



## IMPACT OF SOIL COMPACTION AND MULCHING ON GROWTH AND YIELD OF COWPEA IN ILE-IFE, NIGERIA

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### ABSTRACT

Agricultural vehicle traffic is one of the principal factors responsible for the compaction of surface and subsurface horizons of soil under field conditions. To control this, a field experiment was conducted to examine the response of tractor wheel passes and mulching on the growth and yield of cowpeas. A tillage model can simulate the effect of different components that contribute to the formation of yields and can facilitate the design of alternative agricultural systems.

High bulk density was obtained using the core sampler method within the ploughed layer and the active portion of the crop root zone (10-30 cm), while there were increasing trends in bulk density from planting to crop maturity. A model to predict the crop yield as a function of the degree of compaction and extent of mulching was developed. The model summary was significant at a 5 % probability level ( $p < 0.005$ ). Moreover, interactions between compaction and mulching on cowpea yield showed that the least (0.21 tha<sup>-1</sup>) and highest (0.51 tha<sup>-1</sup>) cowpea grain yield occurred at the point when treatment was 4 tractor passes and no mulch and 0 passes with 60 kg mulch, respectively. Mulch with no compaction performed better in growth and yields as well as yield-related parameters compared to compaction only without mulch. This gives the best soil management practice that will result in good growth and maximum productivity of cowpeas.

### 1.0 Introduction

Cowpea has been cultivated and domesticated in Africa for centuries. It is now grown worldwide, especially in the tropics. It is a warm-season crop that can be produced in semi-arid regions and dry savannahs. It adapts better to sandy soils and dry conditions than soybeans (TJAI, 2010). The largest producers of cowpea are Nigeria, Niger, Brazil, Haiti, India, Myanmar, Sri Lanka, Australia, and the United States (TJAI, 2010). In addition to their health-related benefits, beans are considerably cheaper than rice or any other dietary fibre type (Ayenlere et al., 2012). It is a good food security item as it mixes well with another recipe (Muoneke et al., 2012).

Cowpea is commonly cultivated as a nutritious and highly palatable source of food in the southern United States, the Middle East, Africa, Asia, and throughout the tropics and subtropics. The seeds of cowpeas have been reported to contain 24 % crude protein, 53 % carbohydrates, and 2 % fat (FAO, 2012). Cowpea fixes atmosphere nitrogen through symbiosis with nodule bacteria (Shiringani and Shimeles, 2011). It is an extremely resilient crop cultivated under some of the most extreme agricultural conditions in the world (Muoneke et al., 2012).

The advent of mechanized and intensive agriculture with its associated soil compaction problems, during the past decades, led to a sharp interest in wheel traffic and soil compaction. The level of tractor utilization in food production in Nigeria is a much-debated subject. There is little doubt of the economic and ecological damage of soil compaction to society (Graves et al., 2015). The use of agricultural machinery on farms has increased steadily. For example, wheel loads of combine harvesters have increased by about 65 % between the years 1989 and 2009 (Schjonning et al., 2015). Consequently, the mechanical stresses exerted by today's machinery may exceed the strength of many arable soils (Hornand Fleige, 2003; Schjonning et al., 2015; Zink et al., 2010). It is reasonable to assume that the increase in agricultural machinery loads has exacerbated the extent and severity of soil compaction. Compaction is estimated to affect between 25 and 45 % of agricultural land (Brus and van den Akker, 2018; Graves et al., 2015; Schjonning et al., 2015). Soil compaction may increase flooding incidence and severity (Alaoui et al., 2018), and trigger soil erosion (Horn et al., 2017), declining water quality through increased nutrient and pesticide leaching (Jarvis, 2007), and increase greenhouse gas emissions (Ball, 2013). Crops and soils can react to the same or different levels of compaction differently. Thus, there is a need to assess the impact of compaction under a particular environment and determine the best combination of agronomic and tillage practices that will result in optimum growth and land productivity of cowpeas. Therefore, the objective of the study was to develop a model for predicting the impacts of soil compaction and mulching on the yields of cowpeas under sub-humid conditions.

