Effect of Auger size and Depth of Operation on Bulk Density, Cone Index, Germination, Root Length, Root Weight and Cob Weight for Maize Crop

Abstract

Minimum tillage methods offer numerous benefits compared to conventional tillage, including reduced farm operations to establish a good seedbed. Spot tillage, in particular, has advantages such as preserving soil structure, preventing erosion, saving time and energy, and reducing input costs. For this study, the effect of different auger size (40, 50 & 70mm) which was operated by 12V DC motorat different depth of operations (80, 120 & 160mm) were determined. The different parameters were measured such as bulk density, cone index, germination percentage, root length, root weight and cob weight for maize crop (GAYMH-3) and same for traditional sowing method. The results showed that auger size (40, 50 & 70mm) and depth of operation (80, 120 & 160mm) significantly influenced bulk density as bulk density of the soil increased with depth and decrease with increase in auger size. The larger auger (70mm) resulting in lower values in bulk density due to more soil removal. However, cone index was not significantly affected by auger size (40, 50 & 70mm) and depth of operation (80, 120 & 160mm).Seed germination for maize was consistently around 90%, with no significant effects of auger size and depth of operation were observed. An auger size (70mm) was associated with shorter root lengths. Increasing depth resulted in greater root development, leading to longer roots was observed in small size augers. Larger auger size and deeper depths generally resulted in higher root weights. Cob weight increased with auger size (70mm) and deeper depths. Auger size and depth significantly impacted cob weight.Overall, results showed that auger having the size of 70mm and depth of operation at 160mm was desirable compared to other auger size in terms of lower bulk density and cone index but increased root weight and cob weight of maize crop.

Keywords: Minimum tillage, tillage, spot tillage, auger, maize

1. Introduction

Tillage is an integral part of crop production system. Tillage can be referred to as the practice of changing the condition of the soil to provide favorable conditions for plant growth. Conventional tillage often wastes energy and sometimes destroys soil structure(Sahay, 2008). A significant change in tillage practices has recently occurred and various new concepts including minimum tillage, zero tillage, and stubble mulch tillage, have been introduced.

Minimum tillage reduces tillage operations to what is necessary to provide a good seed bed. The least amount of soil disturbance, such as ripping or planting at spot, constitutes minimum tillage. According to the fundamentals of minimum tillage, soil turnover should be limited by limiting soil disturbance to a specific region. In essence, it improves the soil structure, influences plant growth and development, thus increasing productivity. This refers to those tillage practices whereby minimum or no disturbance is affected on the soil for purposes of crop production (Rusu *et al.*, 2009).

It comprises digging holes or furrows into which seeds are to be planted. The remaining portion of the field appears unaltered, and crop residue is still visible on the ground. This practice reduces soil erosion, causes build-up of organic matter in the soil, hence better chemical and physical soil fertility. Moreover, minimum tillage indicates less labour, less energy, and less time spent on the preparation of the ground. As a result, cropping may be accomplished in a short period of time (Biamah. 2005). Spot tillage, a subset of minimum tillage, further refines the approach by addressing specific soil issues while minimizing overall disruption. Spot tillage is a soil management technique that involves selectively tilling of the soil in the exact “spot” where the planting is needed. Spot tillage causes the least amount of soil disturbance and conserves soil moisture while still achieving effective soil management(Texas A&M Forest Service). Therefore, thestudy for spot tillage operation using different auger size and depth of operation was conductedand assessed for determining the effect of bulk density, cone index, seed germination, root development and cob weight using different auger size and depth of operation for maize crop (GAYMH-3).

2. Materials and Methods

Field experiments were conducted at Instructional Research Farm, College of Agricultural Engineering and Technology, AAU, Kakanpur, Godhra, Panchmahal during 2022-23. The experimental site is located in middle Gujarat Agro-climatic Zone of Gujarat State having sandy loam soil.

The experiment aimed to evaluate tillage operation by varying auger size (40, 50, & 70mm), depth of operation (80, 120, & 160mm) which was operated by 12V DC motor respectively. The optimal auger speed for operation was 350 rpm. The experiments were conducted on 27 plots of net size 1.2 m x 10m and for control plot of net size 5m x 32m. The maize crop (GAYMH-3) variety was taken for experiment having crop spacing of 20 x 60 cm plant to plant and row to row spacing. The effect of various parameters like auger size and depth of operationwith 3 replications including different parameters under study and treatments combinations are given in Table1&2 respectively.

