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Influence of soil compaction and moisture variation on development of sesame (*sesamum indicum l.*) plant in a sandy loamy soil

Abstract

This study determines the influence of soil compaction on shoot, root development and nutrients uptake of sesame (*sesamum indicum l.*) plant in a sandy loamy soil. The research was carried out in Mokwa local government of Niger state during wet season. Three soil samples of 300g weight from the top 20cm of the soil profile were taken from college farm. The initial moisture content of the soil was determined using oven-drying method. The soil samples were air dried, large clods broken and grounded. The soil samples were then mixed to obtain a homogenous mixture of the sample. The soil moisture content was then raised to varying moisture levels of 10%, 12%, and 14% exceeding the optimum moisture content of sandy loam which is 12% moisture. Each sample was subjected to five levels of compaction energy using 0,5,10,15,20 blows of a standard proctor hammer in cylindrical cores of 17cm in height and 10cm diameter in accordance with the standard proctor compaction procedure. Four holes were made in each can and four seeds were sown in each hole to be thinned into one seed per hole (four plants in each can). The depth of sowing was one cm. The seedlings were tinned to a maximum of five (5) per core at 15 days after planting. The heights (cm) of the seedling were taken with a measuring tape at 5-days interval to 20 days after planting. The experiment was laid out in randomized complete block design (RCBD). The data collected were subjected to descriptive statistical analysis, regression analysis and analysis of variance. The results from the soil physical properties analysis shows that the soil is sandy loam with sand being 76.8 % and clay as 11.2%. The bulk average density was 1.75 g/cm^3. Results obtained from the study shows that compactive efforts significantly affect plant growth and development. It also shows that as compactive effort increases, the soil bulk density and penetration also increases. The effect of number of hammer blows on soil bulk density and penetration resistance was significant. The effect of excessive moisture also affects germination and plant growth. Moderate soil compaction has beneficial effect. This is due to greater water retention. In general, it appears that there is a great potential in growing sesame on sandy loam soil, if the level of compaction is maintained at moderate level, which does not impede root development and other plant requirements.

Keywords: compaction, penetration resistance, hammer blows, germination, sesame, soil

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Introduction

Sesame (*Sesamum indicum L.*) is otherwise known as sesamum or benniseed is an important oilseed crop cultivated worldwide for its edible oil and food.[1] Sesame seeds contain high oil content (44–58%), proteins (18–25%), carbohydrates (13.5%), ash (5%) Borchani[2] and mineral components, such as K (815 mg/100 g), P (647 mg/100 g), Mg (579 mg/100 g) and Ca (415 mg/100 g).[3] This contributes to its health and nutritional benefits. Therefore, demand for sesame seeds is increasing due to the increasing knowledge on their dietary and health benefits, but there has been limited research on sesame evidenced by low yield in most growing areas hence hampering its adoption and expansion in the world.[4] Compaction reduces the soil's permeability to water, so that runoff and erosion may occur and adequate recharge of ground water is prevented. Compaction reduces aeration of the soil, so that metabolic activities of roots are hampered. Compaction increases the mechanical strength of the soil, so root growth is impeded. All of these effects may reduce the quality and quantity of food and fiber grown on the soil (Gill and Vanden Berg, 1968).

The effects of compaction on growth and yield of crops have been extensively studied by researchers all over the world.[5–9] The degree to which a soil can be compacted varies with the water content of the soil, soil texture and the force of compaction applied to the soil.[10] The objective of the study is to determine the effects of compaction on the early growth of sesame in a sandy loam soil.

Compaction is caused by the use of heavy machinery, pressure from wheels, tillage equipment, trampling by animals, reduced use of organic matter, frequent use of chemical fertilizer and plowing at the same depth for many years.[11] Soil compaction has been recognized as a major physical threat to soil fertility throughout the world.[12] Plant height is considered a genetic character which is modified by environmental factors like availability of moisture and nutrients at active growth stages. Significant differences for plant height observed in compacted treatments may be attributed to reduced ability of roots to penetrate in deep layers for extraction of moisture and nutrients, therefore, growth and development was retarded, which ultimately affected overall plant structure. Gaultney[13] reported that impeded plant height during all crop growth was due to compaction problem.

