

EFFECTS OF TILLAGE METHODS ON SOME PHYSICAL PROPERTIES OF SANDY LOAM SOIL AND SEEDLING EMERGENCE OF COWPEA IN GIREI, ADAMAWA STATE, NIGERIA

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ABSTRACT

An appropriate tillage method is necessary to create an optimum seed bed condition for optimum seed germination. Field experiment was conducted at Modibbo Adama University of Technology, Yola, in the research farm, Department of Agricultural and Environmental Engineering to investigate the effect of different tillage methods on some physical properties (bulk density, moisture content and penetration resistance) of sandy loam soil and early emergence of cowpea in a semi-arid environment. Tillage treatments were Disc Ploughing and Disc Harrowing; Disc Ploughing, Disc Harrowing, and Zero Tillage as a direct drilling method (control). The experiment was laid out in a Randomized Complete Block Design with four replications. The result indicate that zero tillage treatment had the lowest mean moisture content of 46%, bulk density of 1.59g/cm³ with high penetrating resistance of 2.40 Mpa. It was also observed that Disc Ploughing and Disc Harrowing treatment had the highest seed germination number than the other treatments. Results showed that Disc Plough and Disc Harrow was found to be more appropriate and profitable tillage method for improving bulk density, moisture content and penetration resistance in sandy loam soil and germination of cowpea. Statistically, results of the study indicate that the effect of tillage methods on some soil physical properties and seed germination were highly significant at 5% level of significance. It is recommended that the Disc Ploughing and Disc Harrowing tillage treatment be adopted for Cow pea production in the study area.

Keywords: Tillage, Physical properties, emergence, seedling, cowpea, Girei

1 INTRODUCTION

Cowpea (*Vigna unguiculata* L.) is a vital crop that is used as food and animal feed crop grown in the semi-arid and tropics covering Africa, Asia, Europe, United States, Central and South America [1]. In northern Nigeria, depending on location, farmers grow cowpea on zero-tilled and tilled soils with or without ridges. In the humid tropics where most of the farmers are smallholders and chemical fertilizer is scarce and expensive, soil working and tillage methods can be a suitable alternative to enhance nutrient availability to crops [2]. Tillage practices are critical components of soil management systems and it creates an ideal seedbed condition for plant emergence, plant development and unimpeded root growth [3]. Inappropriate tillage practices could inhibit crop growth and yield. Selection of an appropriate tillage practice for the production of crops is a step in realizing optimum growth and yield. A good soil management and tillage practices should protect the soil from water and wind erosion, provides a good seedbed for planting [4]. Resource poor smallholder farmers in sub-Saharan Africa produce cowpea under rain-fed conditions, using different tillage practices. The type of tillage systems employed by these farmers sometime depends on

the availability of labour services and input cost implications. Zero tillage crop production can reduce input costs and labour and conserve the soil. The soil, however, suffers from compaction when not tilled which can negatively affect plant growth. When tilled, crops benefit from the improved looseness, oxygen supplies and water intake. Therefore, this research will evaluate the effects of zero tillage, disc plough, disc harrow and the combination of disc-harrow + plough on some soil physical properties and germination of cowpea and identify the best tillage method suitable for the production of cowpea in the study area.

2 LITERATURE REVIEW

2.1 Tillage

According to [5] tillage is defined as physical, chemical or biological soil manipulation to optimize conditions for germination, seedling establishment and crop growth. In addition, [6] define it as any physical loosening of the soil carried out in a range of cultivation operations, either by hand or mechanized. However, [7] stated that soil manipulation can change fertility status markedly and the changes may be manifested in good or poor performance of crops. In addition, they observed that tillage operations loosen, granulate, crush or compact soil structure, changing soil properties such as bulk density, pore size distribution and composition of the soil atmosphere that affect plant growth. Tillage is a labor-intensive activity in low-resource agriculture practiced by small land-holders, and a capital and energy-intensive activity in large-scale mechanized farming [5]. For any given location, the choice of a tillage practice will depend on one or more of the following factors such as soil, climate, water balance, crop, socio-economic and Government policies [8].

