.. The K^+ and Na^+ concentrations in the extract were determined using the flame photometer while Mg^{2+} and Ca^{2+} were determined using the atomic absorption. Actual evapotranspiration (ET_a) was estimated using the soil water balance approach. Cowpea production on sandy loam top-soil can be optimally produced on Zero tillage system. Considering the profit over two years and the relative energy requirements, ZT system resulted in recording $ 573 profit, which was the highest profit margin among the treatments considered over the two growing seasons, RT ($ 89) had the least value.*

Key words: *tillage, volumetric moisture content, crop productivity, soil penetration resistance, evapotranspiration*

INTRODUCTION

Management of soil tillage affects soil respiration, temperature, water content, pH, oxidation-reduction potential, and, available microorganisms [17]. Poor tillage practices could have detrimental effects on the physical, chemical, and biological properties of soils. In most farming communities, poor tillage directly affects soil aggregate, temperature, water, infiltration and retention [11]. These effects go beyond crop productivity and sustainability [19], emissions of greenhouse gas [32], deformation of soil structure and carbon (C) sequestration [12, 10]. Intensive tillage over a long period of time caused soil degradation, compaction, and loss of soil and soil organic matter (SOM) in many agroecological areas around the world. Good soil management practices, therefore, protect soil from water and wind erosion, as well as, provision of a good and weed-free seedbed for planting. It also destroys soil hardpans and compacted layers that could limit root development and maintenance, and increase organic matter content [35]. Cowpea is a plant that provides nitrogen to the soil system through N_2 fixation hence enriches itself with protein with or without external application of mineral nitrogen fertilizers [30]. The crop plays a vital role in the livelihood of many people dwelling in the developing world [9], being a rich source of protein and carbohydrates with high nutritive values [8, 34]. Apart from being a component of the conventional cropping systems in crop rotation plans, it is well suited to dry conditions owing to its adaptive capacity to various environmental stresses where other crops grow abnormally [7]. Soil physical quality is the capacity of a given soil to meet plant and environmental demands for necessities of water and aeration over time and to resist processes that might decrease that capacity [21]. Deterioration of soil physical property is facing unprecedented degradation under continuous land use and fast economic growth into agricultural lands thereby posing a threat to resource sustainability in Ile-Ife, Nigeria and other developing countries. There are three major crucial, and interdependent aspects of soil that affect crop productivity, these are biological, chemical and physical health. However, most times, soil's physical properties are given little or no attention while much attention is often given to the chemical and biological conditions. For instance, many commercial farmers use heavy farm machineries for land preparation without prior knowledge of the adverse effects of such practiceon soil quality [4]. This practice consequently has led to the removal of the productive topsoil and exposes sub-soils to further degradation. The suitability of soil for sustaining plant growth and biological activity is a function of its physical properties [14]. Various reports on soil degradation [26, 5, 3] indicated that plough and harrow are among the heaviest machines used for farming operations. The effects of these farm implements on selected physical and chemical soil properties were not encouraging. Information on response of cowpea to different tillage practices in African countries particularly Nigeria is very scarce. In this study, four tillage practices were studied in cultivating cowpea under rainfed conditions. The main aim of the study was to determine the effects of tillage practices on grain yields of cowpea in relation to economic value in Ile-Ife, south west Nigeria.

MATERIALS AND METHODS

Site Description

Field trials were conducted at the Teaching and Research Farm, Obafemi Awolowo University Ile-Ife, Nigeria (N 7° 31' E 4° 33') Nigeria with 244 m above mean sea level (a.s.l.), in 2018 and 2019. It is located in tropical rain forest, of Nigeria. Total annual rainfall in the study area is about 1,350 mm with a bimodal pattern typical of humid South of Nigeria.

The first cycle occurs from March and July while the second occurs from September and November.The average daily minimum temperature ranged between 20°C and 22°C and the average maximum temperature between 27°C and 35°C. The experimental site was under vegetation fallow for three years before the experiment started and guinea grasses dominated the bush where the investigation was conducted. The soil was deep, well drained and underlain by coarse grained granite gneisses bedrock. The soil is locally classified as Iwo series [31] and as an Alfisol [25].