The degree of soil compaction depends on soil texture, pH, cation-exchange capacity, clay particle thickness and water content, and on the presence of organic matter, iron oxides and free aluminum hydroxide, which determine the nature of the resulting cohesive forces between soil constituents.[14]

Studies conducted by Amezketa[15] revealed adverse effects of soil compaction on root penetration, air and water availability to plants.

Phillips and Kirkham[16] reported a reduction of 10% and Raghavan[17] found reduction of 45 to 50 tons of corn yields due to soil compaction. Khan[18] observed significant reduction in fate of wheat with increase of soil bulk density from 1.25 g cm-3 and 1.35 g cm-3 to 1.45 g cm-3.

The effects of soil compaction on plant growth are very complex and vary from beneficial to harmful, with the latter being much more common. Mild compaction of soil after seeds are planted may benefit plant growth and development by improving capillary movement of water to the seeds. Nevertheless, a voluminous literature shows that soil compaction in the field is predominantly severe enough to create conditions that lead to inhibition of plant growth and yield. Severe soil compaction typically leads to physiological dysfunctions in plants that alter availability of water, mineral nutrients, growth hormones and carbohydrates to meristematic sites as a prelude to reducing plant growth. Furthermore, there is growing concern that progressively severe levels of human-induced soil compaction will occur as the world population increases. The aim of the study is to determine the influence of soil compaction on shoot and root development and nutrients uptake of sesame (*sesamum indicum L.*) plant in a sandy loamy soil.

Materials and methods

Materials

The materials used include; 80 cans of 13cm length and 10.8cm diameter, A digital balance, A measuring rule, an electric oven, A scissor, A clipper, Micrometer for measuring the can dimensions, Newman apparatus for root length measurement.

Study area

Location

Mokwa is a Local Government Area in Niger State, Nigeria. Its coordinates are 9°16'60"N and 5°3'0" E in DMS (Degrees Minutes Seconds) (Figure 1).

Figure 1 Map of Mokwa. Source: Adepoju, 1993.

Climate and agro-ecology

Mokwa local Government experiences two distinct seasons, the dry and wet seasons. The annual rainfall varies from about 1000mm in the south to 1,200mm. The duration of the rainy season ranges from 150 to 210 days. Mean maximum temperature remains high throughout the year, hovering about 32 ˚F, particularly in March and June. However, the lowest minimum temperatures (21 - 23^{o}C) occur usually between December and January when most parts of the state come under the influence of the tropical continental air mass which blows from the north. Dry season commences in October.

Topography and soil

The study area has a flat to low land terrain with more than half the total area rising to an average height of about 88 meters above sea level. The land is relatively flat. The soils are mostly sandy loam, having relatively high silt contents. This may be due to the nature of the parent material which is sedimentary rock.[19]

Methods

Soil sampling and experimental design

Three samples of soil of 300g weight from the top 20cm of the soil profile. were taken from college farm. The initial moisture content of the soil was determined using oven-drying method. The soil samples were air dried, large clods broken and grounded. The soil samples were then mixed to obtain a homogenous mixture of the sample. The soil moisture content was then raised to varying moisture levels of 10%, 12%, and 14% exceeding the optimum moisture content of sandy loam which is 12% moisture. Having raised the moisture content to 10% 12% and 14% they were tightly sealed in a polythene bag to avoid moisture loss and to obtain a homogenous sample. The amount of water to be added (Q) to condition the sample to different moisture levels was determined using the following expression.[20]

$$Q = \frac{A(a-b)}{a \times 100} \tag{1}$$

where Q is the mass of water to be added in kg. A is the initial mass of sample in kg. a is the initial moisture content of the soil in % dry basis, and b is the final (desired) moisture content of the soil in % dry basis.