2.2 Bulk Density

Bulk density is the mass of unit volume of soil (Mg/m^3), and the volume includes solids and pores. Sandy soils generally have more pore spaces and lower bulk densities than fine textures soil like silt loams and clay. Soil structure and the degree of looseness or compactness affects bulk density. Bulk density is a factor in the specific heat capacity, thermal conductivity and thermal diffusivity of the soil [9]. According to [10], low bulk densities in soil indicates high organic matter content, good roofing medium while high bulk density show low soil aggregate, inhibited root penetration and low infiltration and permeability. In addition, soil bulk density may vary due to textural differences, organic matter content and cultivation practices. [11] Also noted that increases in soil bulk density were found to result in greater increase in soil strength in coarse textured soil than fine textured soils, while decreasing soil moisture content had a greater effect in increasing soil strength in fine textured soil compared to coarse textured soils. The bulk density of agricultural soils is typically from 1.1 – 1.6 Mg/m^3 and root growth is greatly impaired when bulk density exceeds this range [12]. Agricultural activity has been reported to increase the bulk density and reduce the pore size through compaction of the soil and the resultant loss in the soil structure. Wheel traffic compaction eliminated the effect of tillage on bulk density in a study that compared mold board plowing and conservation tillage on bulk density [13]. Soil compaction from tillage and production activity increases bulk density, reduces water intake, and create perched water tables resulting in less than optimal plant growth conditions [14].

2.3 Moisture Content

Determination of water content in the various soil samples was carried out using moisture meter. A portion of the samples collected was measured at a temperature of 105°C. This is in accordance with the work of [15]. The initial weight of the container W_1 was determined and soil sample was placed on the container and weighed as W_2 . The total weight of soil sample and the container weighted as TW. The moisture content was calculated using the following relation:

$$\text{Mc\%} = \frac{W_2 - W_1}{TW} \times 100 \quad (1)$$

Where; Mc = moisture content, W_1 = weight of container, W_2 = weight of container and sample, TW = Total Weight.

2.4 Penetration Resistance

Penetration resistance is an indicator for the level of compaction of the soil. Compaction limits roots growth and the availability of air and water to the roots [16]. A measure of penetration resistance is calculated by the resistance of a soil to the movement of a penetration cone divided by the penetration distance. The penetration resistance was determined by the following formula [17] as;

$$R = \frac{(N \cdot M \cdot g \cdot SD)}{(A \cdot PD)} \quad (2)$$

Where; R = the penetra on resistance (Pa); N = the number of impacts; M = the mass of the sliding weight (kg); g = the gravity = 9.81 m/s²; SD = the sliding distance of the hammer (m); A = the surface area of the cone (m²); PD = the penetration distance (m)

The surface area of the cone is calculated as:

$$A = \pi \times r \times s \quad (3)$$

Where; A = the surface area of the cone (m²); r = the radius of the cone (m); s = the longitudinal length of the cone (m)