## **2. Materials and Methods**

### **2.1 Study area**

The experiment was carried out at the Teaching and Research Farm, Obafemi Awolowo University, Ile-Ife, Nigeria. The study location is between Latitude of 7°26'N-7°33'N and Longitude of 4°30'E-4°35'E. The temperature of the study area ranged between 14 and 38°C from September to December. There were two distinct seasons in the study area, the rainy season which begins in March and ends in October, and the dry season which lasts for the rest of the year (Adekalu and Osunbitan, 2006).

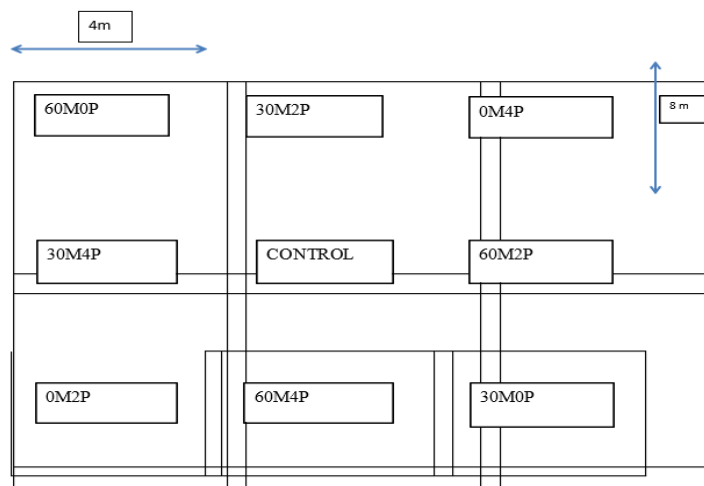
### **2.2 Experimental procedure**

The treatments consisted of 0, 2, and 4 tractor-traffic tyre passes imposed on the soil before planting (Table 1). A Massey Ferguson (MF 375E) 2-wheel drive tractor with a rear tyre dimension of 0.44 x 0.70 m, a weight of 43.30 kN, and a resulting ground pressure of 240 kPa was used for the compaction of soil. Forward tractor speed was kept constant at 6 km/h for all the treatments. The treatments were arranged in a randomized complete block design in a uniform field of sandy loam soil. The seasonal rainfall was 535 mm while maximum and minimum air temperatures were 32.1 and 29.1°C respectively. The sunshine hour was 6 hrs during the cropping season. The land was ploughed and harrowed after one week. The layout was marked using tape, pegs, and ropes. Spacing between plots was 1.5 m and planting spacing was 50 x 75 cm. The areas/plots to be compacted were covered completely with the wheeling at an average soil moisture content of 11.05 % using the gravimetric method and bulk density of 1.09 g/cm<sup>3</sup>. Cowpea (IT81D-994) seeds were planted manually on the 16<sup>th</sup> of September, 2015 at a soil depth of 5 cm in an 8 x 4 m area of each plot by placing three seeds in a hole.

**Table 1:** Description of experimental treatments

Treatment label	Description
Control	0 kg mulch and zero tractor pass
60M0P	60 kg mulch and zero tractor pass
30M0P	30 kg mulch and zero tractor pass
0M2P	0 kg mulch and two tractor passes
30M2P	30 kg mulch and two tractor passes
60M2P	60 kg mulch and two tractor passes
0M4P	0 kg mulch and four tractor passes
30M4P	30 kg mulch and four tractor passes
60M4P	60 kg mulch and four tractor passes

The experiment consisted of 9 treatments and was replicated three times (Figure 1). The seedlings were thinned to one stand per hole 10 days after planting (DAP). Mulch was applied on the soil surface 14 DAP. The experimental area was weeded using a local hoe regularly until maturity. The weight of mulch was 30 and 60 kg, and 0 kg mulch at 8 t/ha served as the control. The area of each plot was 32 m<sup>2</sup>. Ten plants were selected from each plot and tagged for observations at intervals of one week. The established plants were counted at twenty-eight days after planting. The number of leaves on the tagged plants was counted and averages were determined for each treatment. The stem girth of the tagged plants was measured at 5ch above the soil surface using digital vernier callipers. A measuring tape was used to measure the plant height from the soil surface to the apex of the tagged plants. The root lengths of the ten tagged plants per plot were measured as the length from the base of the shoot to the tip of the root of each plant using a ruler till harvest (90 days after planting). At maturity, pods were harvested manually, sun-dried for one week, and shelled. The dry pods and grain yields were weighed using an electric balance. The number of pods per plant, pod length, number of seeds per pod, and dry grain yields were measured. The average numbers of pods and grains per treatment were determined from the tagged.