Each sample was subjected to five levels of compaction energy using 0,5,10,15,20 blows of a standard proctor hammer in cylindrical cores of 17cm in height and 10cm diameter in accordance with the standard proctor compaction procedure.[21] The above hammer blows correspond to static equivalent pressure of 66.7Kpa, 177Kpa, 288Kpa, 399Kpa and 510Kpa as obtained from Raghavan and Ohu.[22] The experiment was replicated three times. The compacted cores were covered with polythene bags fastened with rubber bands to avoid moisture loss and left for 24 hours in the laboratory. No compaction (0 hammer blow) was used as a control. The dry bulk density and penetration resistance of the soil were determined following the method described by Lambe.[21] The penetration resistance of the soil was also measured using a Standard cone penetrometer having a cone base of 15mm and cone angle of 30 degrees operating at 1829mm per minute following the ASAE standard (1982). Four holes were made in each can and four seeds were sown in each hole to be thinned into one seed per hole (four plants in each can). The depth of sowing was one cm. Eighty milliliters of water was applied to each core from planting date till 15days after planting when the first trifoliate leaves appeared on daily basis to take care of evapotranspiration need of the seedlings as suggested by Trouse.[23] Thereafter water was applied to the cores at the rate of 80ml every day morning and evening until the 30th day after planting when the crop final reading was taken. To provide normal heat requirement for seed germination molds with planted seeds were kept in a place where they received maximum sunshine every day and taken back to the laboratory at night for normal heat supply for emerging seedlings and photosynthesis of emerged ones. Head count of seedling emergence was carried out on the 3rd and 5th day after planting at the appearance of first true leaves. The seedlings were tinned to a maximum of five (5) per core at 15 days after planting.

The heights (cm) of the seedling were taken with a measuring tape at 5-days interval to 20 days after planting. The experiment was laid out in randomized complete block design (RCBD).

Data analysis

The data collected were subjected to descriptive statistical analysis, regression analysis and analysis of variance (ANOVA).

Result and discussion

Soil physical analysis

The results from the soil physical properties analysis shows that the soil is sandy loam with sand being 76.8 % and clay as 11.2%. Table 1 presents the analysis of soil physical test. The results from the soil physical properties analysis shows that the soil is sandy loam with sand being 76.8 % and clay as 11.2%. The bulk average density was 1.75 g/cm^3. The soil physical test shows high percentage of sand and clay and so classified as loamy sand from the soil textural class triangle.

Table 1 Soil Physical Properties

S/N	Soil properties	Values
1	Sand (%)	76.8
2	Silt (%)	12
3	Clay (%)	11.2
4	Bulk density (g/cm^3)	1.75

Penetration resistance measurement

Figure 2.1 depicts the penetration resistance of sampled soil. Rooting depth and distribution are important traits for absorption of water and nutrients from the soil profile. Soil penetration resistance is an important physical characteristic that may be measured directly in the field. It provides us with valuable information on the properties of the ploughed layer before tillage and makes it possible to choose an appropriate depth of tillage and intensity of soil crushing and to estimate the tillage quality. The figure shows soil penetration resistances to different levels of compaction treatments of 5, 10, 15, 20 blows of proctor hammer at 10 percent moisture content. The control CT which was not compacted has the lowest penetration resistance at 91 Pascals. Followed by T1 which was 5 blows with resistance of 116.1pascals. T4 is the highest number of blows has 133.34Pascals. This shows that the increase in number of blows increases penetration resistance of the sampled soil. The fall at T2 (10 blows) and T3 15 blows may be attributed to the sandy nature of the soil as it interacts with high moisture content levels. The R^2 value of 0.6 is an indication that there is significant trend between the treatments.

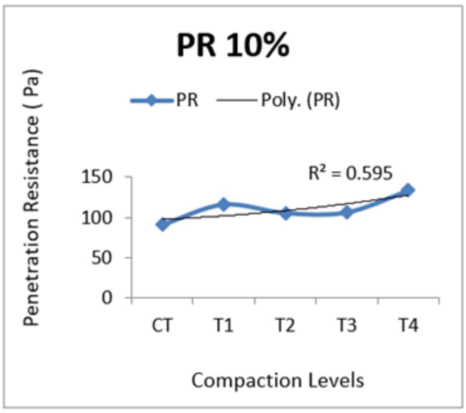

Figure 2.1 Influence of levels of compaction at 10% moisture on Penetration Resistance.

