

RESEARCH ARTICLE

Effects of Tillage Types on Soil Chemical Properties, Growth and Yield of *Arachis hypogaea* L (Groundnut)

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The study purpose was to determine the effect of tillage types: Flat till (FT), Mound till (MT) and Ridge till (RT) on the chemical properties, growth and yield of groundnut. The research was executed in a randomized complete block design (RCBD) to ascertain the effect of tillage types on soil chemical properties. Plant height, leaf area, weight (Fresh/Dry) and number of leaves were measured and subjected to Analysis of Variance (ANOVA) and treatment means were compared using FLSD (Fisher's Least Significant Difference). The results revealed that the different tillage types significantly improved soil pH 5.03 (FT), OM 3.25% (MT), AvP 23.73mg/kg (FT) and BS 77.79% (RT), CEC 7.31cmol/kg (RT), and N 0.22 (MT). The study established that sandy soils with poor soil organic matter and leaching of nitrate below the rooting depth were the reason for the low total N content after harvest, with a mean value of 12 (leaf area), RT had the highest leaf area, 16.83 (no branches) and 52.92 (Plant height) compared to FT and MT. The highest yield observed was 0.28kg plant⁻¹ (flat till), compared to 0.27kg plant⁻¹ (ridge till), and 0.20kg plant⁻¹ (MT) and there was a significant difference between tillage types ($P < 0.05$). This study showed that flat tillage significantly improved the growth and yield of groundnut, while tillage types significantly enhanced chemical properties except nitrogen.

Keywords: Soil chemical properties, Tillage, Growth and yield, yield, Groundnut.

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This is an open-access article distributed under the terms of the [Creative Commons Attribution-NonCommercial 4.0 International License \(CC BY-NC 4.0\)](https://creativecommons.org/licenses/by-nc/4.0/).**1. Introduction**

Groundnut is an energy-rich crop and needs a sufficient amount of nutrients and moisture to meet its requirements for growth and development and high yields. Sustainable groundnut production is ascribed to adopting nutrient management techniques [1]. Tillage, therefore, contributes to sustainability in weed management, erosion control, evaporation reduction, seedbed preparation, and improved water infiltration. The advantages add up to higher crop yields; tillage techniques, however, contribute to yield variability and deteriorating soil quality [2]. A study by authors [3]-[4] in their study on tillage practices show that direct sowing may lead to lower crop yield than conventional tillage. The tillage effect on yield output is enhanced by creating the appropriate seed conditions for plant emergence, development, and unhindered root expansion; thus, crops planted

using different tillage methods have different or fluctuating characteristics [5].

Tillage enhances root vertical and horizontal proliferation, increases root volume, and removes impedance that could otherwise prevent root proliferation [6]. Tillage has a significant effect due to microbial activity that influences soil aeration, moisture, temperature, bulk density, penetration, resistance, water intake, and water extraction by plant roots [7]. The conventional and conservational tillage methods have been prompted by the hunt for good tillage systems [8], [23]. In contrast, conventional tillage exposes soil to factors that could increase nutrient mineralisation and organic matter, which improves soil porosity and water-holding capacity [9], compared to a conservational tillage approach. Conventional tillage increases copper, manganese, and iron levels in arable soil [10]. According to [11], it is important to adopt a tillage pattern that best preserves the soil's physical qualities required for the sustainability of crop production [29]. Despite the function of tillage in crop production, the majority of farmers globally lack knowledge and information on the utilisation of

