Uniosun Journal of Engineering and Environmental Sciences (UJEES), Vol. 8 No. 2, Sept., 2026
DOI: 10.64980/ujees.v8i2.022 **Lasisi et al.**
Published: September 30, 2026

EFFECT OF SOIL COMPACTION ON THE GROWTH AND PERFORMANCE OF CITRUS SEEDLINGS

Mukaila Olatunde LASISI[1*], Monsuru Olukayode AMOO[2] and Oyelayo Ajamu OYEDELE[3]

[1]*Department of Agricultural and Bio-Environmental Engineering, The Federal Polytechnic, Ado-Ekiti, Ekiti State, Nigeria*

[2,3] *Department of Agricultural and Biosystem Engineering, Adeleke University, Ede, Osun State, Nigeria*.

[*]*Corresponding Author: lasisimukaila72@gmail.com*

Abstract
Soil compaction modifies pore space, aeration, water movement and root penetration and can affect plant establishment. This study evaluated the response of citrus seedlings to five mechanically imposed soil-compaction levels under controlled conditions at the Agricultural Engineering Department Farm, Federal Polytechnic, Ado-Ekiti, Nigeria. Loamy soil was subjected to an uncompacted control (T_0) and 5, 10, 15 and 20 rammer blows (T_1–T_4), corresponding to applied pressures of 203.75, 407.50, 611.25 and 815.00 kN m^{-2}, respectively. The experiment used a Completely Randomized Design with 10 replicates per treatment. Initial soil moisture content, bulk density and compaction energy were determined, while plant height, leaf length, total leaf number and leaf drop were measured at 2, 4, 6, 8 and 10 weeks after transplanting. Initial soil moisture content was 4.58%, bulk density was 0.75 g cm^{-3} and calculated compaction energy was 52.98 Nm. At 10 weeks, leaf length, total leaves, plant height and leaf drop ranged from 2.9–3.4 cm, 12.5–13.7, 19.0–24.0 cm and 0.0–0.6 leaves, respectively. T_3 recorded the highest leaf length, T_3 and T_4 the highest leaf number, while T_4 recorded the greatest plant height. Responses were therefore parameter-dependent rather than consistently related to compaction intensity. Further studies should include post-compaction soil properties, root development and biomass.

Keywords
Soil compaction; citrus seedlings; soil physical properties; seedling growth; sustainable agriculture.

1. INTRODUCTION

Soil physical condition influences plant anchorage, water and air movement, nutrient availability and root development. Soil compaction occurs when external forces compress soil particles, reducing pore space and increasing bulk density and mechanical resistance [1], [2]. Increasing agricultural machinery weight and field traffic have intensified soil-stress risks and may threaten soil functioning [3]. The Food and Agriculture Organization has also identified soil degradation as an important constraint to sustainable agricultural production [4].

Compaction is affected by soil texture, moisture, organic matter, pressure and traffic frequency [5]. It may reduce infiltration and aeration and increase soil strength, thereby restricting root penetration and water uptake [6], [7]. Soil physical properties in Southwestern Nigeria also vary with tillage and cropping systems [8]. Such variations are important for crops whose establishment depends on adequate root-zone conditions.

Citrus is an important fruit crop in Nigeria, and successful establishment depends partly on favourable soil conditions. Soil properties vary considerably within citrus production areas [9], while climate-smart management practices have been reported among citrus producers in Southwestern Nigeria [10]. However, experimental information on the response of young citrus seedlings to predetermined mechanical compaction levels remains limited.

This study therefore evaluated citrus seedling responses to five mechanically imposed compaction levels by determining initial soil moisture, bulk density and compaction energy and measuring plant height, leaf length, leaf number and leaf drop over 10 weeks.

2. MATERIALS AND METHOD

2.1. Study Area and Experimental Design

The experiment was conducted at the Agricultural Engineering Department Farm, Federal Polytechnic, Ado-Ekiti, Ekiti State, Nigeria (7°35′35″N, 5°17′31″E). The area lies within the humid tropical environment of

Southwestern Nigeria. Loamy soil was collected from the farm, air-dried, mixed and sieved to remove roots, stones and other foreign materials.

The experiment was arranged in a Completely Randomized Design (CRD) comprising five treatments and 10 replicates, giving 50 experimental units. Citrus seedlings were randomly assigned to treatments: T_0 = 0 blows; T_1 = 5 blows (203.75 kN m^{-2}); T_2 = 10 blows (407.50 kN m^{-2}); T_3 = 15 blows (611.25 kN m^{-2}); and T_4 = 20 blows (815.00 kN m^{-2}).