Figure 2.2 shows soil penetration resistances to different levels of compaction treatment of 5, 10, 15, 20 blows of proctor hammer at 12 percent moisture content. The control CT which was not compacted has the lowest penetration resistance at 86 Pascals. Followed by T3 which was 15 blows with resistance of 120.4pascals. T4 has the penetration resistance value of 130.7Pascals. T1 with the lowest number of blows has 138.17Pascals. This shows inconsistences in the trend of the penetration resistance as affected by moisture level. The inconsistences in trend may be due to the sand behaviour as it interacts with high moisture level. The R^2 value of 0.3 is an indication that there is no significant trend between the treatments as the moisture was increased from 10% to 12%.

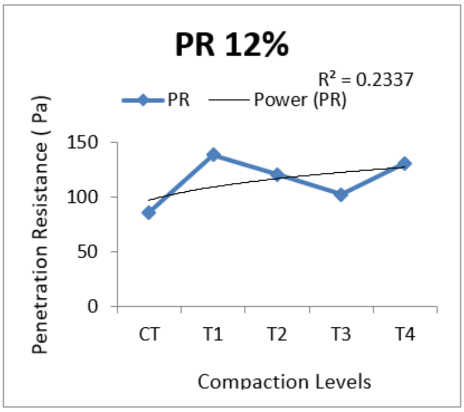

Figure 2.2 Influence of levels of compaction at 12% moisture on Penetration Resistance.

Figure 3 shows soil penetration resistances to different levels of compaction treatment of 5, 10, 15, 20 blows of proctor hammer at 14 percent moisture content. The control CT which was not compacted has penetration resistance of 91 Pascals. T2 has the lowest resistance of 76 Pascals. This could be attributed to the sandy nature of the soil as interacts to increase in moisture content. T1 with 5 blows has 152.7 Pascals. T3 has the highest number of blow and penetration resistance. This shows that the increase in number of blows increases penetration resistance of the sampled soil. The fall at T2 (10 blows) and T3 15 blows may be due to the sandy nature of the soil and moisture content levels. The R^2 value of 0.117 is an indication that there is no significant trend between the treatments as the moisture was increased from 12% to 14%. It shows that as the moisture increases the compaction reduces therefore affecting the penetration resistance.

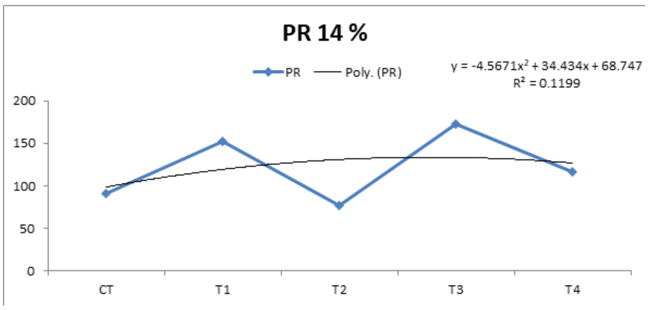

Figure 3 Influence of Levels of Compaction at 14% Moisture on Penetration Resistance.

Soil bulk density

Bulk density (or density in a mass) is the weight of the material including the intergranular air space in unit volume. Bulk density increases with compaction and tends to increase with depth. Sandy soils are more prone to high bulk density. Figure 4 shows the bulk density of the soil at an average of 12.5% moisture content. It reveals that as the compaction increases the bulk density increases. T1 with 5 blows has 1.76g/cm3, T3 has 1.77g/cm^3 and T4 has 1.78g/cm^3. The T4 with the highest blows has the highest bulk density of 1.78g/cm^3. The R^2 value of 0.8 shows strong trend among the compaction treatments.