2.5 Cowpea

Cowpea (*Vigna unguiculata*, L. Walp.), an annual herbaceous legume, is widely grown in Africa, Latin America, Southeast Asia and southern United States. It is used as grain crop, for animal fodder, or as a vegetable [1]. Cowpea growth ranges from indeterminate to fairly determinate with the non-vining types tending to be more determinate. Generally, the crop is strongly tap rooted. Root depth has been measured at 3cm for 7days after seeding [18]. Cowpea is a warm-season crop well adapted to many areas of the humid tropics and temperate zones. It tolerates heat and dry conditions, but is intolerant of frost. Germination is rapid at temperatures above 65°C; colder temperatures slow germination [3]. Emergence is epigeal where the cotyledons emerge from the ground during germination. This type of emergence makes cowpea more susceptible to seedling injury, since the plant does not regenerate buds below the cotyledonary node [19]. Cowpeas are grown under both irrigated and non-irrigated regimes. The crop responds positively to irrigation but will also produce well under dry land conditions. Drought resistance is one reason that cowpea is such an important crop in many underdeveloped parts of the world. If irrigation is used, more vegetative growth and some delay in maturity may result. Application rates should insure that the crop is not overwatered, especially in more northern latitudes, as this will suppress growth by lowering soil temperatures. The most critical moisture requiring period is just prior to bloom and during bloom [20]. Cowpea performs well on a wide variety of soils and soil conditions, but performs best on well-drained sandy loams or sandy soils where soil pH is in the range of 5.5 to 6.5. For forage purposes, the crop may be seeded in rows or broadcast (solid-seeded). Seed should be planted 2.54 to 3.8 cm. deep and good seed-soil contact is important. The amount of seed to sow per acre depends on seed weight, germination percentage, and plant spacing. Recommended field seeding rates range from 18 to 22 kg/ha for viney, indeterminate types to 40 to 50 kg for large-seeded determinate types. Optimum plant spacing depends on vine type. Highly determinate types may be planted 5 to 7.6 cm. apart. Viney indeterminate types require more space, and a final stand with 20.3 to 22.9 cm. between plants in 76 cm. rows is considered to be a minimally acceptable population [21].

3 MATERIAL AND METHODS

3.1 Site Description

The study area is Girei local government area of Adamawa State. Girei is located between latitude 9° 11" and 9° 33" N and longitude 12° 12" and 12° 49" E. The climate is broadly divided into dry and rainy season. Rainy season commence in May and reaching its peak in August and stop in November. The area has an average rainfall of 972mm. Temperature in the area varies with season, which ranges from 27 to 40°C. The coldest month being December and January with mean average temperature of 15°C, while the hottest period in the area are April and May with an average temperature of 34°C. The relative humidity of the area ranges from 15% in February to 68% in August

with an average annual relative humidity of 40.9% [22]. The map of the study area is as shown in figure 1.