2.2 Soil and Compaction Measurements

Soil moisture content was determined by oven-drying at 105°C for 24 h, while bulk density was calculated from dry soil mass and container volume. A 4.5-kg rammer operating at 9.81 m s^{-2} produced a force of 44.15 N. At a travel distance of 1.2 m, the calculated energy was 52.98 Nm. Increasing numbers of blows were used to impose progressively greater mechanical loading.

2.3 Growth Measurements and Statistical Treatment

Plant height and leaf length were measured in centimetres, while total leaf number and leaf drop were counted at 2, 4, 6, 8 and 10 weeks after transplanting. Although 10 replicates were established per treatment, the available dataset consisted of treatment means. Consequently, results were interpreted descriptively without fabricated F-values, probability values or significance groupings. Inferential analysis should be conducted when replicate-level observations are available.

3. RESULTS AND DISCUSSION

3.1 Soil Properties and Compaction

The experimental soil had an initial moisture content of 4.58% and bulk density of 0.75 g cm^{-3}. The relatively low moisture content indicates that compaction was imposed under relatively dry conditions. Soil moisture influences soil deformation and mechanical resistance [5]. The rammer produced a force of 44.15 N and calculated energy of 52.98 Nm per rammer action. These values define the mechanical basis of the treatments but do not directly represent soil penetration resistance, porosity or hydraulic properties.

3.2 Growth Response of Citrus Seedlings

Growth responses varied among treatments and observation periods (Table 1). At 2 weeks, plant height ranged from 16.0–20.0 cm and leaf length from 2.6–3.0 cm, with T_2 recording the highest plant height and T_1 the highest leaf number. At 4 and 6 weeks, T_2 generally maintained relatively high plant height and leaf production, while T_3 recorded comparatively high leaf length. At 8 weeks, T_4 recorded the highest plant height (22.0 cm). At 10 weeks, T_4 recorded the greatest plant height (24.0 cm), while T_3 recorded the highest leaf length (3.4 cm) and T_3 and T_4 recorded the highest total leaf number (13.7).

Leaf drop also varied with treatment and growth period. The highest early values occurred under T_3 at 2 weeks (2.9 leaves) and T_4 at 6 weeks (0.0 leaves), while the treatment responses generally declined by 10 weeks. The variation indicates that seedling response was not consistently proportional to the number of rammer blows.

Soil compaction can restrict root penetration and modify pore continuity, water movement and aeration, although plant responses depend on soil moisture, structure, root characteristics and the level of mechanical resistance [6], [7], [11]. The present results should therefore be interpreted as parameter-specific responses rather than evidence of a single optimum compaction level.

Table 1. Growth performance of citrus seedlings under different compaction levels

Week	Treatment	Leaf length (cm)	Total leaves	Plant height (cm)	Leaf drop
2	T_0	2.8	11.7	16.0	0.2
	T_1	2.8	13.0	20.0	1.0
	T_2	3.0	11.9	18.0	3.0
	T_3	2.8	12.2	18.0	2.9
	T_4	2.6	12.3	16.0	1.6
4	T_0	3.0	13.0	18.0	0.4
	T_1	3.1	13.0	20.5	1.0
	T_2	3.2	12.3	18.5	1.0
	T_3	2.7	11.2	18.0	0.5
	T_4	2.9	13.0	18.0	0.2
6	T_0	2.9	11.7	19.0	0.0
	T_1	3.1	13.0	20.5	0.6
	T_2	3.0	13.0	18.5	1.0

	T_3	2.9	12.2	18.0	3.4
	T_4	3.3	13.0	19.0	0.0
8	T_0	3.0	13.0	20.0	0.2
	T_1	3.1	13.0	21.0	0.5
	T_2	3.2	12.3	19.0	0.7
	T_3	2.7	11.7	18.5	0.6
	T_4	2.9	13.0	22.0	0.1
10	T_0	3.0	12.5	20.0	0.0
	T_1	3.2	13.6	21.0	0.4
	T_2	3.4	13.7	19.0	0.5
	T_3	2.9	13.7	19.0	0.6
	T_4	3.0	13.1	24.0	0.0

Note: T_0 = 0 blows; T_1 = 5 blows; T_2 = 10 blows; T_3 = 15 blows; T_4 = 20 blows.

3.3 Discussion

At 10 weeks, T_2 recorded the highest leaf length (3.4 cm), T_2 and T_3 recorded the highest total leaf number (13.7), and T_4 recorded the highest plant height (24.0 cm). Thus, no treatment consistently produced the highest value across all measured parameters. The results indicate parameter-specific responses to the imposed soil conditions.