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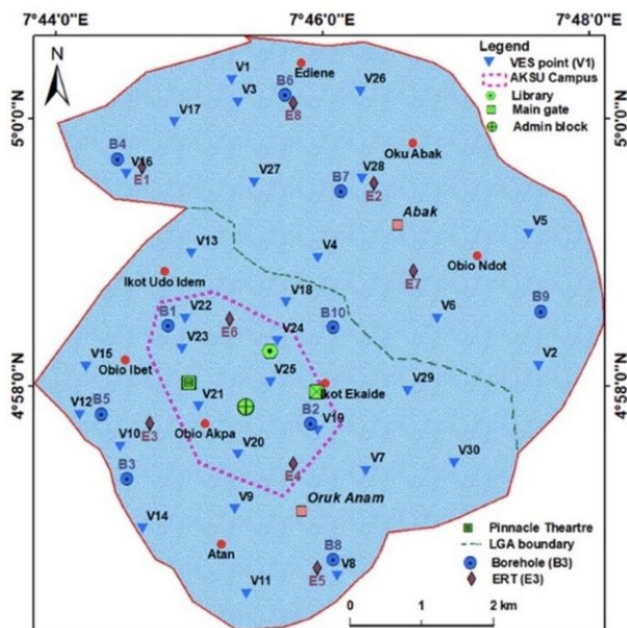


Figure 1: Google Maps image of case study area.

tillage. Hence, the study's objective was to ascertain how types of tillage affect groundnut growth, yield, and the soil characteristics.

2. Materials and method

2.1. The Area of case study

The investigation took place within Akwa Ibom State University, Research Farm, Obio Akpa Campus, Oruk Anam Local Government Area, Akwa Ibom State, Nigeria, from March 31, 2019, to August 30, 2020. The study area is located between latitudes 4.5000° S and 5.5000° N and longitudes 7.5000° E and 8.0000° E, and it is located within the humid tropical rainforest, characterised by two seasons: rainy (March – October) and dry (November – early March) seasons with a short dry period in August, otherwise called the 'August break'. This region receives high rainfall of between 2000 and 2500 mm [12]. The temperature is 23.27°C, and the relative humidity ranges from 75% to 79%. Soils are acidic [13]. The vegetation is mostly secondary forest [14]. The case study area is shown in Figure 1.

2.2. Soil sampling and analysis

Composite samples (soil) were delineated at depths of 0 to 15 cm at the commencement and after crop harvest for analysis. The physical and chemical properties were examined at the first and second years from the beginning of the experiment and after the completion of the first and second cropping cycles. Soil pH was measured in a 1:2:5 soil water suspension [15]. Particle size distribution was established by the Bouyoucos hydrometer method after dispensing the soil sample with sodium hexametaphosphate (calgon) solution [16]. Bulk density (Bd) was ascertained by the direct core sampling method [17] and determination of SOC by the Walkley and Black method [18], while the Kjeldahl method was used for the determination of nitrogen [19], P by the Bray and Kurtz No. 1 method [20], K by the

ammonium acetate method, and cation exchange capacity (CEC) was ascertained by summing up total exchangeable bases (TEB) [21]. Base saturation was ascertained using TEB and ECEC.

2.3. Experimental designs and treatment application

The research was carried out using three tillage types (zero till, mound till and ridge till) in a randomised complete block design. Each replication was 12 plots; each plot measured 1.2 x 4 m. The distance between blocks was 1.5 m, while that of plots within a replicate was 1 m; each subplot was 4 x 1.2 m. The plot was cleared, mapped, and planted at various tillage types as required by the experiment.

2.4. Agronomic practices

The groundnut was sown immediately after the initial rain, which was on the 31st of March 2020 as shown in table 0.2. Seeds were treated with an insecticide to prevent insects and fungal attacks. Three seeds were planted at a depth of 3-5 cm per stand at a spacing of 0.4 x 1 m as shown in table 0.2 and plant population was 108 plants. A blanket application of poultry manure and potassium was done a week before and two weeks after crop emergence, and weeds were kept free and controlled manually [22].

2.5. Collection of data on growth and yield

Data collected was within four mid rows of groundnut stands; agronomic variables measured were height and leaf area index which was assessed by measuring the length and maximum breadth of randomly chosen functional leaves multiplied with 0.75 as a factor [23]. The data were taken at two-week intervals; threshing percentage, 100-seed weight, and pod and seed yields (6 ha¹) were taken at crop harvest.