**Figure 1:** Experimental layout for treatments

### 2.3 Soil properties

The soil samples were analyzed for physical and chemical properties such as bulk density and textural class using standard methods (Table 2). The upper 20 cm was characterized by sandy loam, while the lower 20 -30 cm was sandy clay loam. The electrical conductivity of soil was determined in the filtrate of the water extract using a conductivity meter. The bulk density was lower in the upper 20 cm than in the lower 20 to 30 cm. Soil pH in the upper 30 cm is adequate for the cultivation of cowpea. The cation exchange capacity of the soil was higher in the upper 20 cm than in the lower 20 to 30 cm.

**Table 2: Physical and chemical properties of the soil**

Soil depth (cm)	0-10	10-20	20-30
pH CaCl <sub>2</sub>	5.2	5.1	5.05
EC (mS/cm)	0.11	0.14	0.14
Bulk density (g/cm <sup>3</sup> )	0.98	1.20	1.48
P (ppm)	54.24	38.50	39.47
Sand %	75	75	77
Silt (%)	10	10	8
Clay (%)	15	15	15
Ca <sup>2+</sup> (cmol/kg)	47.64	47.43	47.47
Mg <sup>2+</sup> (cmol/kg)	6.14	5.98	5.84
Na <sup>2+</sup> (cmol/kg)	1.15	1.26	1.20
K <sup>+</sup> (cmol/kg)	0.51	0.26	0.1

## 2.4 Statistical analysis

Data obtained were analyzed using response surface methodology RSM (Design Expert 7.0) Dx7 MFC Application, Stat. Ease Inc., file version 7.0.1.0 using central composite design (CCD); test of significance of treatments and their interactions was determined at 5 % significant level. The fractional design points were used to generate the experimental runs and predicted values. The graphs of treatments and their interactions with the yields and growth of cowpeas were plotted. The experimental procedures were repeated twice.

## 3. Results and Discussion

### 3.1 Effect of compaction and mulching on yield

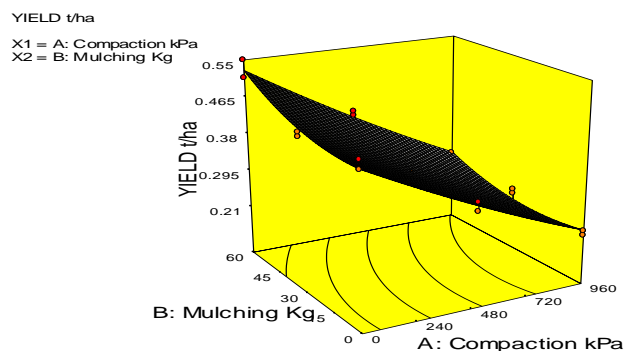
The effect of the varying levels of compaction and different mulch applications on the yields of cowpeas is shown in 3D format (Figures 2 and 3). The 4 and 0 tractor passes with 0 kg and 60 kg of mulch produced 0.21 and 0.51 t/ha of cowpea respectively. This implies that yield decreases with an increase in compaction but increases with mulch ( $p < 0.05$ ).

The model relating yield, compaction, and mulching (Equation 1) is significant ( $p < 0.05$ ) and with an  $R^2$  of 0.99 which indicates a good degree of reliability. This means that the sample variation of 99 % for cowpea yields is attributed to compaction and mulching. This is above the recommended lower limit of Gan and Yao (2008) that for the good fit of a model, at least  $R^2$  of 0.80 is required. The adjusted determination coefficient (adj.  $R^2$ ) was 0.98 supporting the high significance of the model.