The soil at the site is characterized by brownish gray colour with the surface texture varying from sandy loam to loamy sandy at sub-surface surface [31].

Experimental Design and Layout

The experiments were conducted during the 2018-2019 for two consecutive rainy seasons on a gentle slope field (< 1 %).

The treatments consisted of four tillage practices: Zero Tillage (ZT), Reduced Tillage (RT), Conventional Tillage + Mulching (CT + ML), Conventional Tillage (CT), (Table 1).

They were arranged in a randomized complete block design in triplicate. The ZT and RT are the predominant practices by most of resource-constrained farmers in sub-Saharan Africa (SSA) who do not use much fertility inputs and lack of access to funds [36].

The CT and CT + ML represent the practices of the few resource-endowed farmers in SSA who can afford the cost involved and are located in high potential farming areas similar to the experimental site.

In order to have a fully replicated experiment for CT+ML, mulch was applied three weeks after ploughing and harrowing.

Table 1. Treatments and description

Treatment	**Description**
Zero Tillage (ZT)	Plots were sprayed with mixed herbicides containing the active ingredient of dimethyl 2.4-D amine and Paraquat dichloride which each concentration was 825 g/L and 297 g/L. The dosage used was 30 ml of dimethyl amine herbicide active ingredient mixed with 14 liters of water and 450 ml mixture of herbicide active ingredient herbicide Paraquat dichloride in the Knapsack sprayer.
Reduced Tillage (RT)	First plough (tillage depth of 12.5 cm) + spraying with herbicides containing the active ingredient dimethyl 2.4-D amine which concentration was 297 g/L. The dosage used was 30 ml of dimethyl amine herbicide active ingredient mixed with 14 liters of water in the Knapsack sprayer.
Conventional Tillage + Mulching (CT + ML)	Ploughed twice (tillage depth of 12.5 cm) + harrow (tillage depth of 12.5 cm) + mulch (7.5 t/ha Guinea grass (*Panicum maximum* grass residue)
Conventional tillage (CT)	Ploughed twice (tillage depth of 12.5 cm) + harrow (tillage depth of 12.5 cm)

Source: Explanation of the Treatments.

Early maturing cowpea variety, (IT89KD-288, 56-63 days) obtained from the International Institute of Tropical Agriculture (IITA), Ibadan, was planted on 21st September 2018 and 30th of August, 2019 at a target approximate population of 133,333 per ha (0.5 m x 0.30 m, two seeds per hole).

Weeds were controlled manually by using a local hand hoe and by hand picking. Cypermethrin, a pyrethroid compound was used to control insect fortnightly manually. Cypermethrin was applied 2 weeks after planting to control insects. Cypermethrin, was applied starting at two (2) weeks after sowing during cropping seasons and was repeated for four times consecutively.

The surface and subsurface soil layer, i.e. (0–15 and 15-30 cm) of the soil profile, were sampled because these layers control many critical and environmental processes, including seed germination and early seedling growth.

Soil Sampling and Laboratory Analysis

Soil samples were collected before land preparation to quantify the baseline status of the soil before the trial. Ten composite samples (0-15 cm soil depth) were taken randomly from the experimental site and bulked for laboratory analyses. This same process was repeated for 15-30 cm soil sample, before commencement of the experiment in the year 2018. The soil samples were air-dried at room temperature for some days and later crushed and sieved using 2 mm sieve before analysis. Chemical and physical soil analyses were carried out (Table 2).