2.6. Data analysis:

The data collected was analysed using [24] for variance analysis at the 5% probability level while Fisher's Least Significant Difference (FLSD) was used to compare the significant treatment means.

3. Results and discussion

3.1. Initial soil test result (soil properties) before planting:

The initial soil test result before treatment application, as shown in table 1, shows that the soils are mostly sandy with 83.40% sand, 2.70% silt, and 4.0% clay, respectively [25]. The soil texture could adversely affect crop growth because of low water-holding capacity. Soil pH was very strongly acidic (4.68), probably due to leaching. This may affect soil microorganisms and form certain toxic chemicals.

Organic matter content was low at 3.72%; this value is less than 10% given by [26] as ideal for soils in Akwa Ibom State. This suggests that the soil could not supply essential nutrients, for instance, OM and exchangeable cations, to crops needed for improved crop production.

The nitrogen value was 0.81% (high), which was above the initial limit of 0.15%. The high level of nitrogen supports plants' rapid growth and encourages the development

Table 1: Results of chemical properties before treatment application at (0–15 cm) depth.

Soil properties	Values
pH (H ₂ O) 1:2.5	4.68
EC (dS/m)	0.016
Organic matter (%)	3.72
Total nitrogen (%)	0.81
Available phosphorus (mg/kg)	17.67
Exchangeable bases	Values
Ca (cmol/kg)	13.16
Mg (cmol/kg)	5.39
Na (cmol/kg)	0.53
K (cmol/kg)	1.71
Exchangeable acidity (cmol/kg)	4.68
ECEC (cmol/kg)	25.47
Base saturation (%)	81.63
Particle size distribution	Values
Sand (%)	93.30
Silt (%)	2.70
Clay (%)	4.00
Textural class	Sandy clay

Table 2: Cultural practices followed in groundnut production.

Cultural practices	Groundnut
Variety	SAMNUT-16 (M554.76)
Spacing	0.4 m × 1 m
Date of planting	31 March 2020
Planting season	2019/2020
Planting depth	3–7 cm
Water management	Rain-fed
Insect and disease management	No pests or diseases observed
Weed control	Hand weeding
Maturity	4 months
Harvesting	August 2019/2020

of healthy foliage and fruits. Exchangeable calcium was 13.16 cmol/kg, which was reported as high above the critical value of < 20 cmol/kg [27]. Exchangeable magnesium content was 5.39 cmol/kg; this value was higher than the critical value of 0.05 cmol/kg. The exchangeable sodium value was 0.53 cmol/kg compared to the critical value of 0.1 cmol/kg, as reported by [27]. Exchangeable K was very high (1.71 cmol/kg), and the value was higher compared to the critical level of 0.20 cmol/kg as reported by [27]. This level of K may lead to a reduction in magnesium and calcium uptake by plants.

Available phosphorus was 17.67 mg/kg in the initial soil analysis, more than the critical value of 0.05 mg/kg. Effective cation exchange capacity (ECEC) was 25.47 cmol/kg, which was above the critical value of 20 cmol/kg regarded to be suitable for crop production [27]. The base saturation (BS) value was 81.63%. This level could be ascribed to a high level of Mg and Ca concentration and some basic cations, which are important indices of fertile soil.

Table 3: Main effects of tillage types on soil chemical properties.

Tillage types	pH	OM	Total N	Av.P	CEC	ECEC	BS
Flat till	5.031a	3.24a	0.084a	23.73a	5.36b	7.613b	67.80b
Mound till	4.15b	3.25a	0.22b	17.63b	5.23b	7.38b	71.04b
Ridge till	4.58a	3.06a	0.100a	14.13b	7.31a	9.16a	77.79a
LSD(0.05)	1.09	0.25	0.17	9.73	1.34	1.38	6.56

3.2. Main effect of tillage types on soil chemical properties

3.2.1. Soil pH

Tillage types had a significant effect on pH ($P < 0.05$). Flat tillage had a mean pH value of 5.031 (highest), ridge plots had 4.58 and mound plots had the lowest pH value of 4.15. The values obtained in mound plots could be ascribed to the low rate of microbial events and OM decomposition to enhance soil pH. The practices lead to a decrease in pH. Hence, MOP changed pH from very strongly acidic as shown in Table 1 to moderately acidic soil, as shown in Table 3 as reported by [27]. This agreed with the result obtained by [28], who observed no tillage to reduce soil pH. This difference could be ascribed to environmental factors and differences in soil and crop characteristics.