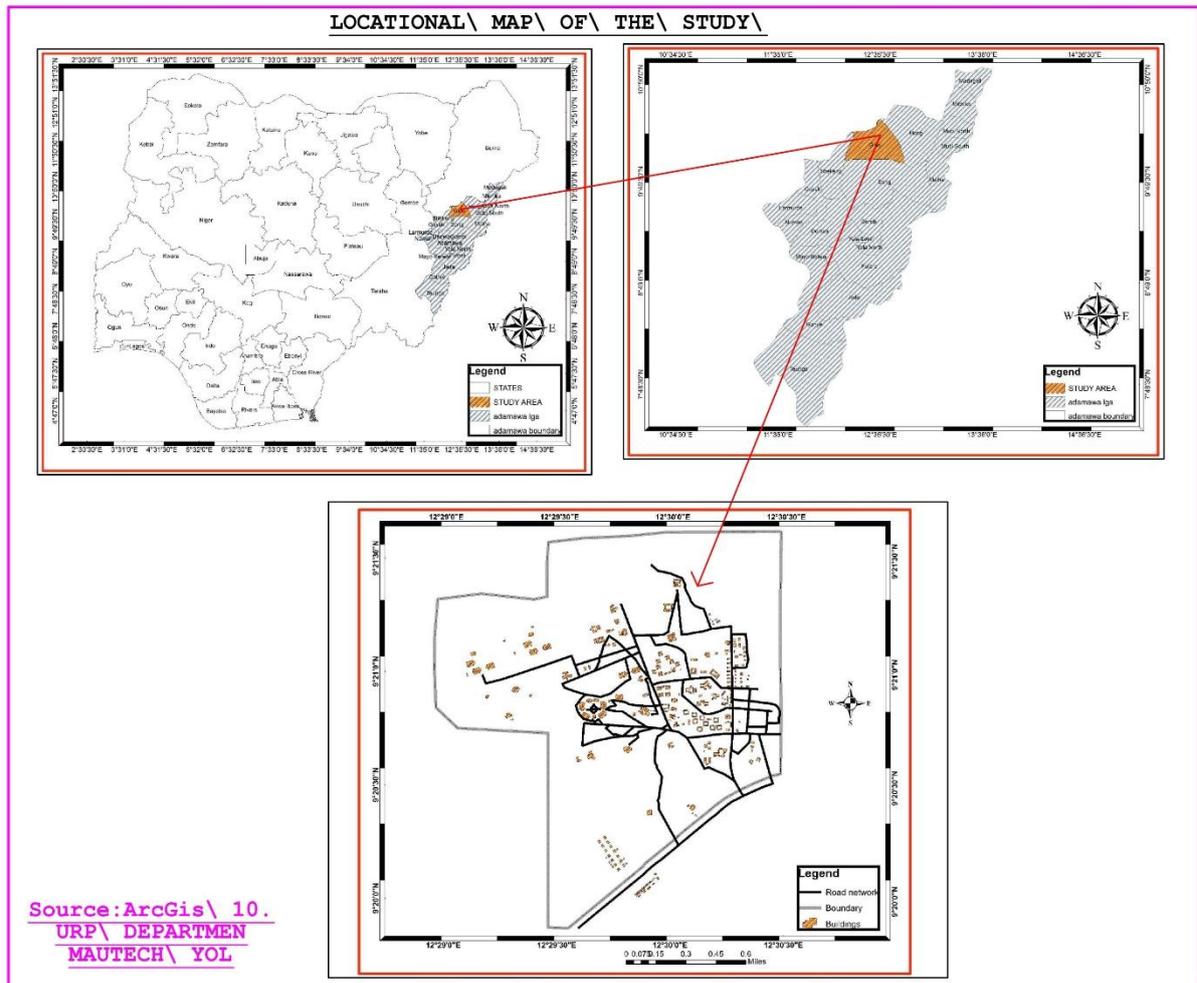


Figure 1. Map of Girei showing the study area.

3.2 Experimental Design and Treatments

Experimental treatments considered in the study consisted of four (4) different tillage operations namely, zero tillage (control), Disc Plough, Disc Harrowing and Disc Ploughing and Disc Harrowing, laid out in a Randomized Complete Block Design, with Three (3) replications. A Massey Ferguson (MF 375) tractor with 31.0kpa contact pressure was used for the tillage operations. A total of 12 plots were used in the study. The experimental field was 40m x 35m (1,400m²), divided into 12 plots of 10m x 10m with alleys of 5m between the plots. The field was cleared and laid out before the treatments were applied. Disc ploughing was done at an average depth of 40cm with a 3-furrow mounted disc plough having 65cm disc diameter. Harrowing was done with an offset disc harrow at an average depth of 20cm with 55cm diameter discs. Zero tillage involves planting on bare land with no soil disturbance, whereas the other treatments were carried out by ploughing followed by harrowing using the above implements. Cowpea (*Vigna unguiculata*, L. Walp.), were planted on the various treatments. Planting was done manually by placing two (2) seeds per hole at an interval of 20 to 23 cm. between plants in 76 cm rows at an average depth of 5 cm in line with [21].

3.3 Determination of Soil Bulk Density

Soil samples were taken at incremental depth of 100 mm down to a depth of 400 mm using mould soil sampling equipment at four locations randomized within the plot units and ensuring that

each treatment was represented within each unit. Soil bulk densities were determined using the following relationship as detailed by [23].

$$BD = \frac{M}{V} \quad (4)$$

Where; BD =bulk density, g/cm³; M = mass of soil,

$$M = m_2 - m_1 \quad (5)$$

Where; m₁= empty weight of mould, g; m₂= mass of compacted soil and mould weight, g; V= volume of the container, cm³

$$V = \pi r^2 h \quad (6)$$

Where; h =height of the mould, cm; r = radius of the mould, cm

3.4 Determination of Soil Moisture Content

Soil samples were taken at incremental depth of 100 mm down to a depth of 400 mm using a soil sampling auger at four locations randomized within the plot units and ensuring that each treatment was represented within each unit. The samples were taken just before and 2 days after irrigation due to the light nature of the soil. The soil moisture, were determined using (Equation1) the gravimetric method. The gravimetric moisture content was determined by weighing a moist sample, oven drying it at 105°C for 24hours, reweighing, and calculating the mass of water lost as a percentage of the mass of the dried soil in line with Ibrahim [24].