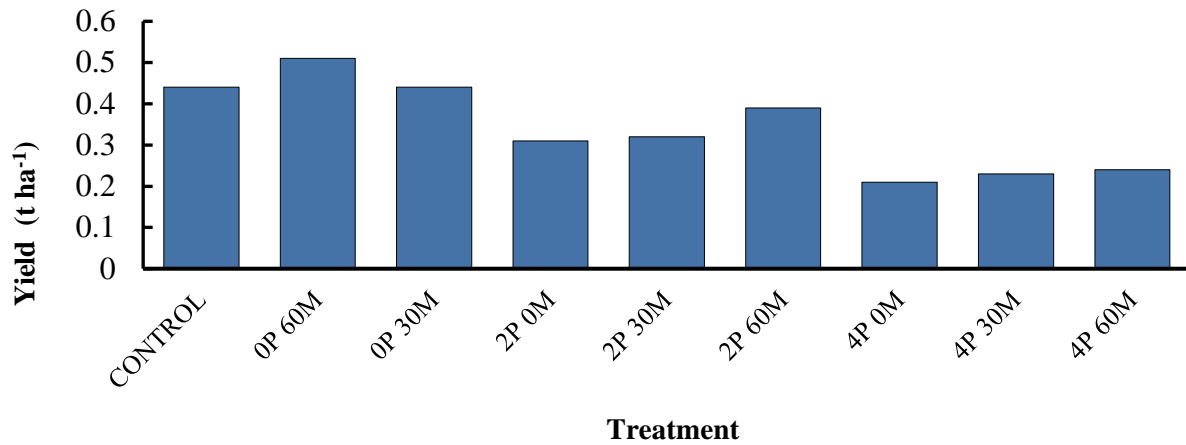
$$Y = +2.04 + 7.70 * C - 0.27 * M - 0.31 * C * M + 6.13 * C^2 + 0.020 * M^2 \quad (1)$$

where:

Y is cowpea yield (t/ha); compaction (C) and mulching (M). Equation 1 can be used in the determination of cowpea yield under varying conditions of the stipulated factors of compaction and mulching treatments.



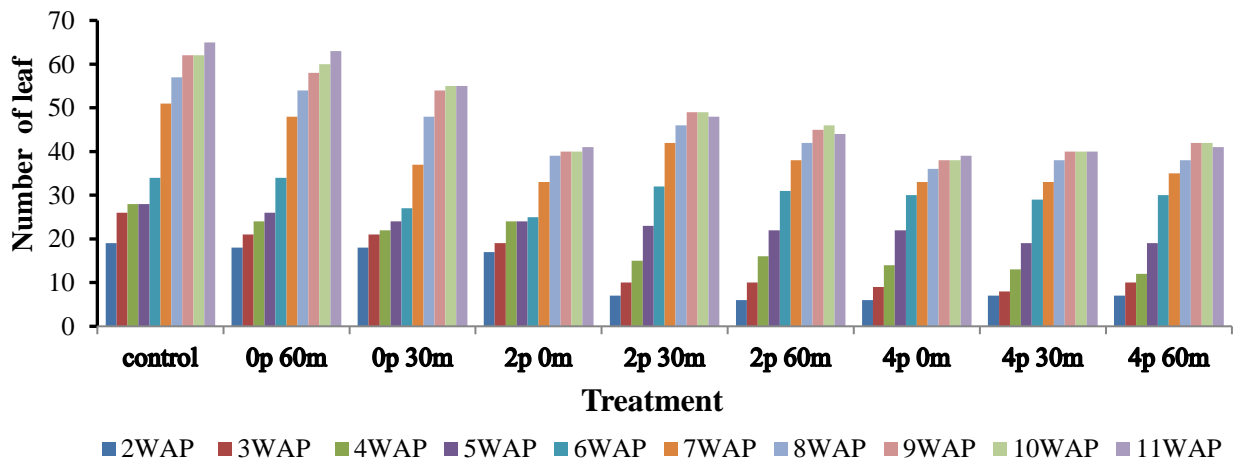
**Figure 2:** Response surface plots showing interactive effects of mulching and compaction on yield



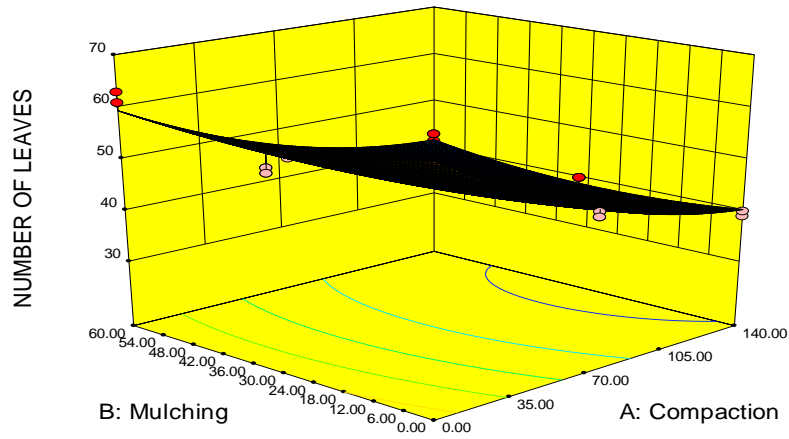
**Figure 3:** Soil compaction and mulching treatments on cowpea grain yield