Table 2. Physical and chemical properties of the experimental site prior to sowing cowpea

Parameters	**Depth (cm)**	
	0-15	15-30
pH1:1 (Soil: Water)	6.39	6.31
Exchangeable cations (meq. 100 g^{-1})		
Exchangeable Ca	0.95	0.93
Exchangeable Mg	0.34	0.30
Exchangeable Na	0.89	0.61
Exchangeable K	0.51	0.36
Hydrogen ion (H^+) (meq. 100 g^{-1})	0.32	0.46
Cation exchange capacity (CEC)	2.69	2.20
Effective cation exchange capacity ECEC (meq. 100 g^{-1})	3.01	2.66
Total Nitrogen (%)	0.25	0.28
Soil particle size distribution (%)		
Clay	11.6	11.6
Silt	8.72	6.72
Sand	79.68	81.68
Textural class	Sandy loam	Loamy Sand

Source: Data from Laboratory.

Soil pH was determined with a glass electrode pH meter in distilled water using 1:1, soil: water [33]. Total nitrogen was determined by the macro-Kjeldahl method [6]; available phosphorus was extracted with Bray-1 P solution by the molybdenum blue method on Technicon auto analyzer as modified by [24].

Exchangeable cations (Ca^{2+}, Mg^{2+}, K^+ and Na^+) were extracted with neutral solution of 1.0 M NH_4OA_C. The K^+ and Na^+ concentrations in the extract were determined using the flame photometer while Mg^{2+} and Ca^{2+} were determined using the atomic absorption spectrophotometer (AAS). The exchangeable acidity (H^+) was extracted using 1.0 M KCl [28]. Aliquot of the extract was titrated with 0.05 M NaOH to a permanent pink endpoint using phenolphthalein as indicator. The amount of NaOH used was taken to be equivalent to the total amount of exchangeable acidity in the aliquot taken [22]. Cation exchange capacity (CEC) was estimated by the summation of exchangeable bases [13]. Particle size analysis was determined by hydrometer method [23].

Evapotranspiration

Actual evapotranspiration (ET_a) was estimated using the soil water balance approach [1, 16] in Equation (1).

$$ET_a = P - RO \pm \Delta S - D \qquad (1)$$

where:
P is rainfall (mm);
RO is Runoff (mm);
ΔS is change of soil water storage in the root zone from 0 to 60 cm;
D is drainage (mm).

Surface runoff within area of 1 m^2 in the replicates was channeled to a graduated plastics container and measured after each rainfall. Drainage was determined from the soil moisture content measured at regular intervals.

Water productivity

Seasonal water productivity was determined using the Equation (2).

$$WP = \frac{Y}{ET_a} \qquad (2)$$

where:
Y is marketable yield (t ha^{-1});
ET_a is actual crop evapotranspiration (mm).

Yield of cowpea

At physiological maturity, the cowpea pods within each plot were harvested and threshed manually and the seeds yield per plot were estimated. Grain yield was moisture corrected to 12.5 %.

Statistical Analysis

The data collected were subjected to analysis of variance (ANOVA) using SAS to assess treatments effects of tillage practices on crop yield. Differences between means were separated by using Duncan Multiple Range Test ($p = 0.05$) [27].

RESULTS AND DISCUSSIONS

Chemical and physical properties of the soil prior to cultivation

The soil pH (water) for 0-15 cm soil depth was 6.39 while that of 15-30 cm soil depth was 6.31 (Table 2). The soil was slightly acidic and can support the optimal growth of cowpea [29]. Such pH levels can substantially affect the availability of nutrients through its effect on soil microbial activity [2]. The cation exchange capacity (CEC) of the top and sub-soil with values of 2.69 and 2.20 meq.100 g-1 respectively. Total N of top soil (0.25 %) and sub-soil (0.28 %) were above the critical value of 0.11 %. Total Nitrogen was generally sufficient in the soil samples [15]. The percent sand in 0-15 cm soil depth was 79.68 while the sand content in 15-30 cm soil depth was 81.68 %. Silt was 8.72% at the top soil and 6.72 % at the sub-soil (Table 2). The soil texture for both top and sub soil was stated in Table 2.

Evapotranspiration

There were variations in the seasonal crop water use of the treatments. The total rainfall in the first season was 238 mm and was considerably lower than that of the second season, 775 mm (Table 3).