3.5 Determination of Cowpea Seedling Germination

Seedling emergence was monitored on daily basis by counting the number of emerged seeds in each plot and the values were recorded. This was observed for seven days and the values obtained were recorded on each day. Emergence rate index was calculated as detailed by [25] as;

$$MED = N_1 D_1 + N_2 D_2 + \dots N_n D_n \quad (7)$$

$$ERI = \frac{\text{Total number of emerged seedlings}}{MED} \quad (8)$$

Where; N₁, N₂ N_n = increase in the number of newly emerged plant stems

D₁, D₂ D_n = number of days after planting

The emergence index rates (ERI) were determined for the various tillage methods and the values were recorded.

4 RESULTS AND DISCUSSION

4.1 Effects of Tillage Operations on Soil Moisture Content, Bulk Densities and Penetration Resistance.

Table 1 indicates that the soil moisture content, bulk density and penetration resistance of the soil varies with depth in all the treatments. It was observed that lower values of moisture content was obtained for Zero tillage while higher values of moisture content was recorded for disc ploughing and disc harrowing in the area. It was also observed that soil moisture content values increased with depth which had the lowest mean moisture content value of 46% for Zero and the highest mean moisture content value of 50% obtained for Disc Ploughing and Disc Harrowing. The result revealed that the effect of using primary and secondary tillage implement improved porosity and water holding capacity of the soil which is in line with the findings by [26].

Table 1. Soil Moisture Content, Bulk Density and Penetration Resistance of the Soil in the Study Area

Area	Treatments											
	ZT			DP			DH			DP+DH		
Depth of Sampling (cm)	MC (%)	BD (g/cm ³)	PR (Mpa)	MC (%)	BD (g/cm ³)	PR (Mpa)	MC (%)	BD (g/cm ³)	PR (Mpa)	MC (%)	BD (g/cm ³)	PR (Mpa)
0-10	43	1.15	3.10	47	1.20	2.80	46	1.30	2.20	48	1.40	1.25
11-20	45	1.62	2.50	49	1.63	2.20	49	1.64	1.80	50	1.65	1.10
21-30	47	1.70	2.30	50	1.72	2.15	50	1.74	1.50	50	1.76	0.85
31-40	50	1.89	1.70	51	1.90	1.20	51	1.88	1.40	52	1.91	0.62
Mean	46	1.59	2.40	49	1.61	2.09	49	1.64	1.73	50	1.68	0.96

Note: MC=Soil Moisture content, BD=Bulk density and PR=Penetration Resistance

The values for the various soil bulk densities for the different treatments in the study area are presented in Table 1. It was observed that soil bulk densities vary among the treatments for the respective depth of soil sampling. For 0-10 cm depth, highest soil bulk density value of 1.4 g/cm³ was obtained when the treatment operation was Disc Ploughing and Disc Harrowing, while the lowest soil bulk density value of 1.15 g/cm³ was recorded for Zero Tillage operation. This follows the same trend for soil depths of 11-20, 21-30 and 31-40 cm, respectively for all the treatments. However, highest soil bulk density mean value of 1.68 g/cm³ was found for tillage operation treatment of Disc Plough and Disc Harrow, and lowest soil bulk density mean value of 1.59 g/cm³ was obtained with zero tillage operation treatment for the study area. The overall result revealed that the mean soil bulk density of 1.63 g/cm³ was obtained for the study area. The result indicates that soil bulk densities increased with tillage depths which are in line with [27; 28]. Effects of different tillage methods on penetrating resistance of the soil in the study area are as shown in Table 1. The Table indicates that significant effect of different tillage treatments on soil penetration resistance was observed. The result revealed that highest soil penetration resistance mean value of 2.40Mpa was obtained for zero tillage treatment while the lowest soil penetration resistances mean value of 0.96Mpa was recorded for the disc plough and disc harrow treatment. The difference in penetration resistance observed may be due to differences in amount of moisture retention for each tillage treatment operation. The result revealed that penetration resistance decreased with increase in soil moisture content which is expected because after load application from tractor traffics, ploughing which is primary tillage operation broke the soil that result in larger clods since the soil had been compacted. Thus depression of the penetrometer probe into the soil was affected by over-burden pressure from the soil which leads to high penetration values. Harrowing as secondary tillage produced better tilth than ploughing and hence the reduction in penetration resistance compared to ploughing leading to lower penetration resistance. However, the combination of primary and secondary tillage operation on the soil produced the best tilth, which resulted in the difference in the values of penetration resistance. Thus it could be stated that tillage operation treatment (Disc Plough and Disc Harrow)) has lower penetration resistance than that of the other treatments (Disc Plough, Disc Harrow and Zero Tillage) which is in agreement with earlier studies by [29].