3.2.2. Organic Matter (OM)

Different tillage types improved OM generally. The highest OM content was obtained in mound tillage at 3.25%, followed closely by flat tillage at 3.24% while ridge tillage was 3.06%. This significant soil OM increase confirms that OM breakdown is aided by tillage practices through aeration and microbial activity.

3.2.3. Total Nitrogen (TN)

Tillage types had no significant effect on TN; the nitrogen decrease could be ascribed to the uptake of nitrogen by the plant even though groundnut fixes nitrogen, and the uptake exceeds the residual soil nitrogen. This result shows that the low total N content after harvesting groundnut to sandy soils with low SOM content and leaching of nitrate below the rooting depth and also observed a trend of soil OM showing potential OM decomposition and total nitrogen release.

3.2.4. Available Phosphorous (AvP)

Tillage types significantly improved phosphorus. Flat tillage available phosphorous value was 23.73 mg/kg, followed by mound tillage at 17.63 mg/kg, while ridge tillage had the least mean available P, 14.13 mg/kg, respectively.

Means not sharing the same alphabet under the same column are significantly different at 5% level of probability.

3.3. Effective cation exchange capacity (ECEC)

As shown in Table 3, the effect of tillage types on ECEC after harvest was significant ($p < 0.05$); ridge till was 9.16 cmol/kg, followed by flat tillage (7.613 cmol/kg), while mound tillage had the least value. The higher the ECEC, the more the negative charge and cations are seen in soil.

3.3.1. Base saturation (BS)

Tillage types significantly increased base saturation ($p < 0.05$). Ridge tillage had a base saturation of 77.79%, followed by mound tillage (71.04%), while flat tillage had the least base saturation (67.80%).

4. Tillage types effect on growth of groundnut plants

4.1. Tillage effect on plant height in cm after treatment application

Tillage systems significantly affected groundnut height at different growth stages. Groundnut height varied between 34.75 and 52.92 cm at 6, 8 and 12 weeks after treatment. Ridge tillage recorded the highest mean value of 52.91 cm and mound tillage 47.83 cm, while at 12 weeks, respectively, the mean value was 47.41 cm in flat tillage. Secondly, there was no significant tillage effect on plant height. Means not sharing the same alphabet under the same column are significantly different at 5% level of probability.

4.1.1. Tillage effect on groundnut number of branches at 6WAP, 8WAP, and 12WAP

Considering the various tillage types – flat, mound, and ridge tillage types – groundnut branches increased significantly at $p < 0.05$. As shown in table 4, under ridge tillage, groundnut had more branches, 104% (16.83), equal to other types of tillage. Mound tillage was followed by 95.79% (15.33), while flat tillage produced a smaller number of branches 12 weeks after planting. Tillage had a significant effect on the number of branches at 12WAP ($p=0.49$) at a 0.05 level of significance.

4.1.2. Tillage effect on leaf area of groundnut:

The tillage method's effect was not significant ($p > 0.05$). Leaf area (12.25 cm²) at 6 WAP obtained in groundnut plants grown on mound tillage was highest, followed by ridge tillage (12.19 cm²), while those grown on mounds at 8 WAP and 12 WAP had the least leaf area (10.12±10.03 cm²). The result in Table 4 shows that tillage types had no substantial effect on groundnut leaf area throughout the growth period. Supplementary application of K promoted growth biomass in various crops [30].