### 3.2. Effect of compaction and mulching on the number of leaves of cowpea

The 0 kg mulch and 0 tractor pass (control) had an average of 19 leaves at 14 DAP to 65 leaves at 77 DAP, compared to 4 tractor passes and 0 kg mulch which had 6 leaves from 14 DAP to 39 leaves at 77 DAP. There was an increase in the number of leaves with mulch but a decrease in the number of leaves with an increase in compaction (Figure 4). This could be attributed to an increase in moisture contents which resulted in higher evapotranspiration. With higher compaction, interstices in the soil which accommodate water have been blocked and water which is essential for cellular activities and canopy formation has been reduced substantially. The response surface plot of mulching, compaction, and number of leaves is shown in Figure 5.



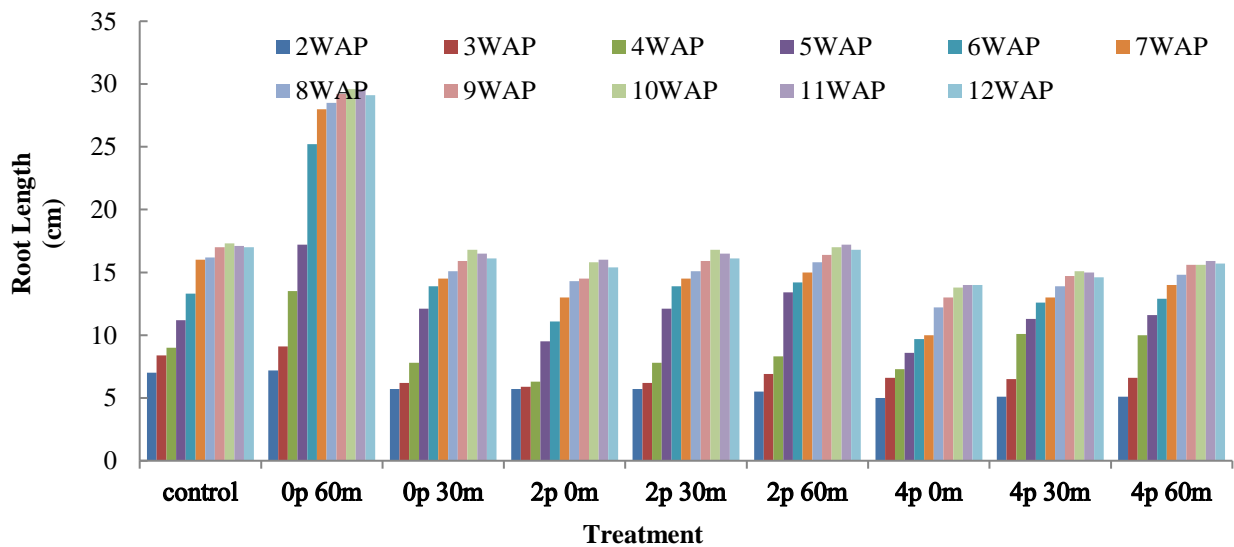
**Figure 4:** Effect of compaction and mulching on cowpea number of leaves.



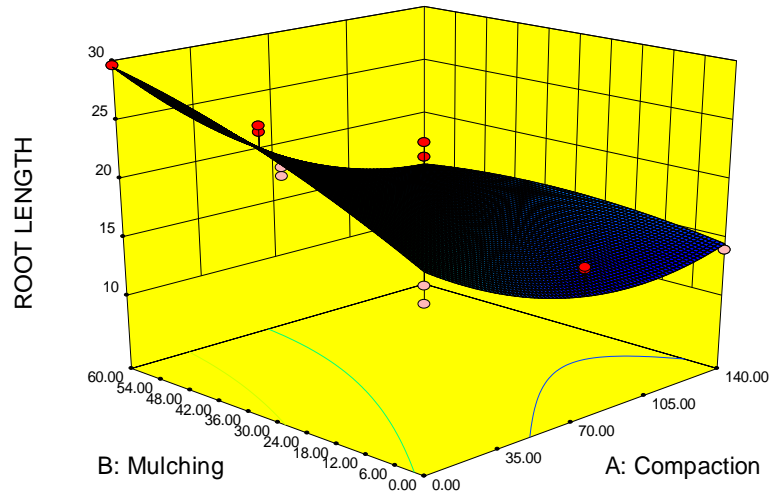
**Figure 5:** Response surface plots showing interactive effects of mulching and compaction number of leaves