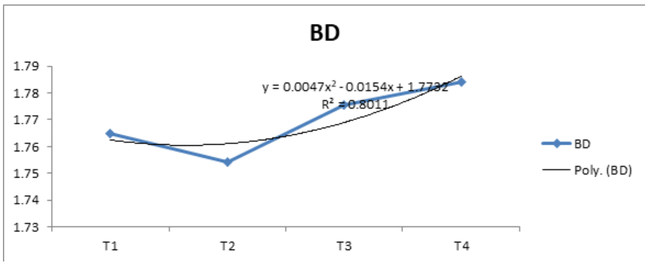

Figure 4 Influence of Levels of Compaction at Soil Bulk Density.

Germination count

A germination test determines the percentage of seeds that are alive in any seed lot. The level of germination in association with seed vigor provides a very good estimate of the potential field performance. Figure 5 shows the germination of sesame as its affected by the level of compaction treatments at 10% moisture content T1 with 5 blows has the germination rate of 7 out of 20 seeds planted, T2 with 10 blows has 4 seeds germinated out of 20, T3 has 7 seeds germinated out of 20, and control with no compaction has the highest germination of 12 seeds out of 20. T4 with the highest number of blows has germination of 5 seeds out of 20. It shows that compaction hinders germination, as can be seen that rate of germination reduces with the increase in compaction levels. The R2 value of 0.8 shows strong trend among the treatments in germination rate.

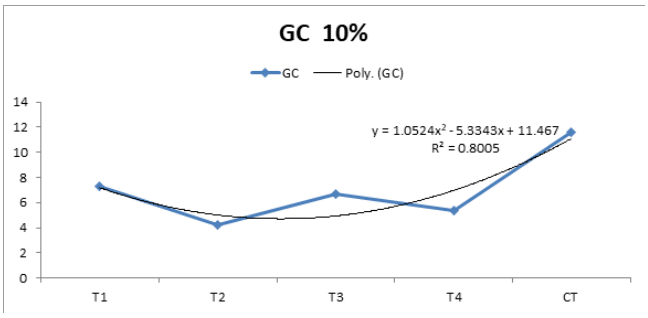

Figure 5 Influence of levels of compaction at 10% Germination Count.

Figure 6 shows the germination of sesame as its affected by the level of compaction treatments at 12% moisture content T1 with 5 blows has the germination rate of 12 out of 20 seeds planted, T2 with 10 blows has 6 seeds germinated out of 20, T3 has 8 seeds germinated out of 20, and control with no compaction has the highest germination of 13 seeds out of 20. T4 with the highest number of blows has germination of 6 seeds out of 20. It shows that compaction hinders germination, as can be seen that rate of germination reduces with the increase in compaction levels. It also shows the influence of increase of moisture on compaction, it reduces the compaction and enables mores germination, as can be seen in the figure in 4.6 as compared to 4.5. The R2 value of 0.7 shows strong trend among the treatments in germination rate.

Figure 7 shows the germination of sesame as it's affected by the level of compaction treatments at 14% moisture content. T1 with 5 blows has the germination rate of 13 out of 20 seeds planted, T2 with 10 blows has 6 seeds germinated out of 20, T3 has 6 seeds germinated out of 20, and control with no compaction has the highest germination of 12 seeds out of 20. T4 with the highest number of blows has germination of 4 seeds out of 20. It shows that compaction hinders germination, as can be seen that rate of germination reduces with the increase in compaction levels. It also shows the influence of increase of moisture on compaction, it reduces the compaction and enables mores germination, as can be seen in the figure in 4.6 as compared to 4.5. It also shows the tolerable limit of moisture to germination. As can be seen when the moisture limit is exceeded there is the tendency of hindrance to germination. This is obvious in figure 4.7. The R2 value of 0.9 shows strong trend among the treatments in germination rate.