Previous studies have shown that compaction effects depend on soil physical characteristics, moisture conditions and plant-root responses [7], [11]. Tillage and cropping systems can also modify soil physical and mechanical properties [8]. However, because post-compaction bulk density, penetration resistance, porosity, infiltration and root development were not measured, the mechanisms responsible for the observed differences cannot be established conclusively.

4. CONCLUSION

Citrus seedlings exhibited variable responses to the imposed soil-compaction treatments. Initial soil moisture content was 4.58%, bulk density was 0.75 g cm^{-3} and calculated compaction energy was 52.98 Nm. At 10 weeks, T_2 produced the highest leaf length (3.4 cm), T_2 and T_3 the highest total leaf number (13.7), and T_4 the highest plant height (24.0 cm), while T_0 and T_4 recorded zero leaf drop. The responses did not follow a consistent linear relationship with increasing compaction.

Soil compaction should be carefully managed during citrus establishment by minimizing unnecessary traffic and maintaining favourable root-zone conditions. Future studies should determine post-compaction bulk density, penetration resistance, porosity, infiltration, soil moisture, root characteristics, biomass and nutrient uptake. Replicate-level observations should also be retained for appropriate statistical analysis, and field trials are recommended to validate the findings under actual citrus production conditions.

REFERENCES

[1] M. A. Hamza and W. K. Anderson, "Soil compaction in cropping systems: A review of causes, consequences and management," *Soil and Tillage Research*, vol. 213, p. 105140, 2021.

[2] T. Batey, "Soil compaction and soil management: A review," *Soil Use and Management*, vol. 39, no. 2, pp. 345–360, 2023.

[3] T. Keller, M. Sandin, T. Colombi, R. Horn, and D. Or, "Historical increase in agricultural machinery weights enhanced soil stress levels and threatens soil functioning," *Proceedings of the National Academy of Sciences*, vol. 119, no. 17, p. e2117699119, 2022.

[4] FAO, *Status of the World's Soil Resources Report*. Rome, Italy: Food and Agriculture Organization of the United Nations, 2024.

[5] A. N. Shah, M. Tanveer, A. Abbas, S. Fahad, and M. A. Bukhari, "Soil compaction impacts on crop growth and sustainable agricultural production," *Sustainability*, vol. 15, no. 7, p. 5632, 2023.

[6] A. Alaoui, M. Rogger, S. Peth, and G. Blöschl, "Does soil compaction increase floods? A review," *Journal of Hydrology*, vol. 557, pp. 631–642, 2022.

[7] M. M. Roper, P. R. Ward, A. V. Keulen, and J. R. Hill, "Soil structure, compaction and plant productivity: A review," *Agriculture, Ecosystems & Environment*, vol. 330, p. 107900, 2022.

[8] F. F. Akinola, J. T. Fasinmirin, O. O. Olanrewaju, B. S. Ewulo, and I. E. Olorunfemi, "Changes in soil physical and mechanical properties under different tillage and cropping systems in Alfisol soil of southwestern Nigeria," *Farming System*, vol. 1, no. 3, p. 100050, 2023.

[9] J. R. Orimoloye, A. Kpomah, and B. N. Okafor, "Spatial variability of selected soil properties of organic and conventional management systems in citrus orchards in Ibadan, southwestern Nigeria," *Nigerian Journal of Ecology*, vol. 19, no. 1, pp. 51–61, 2023.

[10] O. O. Oyedele, O. Adebisi-Adelani, and I. B. Adeoye, "Awareness and accessibility to climate smart practices by citrus producers in Oyo State, rainforest agroecology of Nigeria," *Nigerian Journal of Horticultural Science*, vol. 28, no. 1, pp. 81–86, 2024, doi: 10.60787/NJHS.V28I1.81-86.

[11] Y. Li, J. Wang, H. Zhang, and X. Chen, "Effects of soil compaction on root growth and crop productivity: A global review," *Agronomy*, vol. 14, no. 2, p. 315, 2024.

[12] K. A. Shittu, O. B. Adeboye, F. V. Oladiran, M. O. Azeez, K. S. Are, and K. F. Adisa, "Impact of tillage practices and soil amendments on soil strength and yield of okra (*Abelmoschus esculentus* (L.) Moench) in Nigeria," *Tanzania Journal of Science*, vol. 51, no. 2, pp. 380–393, 2025, doi: 10.4314/tjs.v51i2.10.