1. Statistical design: FRBD
2. No. of treatment combination: 3 x 3 = 9
3. No. of replications: 3
4. No. of treatments: 27

(a) 40mm **(b) 50mm** **(c) 70mm**

Fig. 1 Auger with different size

Table 1 Details of parameters under field study

Sr. No.	Independent parameters	No. of levels	Values	Dependent parameters
1.	Auger dia (mm)	3	$A_1 = 40$ $A_2 = 50$ $A_3 = 70$	Moisture content, bulk density, cone index, seed germination of maize and root development (root length & root weight)& Cob weight for maize crop.
2.	Depth (mm)	3	$D_1 = 80$ $D_2 = 120$ $D_3 = 160$	
3.	Crop	1	Maize (GAYMH-3)	

Table 2 Details of treatments and their combinations under study

Name of treatment	Combination
T_1	A_1D_1
T_2	A_2D_1
T_3	A_3D_1
T_4	A_1D_2
T_5	A_2D_2
T_6	A_3D_2
T_7	A_1D_3
T_8	A_2D_3
T_9	A_3D_3

3.1 Soil properties

3.1.1 Moisture content

Moisture content for soil was computed on dry basis. Soil samples were collected from 0 to 20cm depth of soil surface before operations for determination of moisture content and bulk density. The moisture content (Dry basis) was determined by the following relationship:

$$\text{Moisture content (\%)} = \frac{W_w - W_d}{W_d} \times 100$$

Where, W_w = Mass of wet soil sample, g

W_d = Mass of dry soil sample, g

3.1.2 Bulk density

The bulk density was measured before tillage from 0 to 20 cm depth.

$$\text{Bulk Density} \left(\frac{g}{cc}\right) = \frac{\text{Mass of dry soil sample (g)}}{\text{Volume of the core sample (cc)}}$$

3.1.3 Cone index

The cone index was measured from 0 to 20 cm depth by cone penetrometer. The cone index was determined by the formula as given in Eq.

$$\text{Cone index (kPa)} = \frac{\text{Force applied (kg)}}{\text{Unit area (cm}^3\text{)}}$$

3.2 Seed germination

Germination percentage is an estimate of the viability of population of seeds. The germination percentage was assessed in laboratory test for maize. Total 50 seeds were taken and seeds were spread on a layer of moist filter paper and place in dark for 4-5 days. Also, the field test was assessed for germination percentage. To calculate germination percentage (GP) is given in the formula as follows

$$GP\ (\%) = \frac{\text{Seeds germinated}}{\text{Total seeds}} \times 100$$

Fig.2Germination of maize crop in laboratory

Fig. 3 Germination of maize crop in field

3.3 Root development

3.3.1 Root length

The longest root for fully matured plant was measured by measuring scale for maize crop as shown in Fig. 4.

3.3.2 Root weight

Also, the root weight was measured by weighing balance for different treatments and form control plot.

3.3.3 Cob weight

The fresh cobs were taken from the test plots from different combinations of treatments. Total 10 fresh cobs were randomly taken each treatment and also from control plot for measuring weights of cobs using weighing balance.

Fig. 4Root developed of maize crop of different treatments
(where, T_1 = 80mm, T_2 = 120mm & T_3 = 160mm tillage depth)

3. Results and Discussions

Field experiments were carried out by varying different auger size and depth of operation on soil properties.

3.1 Soil properties

The physical properties of soil were measured in terms soil moisture content, bulk density and cone index. The soil moisture content of the field was measured and the results revealed that the average moisture content was 12%. The data regarding bulk density of soil was recorded before tillage operations. The results show that the average bulk density was 1.70 g/cc before tillage operation. Similarly, the data regarding cone index of soil was recorded before tillage operations and results show that average cone index was 91.66 kgf before tillage operation.

The effect of different independent parameters on each dependentparameter are discussed as below:

3.2 Effect of Auger Size and Depth of Operation on Soil Properties

The effect of auger size and depth of operation on soil properties in terms of bulk density and cone index was observed and their results obtained are discussed below.

3.2.1 Effect on bulk density

The effect bulk density of soil (Appendix A) at three different depths D_1, D_2 and D_3(80, 120, and 160mm) for three different augers A_1, A_2, and A_3 having dia. size of 40, 50 and 70mm were measured as shown in Table 3.