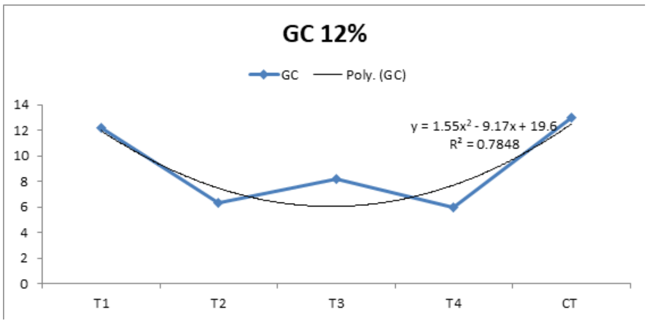

Figure 6 Influence of levels of compaction at 12% Germination Count.

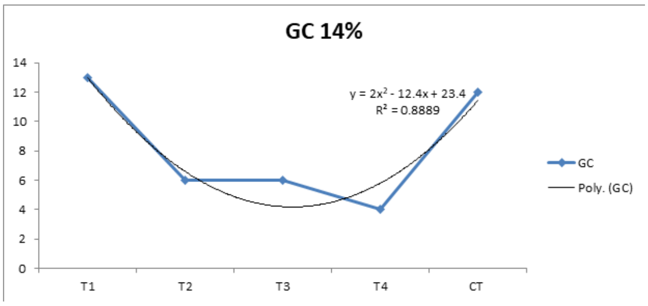

Figure 7 Influence of levels of compaction at 14% Germination Count.

Plant height (PH)

Plants roots are strongly affected by physical factors in soil. Typical responses of plant root system structure to soil compaction include reduction of number and length of root, restriction of downward penetration of the main root axes, decrease in leaf thickness, increase in dry matter shoot –to- root ratio and decrease in crop yield. Figure 8 shows the effect of compaction levels as affected by 10% moisture content. The T1 with compaction levels of 5 has the average plant height of 6cm at three weeks after planting. T2 with 10 blows has 3.8cm at 3 weeks after planting, T4 with 15 blow has 3.7cm at 3weeks after planting, T4 with has 2.8cm at three weeks after planting and control without blows has 8cm at three weeks after planting. The control height recorded and the trend in the figure shows that compaction affect plant development significantly. The R2 value of 0.8 indicates strong variation among the treatments. The model equation can be used to predict the variables involved.

Figure 9 shows the effect of compaction levels as affected by 12% moisture content. The T1 with compaction levels of 5 has the average plant height of 7.3cm at three weeks after planting. T2 with 10 blows has 6cm at 3 weeks after planting, T3 with 15 blows has 5cm in height, T4 with 20 blows has 4.3cm at 3weeks after planting and control without blows has 12cm at three weeks after planting at 12% moisture content. The control height recorded and the trend in the figure shows that compaction affect plant development significantly. The increase in the values of the plant height can be associated to the increase in the moisture content of the soil which reduces the compaction and increasing the ability of the plant to uptake nutrient. The R2 value of 0.8 indicates strong variation among the compaction treatments as it affects the plant height. The model equation can be used to predict the variables involved.

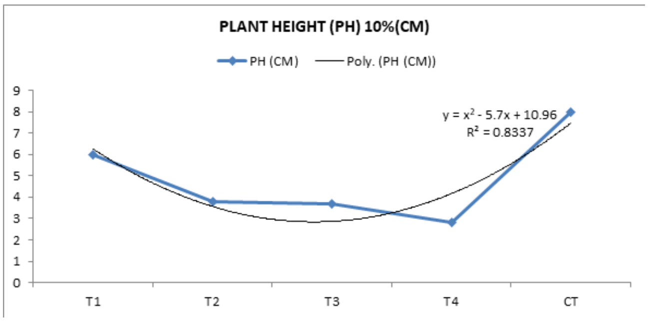

Figure 8 Influence of levels of compaction at 10%M.C on Plant Height.