Table 3. Water productivity for the two growing seasons

Year	Treatment	Yield (kg ha^{-1})	Evapo-transpiration (mm)	Water productivity (kg m^{-3})
2018	CT	210 ± 14^a	166 ± 9^a	0.79 ± 0.02^b
	ZT	172 ± 18^b	181 ± 18^a	1.05 ± 0.11^a
	CT+ML	166 ± 13^b	176 ± 16^a	0.60 ± 0.02^b
	RT	292 ± 9^a	172 ± 11^a	0.53 ± 0.05^b
2019	CT	596 ± 10^a	651 ± 5^a	1.09 ± 0.06^b
	ZT	563 ± 16^a	663 ± 23^a	1.18 ± 0.06^b
	CT+ML	578 ± 18^a	649 ± 12^a	1.12 ± 0.02^b
	RT	384 ± 15^b	650 ± 21^a	1.69 ± 0.08^a

Source: Primary Data: Data gotten from the experimental field.

Note**:** Means within a column (for each treatment factor) not sharing a lowercased italic letter differ significantly at the $P < 0.05$ level.

Hence lower evapotranspiration in the first season compared with the second season. The seasonal evapotranspiration for all the tillage practices were not significantly different in the two seasons despite their variations. In the first season, zero tillage had the highest water productivity while in the second season; minimum tillage had the peak water productivity and was significantly higher than the water productivities of other tillage practices.

The water productivity under CT + ML and RT compares well with). [20]. However, the water productivity for other tillage practices were higher than those in. [20].

The water productivity in the second season was higher and could be attributed to higher seasonal rainfall.

Grain yield

Higher yields were recorded for 2019 growing season for all the treatments (Figure 1).

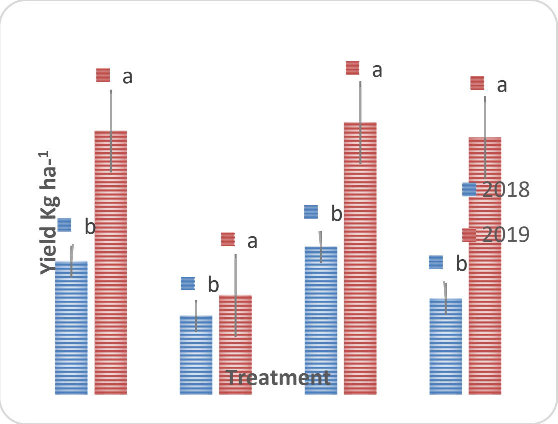

Fig. 1. Mean values of grain yield of cowpea for 2018 and 2019 cropping season in response to different tillage practices
Source: Primary Data: Data gotten from the experimental field.

ZT had an increase of 168 % in the grain yield at the end of second cropping season, the highest among the tillage practices examined, followed by CT+ML (98 %) and CT (84 %); RT had the least increase value of 26 %. In addition, there were significant differences in the cowpea grain yields when the average after two years was considered. The highest (460 kg ha-1) and the lowest (195 kg ha-1) mean values of grain yield for the two seasons were obtained on plots subjected to the CT and RT treatment respectively (Figure 2).

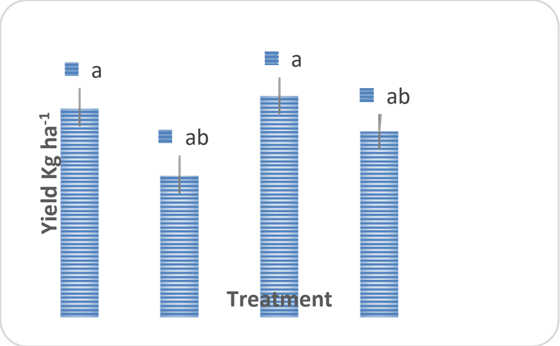

Fig. 2. Mean grain yield of cowpea over the two cropping seasons in response to different tillage practices
Source: Primary Data: Data gotten from the experimental field.