4.2 Effect of Tillage Operations on Emergence of Cowpea Seeds in the Study Area

Table 2 shows the number of emerged seeds for each treatment in the plot at the end of seven days. It was observed that number of seeds germinated vary in each plot even for the same tillage operation. Highest number of seeds emerged was obtained for Disc Plough and Disc Harrow tillage operation which had mean value of 28, while the lowest mean value of seeds of 14 was recorded for Zero Tillage. It could be observed that the number of seeds emerged for Disc Plough and Disc Harrow operation was twice that of Zero Tillage operation. The result revealed that the seed Emergence Index Rate (ERI) value of 0.183 was obtained for Disc Plough and Disc Harrow, while seed emergence index rate value of 0.181, 0.180 and 0.175 were recorded for Disc Harrow, Disc Plough and Zero Tillage, respectively. Thus seeds germination is more for Disc Plough and Disc Harrow than all the other tillage treatments with Zero Tillage operation which performed the least. Statistically (Table 3), it was observed that the difference among the number of seeds emerged for the different treatments

(tillage operations) were highly significant at 5% level of significance. This is in line with earlier studies by [30].

Table 2. Number of Emerged Cowpea Seeds for each Treatment in each Plot after Seven Days

Farm Operation	Farm Plots				Mean	ERI
	A	B	C	D		
ZT	18	12	17	8	14	0.175
DP	20	18	23	18	20	0.180
DH	23	24	26	23	24	0.181
DP+DH	30	28	26	29	28	0.183
Mean	23	21	23	20		

ERI = emergence index rate

Table 3. Analysis of Variance (ANOVA) for mean emergence cowpea seeds

Sources of Variance	Df	SS	MS	Computed F-value	Table F – Value 5%	1%
Replicate	3	35.19	11.73			
Treatment	3	459.69	153.23	666.23**	3.86	6.99
Error	9	61.06	0.923			
Total	15					

cv- 4.37%, ** - highly significant

5 CONCLUSIONS

Evaluation of the effects of different tillage operations; zero tillage, disc plough, disc harrow and disc-harrow +plough was carried out on some soil physical properties which include; soil moisture content, bulk density and penetration resistance of the soil in the study area. In addition, effects of the tillage operations on seed germination of cowpea were evaluated. From the study it could be concluded that; i. The effect of using primary and secondary tillage implement improved porosity and water holding capacity of the soil. ii. Soil bulk densities increases with tillage depths and mean soil bulk density of 1.63 g/cm³ was obtained for the study area. However, Disc Plough and Disc Harrow treatment has lower penetration resistance than the penetration resistances recorded for Disc Plough, Disc Harrow and Zero Tillage treatments, respectively, because the combination of disc plough and disc harrow tillage operation on the soil produced the best tilth. iii. Optimum seeds germination was obtained for Disc Plough and Disc Harrow tillage operation than all the other tillage operation. ZT tillage operation performed the least. The difference among the number of seeds germinated for the different tillage operation treatments were highly significant at 5% level of significance. Thus tillage operation, (Disc Plough and Disc Harrow) which perform optimally among all the other tillage operations could be recommended for adoption in the study area for cowpea production.

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