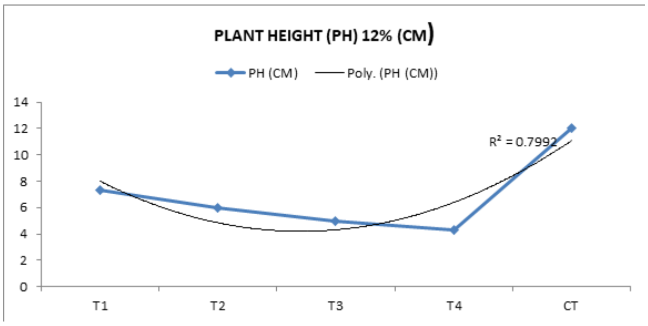

Figure 9 Influence of levels of compaction at 12%M.C on Plant Height.

Figure 10 shows the influence of compaction levels as affected by 14% moisture content. The T1 with compaction levels of 5 has the average plant height of 3.6cm at three weeks after planting. T2 with 10 blows has 3.3 cm at 3 weeks after planting, T3 with 15 blows has 2.3cm in height, T4 with 20 blows has 2.9cm at 3weeks after planting and control without blows has 4.4 cm at three weeks after planting at 14% moisture content. The variations recorded in height and the trend in the figure shows that compaction affect plant development significantly. The reduction in the values of the plant height can be associated to the increase in the moisture content of the soil which reduces the temperature and germination condition of the plant and reduces the ability of the plant to uptake nutrient in conducive environment owing to the saturation level of the soil. The R^2 value of 0.8 indicates strong variation among the compaction treatments as it affects the plant height at 14 percent moisture content. The model equation can be used to predict the variables involved.

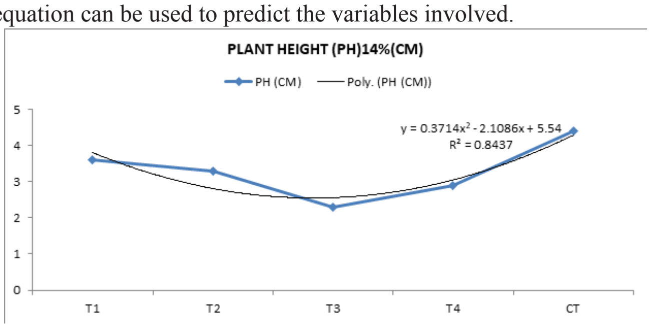

Figure 10 Influence of levels of compaction at 10% Plant Height.

Table 2 shows the ANOVA table on penetration resistance, germination and plant height as influenced by different moisture levels. The means shows the same letter indicating that there is no significant difference in means of all the parameters observed as influenced by different moisture levels. This response can be ascribed to the nature of soil which is sandy loam which is sensitive to moisture. This assertion is in agreement with the findings of Odubanjo and Manuwa,[24] where they concluded the soils were very sensitive to water content during the time of compaction and that percentage increase in soil compaction related more to changes in water content than to applied pressure.[25–86]

Table 2 Influence of Moisture on penetration Resistance, Germination and Plant Height

Treatment Factors	Penetration Resistance	Germination Count	Plant Height
10%	121.8a	9.14a	4.86a
12%	115.52a	8.20a	6.92a
14%	110.53a	7.04a	3.30a

Means that do not share a letter are significantly different.

Conclusion and recommendation

Conclusion

Results obtained from the study shows that compactive efforts significantly affect plant growth and development. It also shows that as compactive effort increases, the soil bulk density and penetration also increase. The effect of number of hammer blows on soil bulk density and penetration resistance was significant. The effect of excessive moisture also affects germination and plant growth. Moderate soil compaction has beneficial effect. This is due to greater water retention. In general, it appears that there is a great potential in growing sesame on sandy loam soil, if the level of compaction is maintained at moderate level, which does not impede root development and other plant requirements.

Recommendations

To achieve high seedling emergence, the soil condition should neither be too loose nor too compact. A little compaction effort is desirable to give maximum percentage seedling emergence because it promotes good contact between the seed and soil. The experiment can be repeated to ensure plant full maturity and this experiment was time constrained.

Acknowledgments

None.

Conflicts of interest

The author declares there is no conflict of interest.

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