Cost analysis

Table 4 shows that plots subjected to the CT+ ML treatment had the greatest input cost of 221.53 USD during the 2018 cropping season, while plots subjected to the ZT treatment had the lowest input cost of 111 USD Similarly, for the 2019 cropping season, the highest (224 USD) and lowest (113 USD) input costs were obtained on CT+ ML and ZT plots, respectively.

Table 4. Cost analysis of different tillage practices

Treatments	Activities	Cost implication (USD ha^{-1})
CT	2-plough, harrow, manual weeding, cowpea seed, insecticide, harvest	# 77,750.00 (213.30-2018, 215.97-2019)
CT+ML	2-plough, harrow, mulching, manual weeding, cowpea seed, insecticide, harvest	# 80,750.00(221.53-2018, 224.31-2019)
ZT	2 bottles of Herbicides, manual weeding, cowpea seed, insecticide, harvest	# 40,500 (111.10-2018, 112.5-2019)
RT	1-plough, 1 bottle of herbicides, manual weeding, cowpea seed, insecticide, harvest	#56,500(155.00-2018, 156.94-2019)

Source: Primary data.

The CT+ ML treatment had a higher input cost than the ZT treatment because cost of hiring tractors coupled with labor involved in mulching are more expensive in Nigeria than using herbicides.

Because the RT required one tillage operation, the CT had a greater input cost than the RT.

The additional tillage operation raises the energy need of the CT when compared to the RT, in addition to raising the input cost.

The seed yield for a given tillage practice has a direct relationship with the money earned for that tillage treatment [18].

The income analysis for the 2018 and 2019 growing seasons for the various tillage treatments was presented in Table 5. The maximum income for the 2018 cropping season was obtained on CT and CT+ ML plots respectively, at 333.72 and 300.35 USD. Similarly, the greatest revenue of $614 and $595 for the 2019 season was obtained on CT and CT+ ML plots, respectively. Reduced tillage plots had the least income, $177 in 2018, and $223 in 2019 (Table 5).

Table 5. Yield and income of the different tillage practices

Treatments	2018		2019	
	Yield Kg ha^{-1}	(\$ ha^{-1})	Yield Kg ha^{-1}	(\$ ha^{-1})
CT	324	334	596	614
CT+ ML	292	300	578	595
ZT	210	217	563	580
RT	172	177	217	224

Source: Primary Data: Data gotten from the experimental field.

The profit associated with each tillage treatment, which is calculated as the difference between the revenue generated and the input cost was shown in Table 6.

The highest profit earnings of 120 USD were obtained on CT plots for the 2018 while ZT ($468) had the highest earning in 2019 cropping seasons.

The lowest profits of $ 22 and $66.98 for the 2018 and 2019 seasons respectively, were obtained on RT plots (Table 6).

Table 6. Profit margins analysis of different tillage treatments ($ ha^{-1})

Treatments	Income			Cost			Profit		
	2018	2019	Sum over 2 years	2018	2019	Sum 2 years	2018	2019	Sum of over 2 years
CT	335	614	948	213	216	429	120	398	519
CT+ ML	300	595	895	222	224	446	79	371	449
ZT	217	580	797	111	113	223	106	468	573
RT	177	224	401	155	157	312	22	67	89

Source: Primary Data.

CONCLUSIONS

Overall, the ZT had $573, which was the highest among the treatments considered as profit margin over the two years which was the largest profit margin among the treatments considered. This was followed by CT (519 $) and CT + ML ($449), RT ($89) had the least. Therefore, ZT practices should be carefully adopted in sandy loam - loamy sand soils to prevent soil compaction at this depth over time. Considering the profit over two years and the relative energy requirements, ZT with $573, was found to be the most suitable tillage method for the optimum cultivation of cowpea on tropical sandy loam soil. Despite the fact that traditional tillage management approaches have gained a lot of attention in African countries in recent years, more research are needed on a variety of textured soils in various agro-ecological zones in Africa to provide food security at a low cost.

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