### 3.3. Effect of Compaction and Mulching on Root Length

The application of 60 kg mulch with no tractor pass produced the highest root length of 7.2 cm at 2 WAP and 29.1 cm at 12 WAP, while 4 passes and no mulch produced the lowest root length of 5 cm at 2 WAP and 14 cm at 12 WAP (Figures 6 and 7). Mulching conserves moisture, reduces soil temperature, and retards weed growth and competition. Compaction-induced productivity losses are primarily a consequence of impeded root system expansion (Bengough et al., 2011; Valentine et al., 2012).



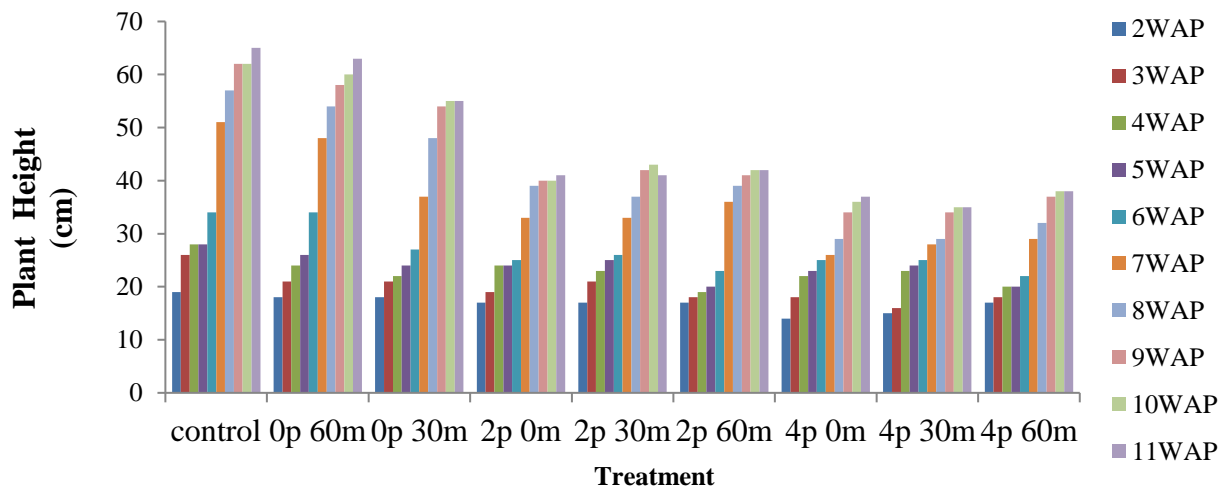
**Figure 6:** Effects of compaction and mulching on cowpea root length



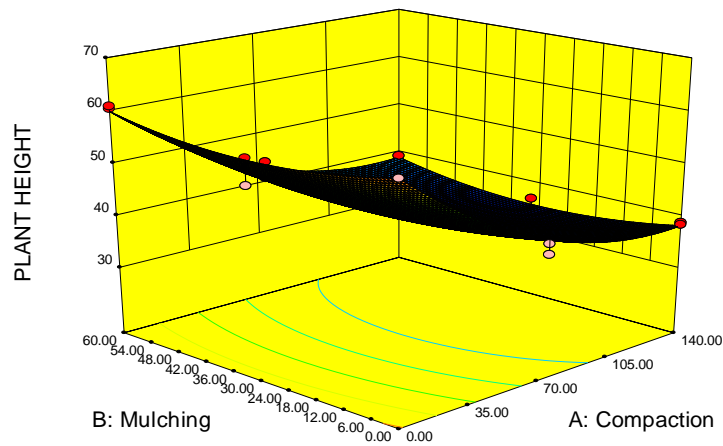
**Figure 7:** Response surface plots showing interactive effects of mulching and compaction on root length