5. Tillage types effect on yield of groundnut plants

5.1. Tillage effects on fresh weight of groundnut after harvesting

'Fresh weight' refers to the weight recorded immediately after the ground plant is harvested. Table 5 shows the fresh weight means of ground plant yield. The table shows that flat till fresh weight (0.28 kg) was the highest, followed by ridge till (0.27 kg), while mound till gave the least fresh weight (0.20 kg), and their mean differences were significant ($P < 0.05$). This result agreed with a field trial conducted by [36] which showed that tillage types had a substantial effect on the fresh weight of groundnut plants. In Table 5, not sharing the same alphabet under the same column

are significantly different at 5% level of probability. Most groundnut pods (77.83) were produced by ridge tillage equaled to other tillage techniques while the seeds (105.25) with the highest number were produced by flat tillage; the mean differences were statistically significant ($p < 0.05$).

5.2. Effects of tillage types on the numbers of groundnut pods

As shown in Table 5, tillage types significantly affected the number of groundnut pods and varied between 57.33 and 69.42; at harvest, ridge tillage had more pods (77.83), followed by flat tillage (69.42) and mound tillage (57.33). The mean difference between ridge-till and flat till was significant compared to mound tillage. The result from the experiment agreed with [37].

5.3. Effects of tillage types on the number of groundnut seeds

The result shown in table 0.5 shows that flat tillage b cv had higher seed numbers (105.25 seeds), followed by those planted on the ridge (103.75), while those planted on the mound gave the least number of seeds (62.67 seeds). This result agreed with the field trial conducted by [31]. The mean differences were significant ($p < 0.05$); hence, tillage types significantly affected the number of groundnut seeds.

6. Conclusion

The soils in Akwa Ibom State University, Research Farm, Obio Akpa Campus, Oruk Anam Local Government Area, Akwa Ibom State, Nigeria, are mostly sandy. The changes in nutrient elements depend heavily upon tillage type and tillage equipment used. The tillage types had a significant effect on chemical properties, with the exception of nitrogen, which was ascribed to plant uptake. Groundnuts grown on flat tillage had 105.25 seeds, followed by those grown on ridges and mounds, which gave the least number of seeds. Therefore, the experimental results would provide some useful information on the appropriate tillage type for groundnut production.

Declarations and ethical statements

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Artificial Intelligence usage statement: During the preparation of this manuscript, the authors utilized Grammarly solely for language refinement and grammatical corrections. The authors carefully reviewed and revised the generated content and take full responsibility for the accuracy, integrity, and originality of the final manuscript.

Availability of data and materials: The data and/or materials that support the findings of this study are available from the corresponding author upon reasonable request.

CRediT authorship contribution statement

Precious C. Emmanuel: Conceptualization, Investigation, Data collection, Original draft writing & Editing.
Okon Udo: Conceptualization, Formal analysis & Validation.

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Table 4: Comparison of leaf area, number of branches and plant height (cm) for tillage at 6, 8 and 12 weeks after planting.

Tillage Types	Leaf area			No. of branches			Plant height (cm)		
	6WAP	8WAP	12WAP	6WAP	8WAP	12WAP	6WAP	8WAP	12WAP
Flat tillage	12.19a	10.35a	11.60a	8.00a	10.83b	15.08b	35.25a	40.83a	47.42a
Ridge tillage	12.19a	11.03a	12.00a	8.25a	12.50ab	16.83a	37.00a	44.50a	52.92a
Mound tillage	12.25a	10.03a	10.12a	7.83a	12.33b	15.33b	34.75a	38.38b	47.83a
LSD (0.05)	2.57	2.13	2.83	1.89	1.77	1.70	6.29	5.95	6.51

Table 5: Main effects of tillage types on the yield of groundnut.

Tillage types	Fresh weight (kg)	No.of grou ndnut pods	No.of seeds per plant	Weight of seeds (kg)
Flat tillage	0.28a	69.42a	105.25a	0.02a
Ridge tillage	0.27a	77.83ab	103.75ab	0.02a
Mound tillage	0.20a	57.33a	62.67b	0.02a
LSD (0.05)	0.11	31.94	48.62	0.00

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