### 3.4 Effect of compaction and mulching on plant height

The Effect of compaction and mulch treatments on plant height is shown in Figure 8, the result shows that the average plant height varied from 65 cm at 0 tractor passes and 0 mulch to 35 cm at 4 passes and 30 kg mulch. The control had a plant height of 19 cm at 14 DAP and 65 cm at 77 DAP, followed by the 0 pass and 60 kg mulch application of 18 cm height at 14 DAP and 63 cm at 77 DAP. The 4 passes and 30 kg mulch had the lowest mean of 35 cm at 77 DAP. The low height could be attributed to high compaction which lowered the rate of interflow in the soil interstices.



**Figure 8:** Effects of compaction and mulching on cowpea plant height.



**Figure 9:** Response surface plots showing interactive effects of mulching and compaction on plant height.

### 3.5 Moisture content and bulk density of experimental plots

The soil bulk densities are presented in Table 3. The tractor passes on the plots affected the bulk densities, in proportion to the number of passes and amount of mulch applied. The higher the number of passes, the higher the bulk density as expected. The higher the amount of mulch, the higher the moisture content of the soil. The higher number of passes slightly reduced the moisture contents. Compaction significantly affected the parameters. Bulk density increased while soil moisture content reduced with an increased number of tractor passes. These results agreed with Dauda and Samari (2002) where high moisture contents decreased with the number of tractor passes.

Mulch treatments alone produced high ranges of soil moisture contents over compaction. However, higher soil bulk density due to compaction could be attributed to the effects of tractor-wheel traffic and implement passes and lower macro-porosity and evaporation rate (Agbede, 2006). The highest moisture status of no pass and 60 kg mulch could be added to the minimum soil disturbance with little exposure of the soil surface to the atmosphere and consequent reduction in water evaporation, therefore conserving soil temperatures and the available water in the soil (Agele et al., 2000).

**Table 3.** Soil moisture contents and bulk densities of the plots

Treatment	21 DAP		42 DAP		63 DAP		84 DAP	
	Moisture contents (%)	Bulk density (g/cm <sup>3</sup> )	Moisture contents (%)	Bulk density (g/cm <sup>3</sup> )	Moisture contents (%)	Bulk density (g/cm <sup>3</sup> )	Moisture contents (%)	Bulk density (g/cm <sup>3</sup> )
0P 0M	12.15	1.17	17.56	1.11	12.04	1.31	7.72	1.13
0P 60M	13.13	1.13	18.52	0.88	12.10	1.36	8.51	1.32
2P 30M	11.14	1.12	16.45	1.12	10.86	1.13	6.22	1.39
4P 0M	8.03	1.12	13.69	1.08	8.68	0.92	7.00	1.71
4P 30M	8.68	1.39	13.09	0.93	9.95	0.95	5.39	1.12
2P 60M	12.26	1.34	16.29	0.97	11.79	1.13	6.24	1.73
2P 0M	10.08	1.18	15.37	1.05	10.03	0.97	6.20	1.42
4P 60M	9.27	1.28	14.74	1.55	10.90	0.87	6.37	1.73
0P 30M	12.49	1.31	17.71	1.06	12.82	1.31	6.82	1.11

DAP – Days after planting



#### 4. Conclusion

This study shows the negative effects of Multiple Tractor Wheel Passes (TWP) on cowpea growth and soil properties. Increases in tractor wheel passes from 0, 2, and 4 tractor passes increased the bulk density of soil but reduced the grain yield. Multiple tractor wheel passes and amendments with mulching affected soil physical properties and conserved soil moisture.

Mulch treatments produced better growth parameters and yields of cowpeas. Compaction of the soil by multiple tractor tyre passes affected the growth parameters and yields of cowpea. The application of 60 kg mulch increased grain yields compared to the zero passes and zero mulch application. This could be attributed to high mulch which conserves moisture and helps root growth.

Thus, farmers should reduce compaction as much as possible to get high yields of cowpea. Research on cost-benefit analysis in cowpea production under different soil management techniques vis-a-vis different planting seasons should be conducted to ascertain the most reliable and effective practice that could be recommended for farmers in the cropping seasons. There is a need to determine the long-term effects of compaction operations on soil properties, crop growth parameters, dry biomass and crop yield.

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