Table 3Data obtained for bulk density

Auger size (mm)	Bulk density (g/cc)		
	Depth of 80mm	Depth of 120mm	Depth of 160mm
40	1.27	1.31	1.33
50	1.27	1.29	1.32
70	1.25	1.27	1.29

The data from the graph (Fig.5) revealsspecific values for bulk density corresponding to each auger size and depth.The results show that at an auger size of 40mm, the bulk density ranges from 1.27 g/cc at 80mm depth to 1.33 g/cc at 160mm depth. For an auger size of 50mm, the bulk density varies between 1.27 g/cc at 80mm depth and 1.32 g/cc at 160mm depth. Similarly, for auger size of 70mm, the bulk density ranges from 1.25 g/cc at 80mm depth to 1.29 g/cc at 160mm depth. Thus, results show that the bulk density of the soil increases with depth. The graph shows that there is some variation in the bulk density of the soil at each depth, even for the same auger.The reason for this decrease in bulk density is that a larger auger dia removes more soil from the hole, which leaves less soil behind to compact. This results in a lower bulk density.

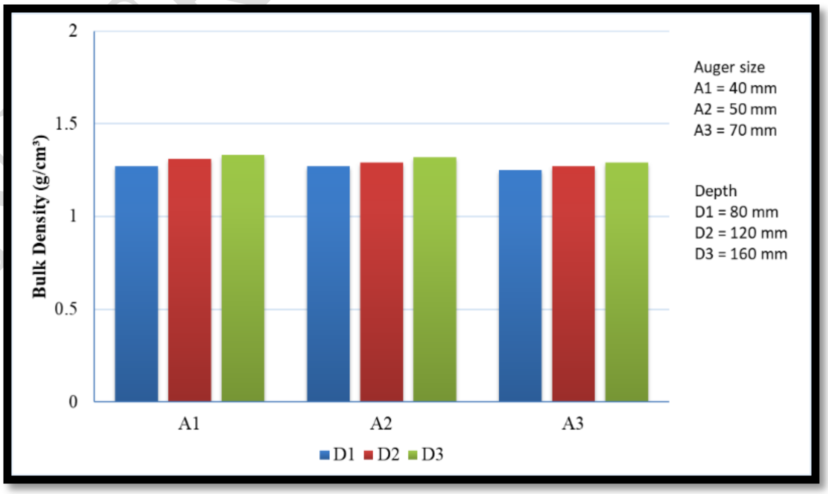

Fig. 5 Effect of auger size and depth on bulk density

The ANOVA Table 4 shows the effect of auger size and depth of operationon bulk density. The effect of auger size on bulk density shows significant ($p < 0.05$). It may be due to different size of augers having different curve angle or pitch. So, larger the dia. of auger, removes more soil. As stated, that the bulk density of soil decreased as the size of the auger increased (Gendy, *et al.* 2009).The effect of depth of operation on bulk density shows significant ($p < 0.05$).This may be due to soil particles are more tightly packed at greater depths. The finding revealed that the bulk density typically increases with depth, as the weight of the overlying soil increases the pressure on the lower layers. This can lead to compaction, which reduces the amount of pore space in the soil (Weil & Brady, 2017). However, the interaction between the auger size and depth of operation on bulk density is not significant ($p > 0.05$).

Table 4 ANOVA for effect of auger size and depth on bulk density

Source of Variation	SS	df	MS	F	P-value	F crit
Auger size	0.0056	2	0.00	24.69	6.9339E-06	3.55
Depth of operation	0.0118	2	0.01	51.96	3.3306E-08	3.55
Interaction	0.0008	4	0.00	1.68	0.19	2.93
Error	0.0021	18	0.00			
Total	**0.0203**	**26**				

3.2.2Effect on Cone Index

The cone index of soil at three different depths D_1, D_2 and D_3(80, 120 and 160mm) for three different augers A_1, A_2 and A_3 having dia. size of 40, 50 and 70mm were measured as shown in Table 5.

Table 5Data obtained forcone index

Auger size (mm)	Cone index (kgf)		
	Depth of 80mm	Depth of 120mm	Depth of 160mm
40	17.84	36.29	71.37
50	17.24	34.32	68.95
70	16.03	32.81	65.47

The data from the graph (Fig.6) revealsspecific values for cone index corresponding to each auger size and depth. These cone index values provide an indication of soil strength and compaction.At a depth of 80mm, the cone index ranges from 17.84kgf to 16.03kgf for auger sizes 40mm to 70mm, respectively. At 120mm depth, the cone index ranges from 36.29kgf to 32.81kgf and at 160mm depth, it decreases further to 71.37kgf to 65.47kgf. The data reveals that, higher values of cone index suggest stronger and more compacted soil, while lower values indicate looser and less compacted soil.

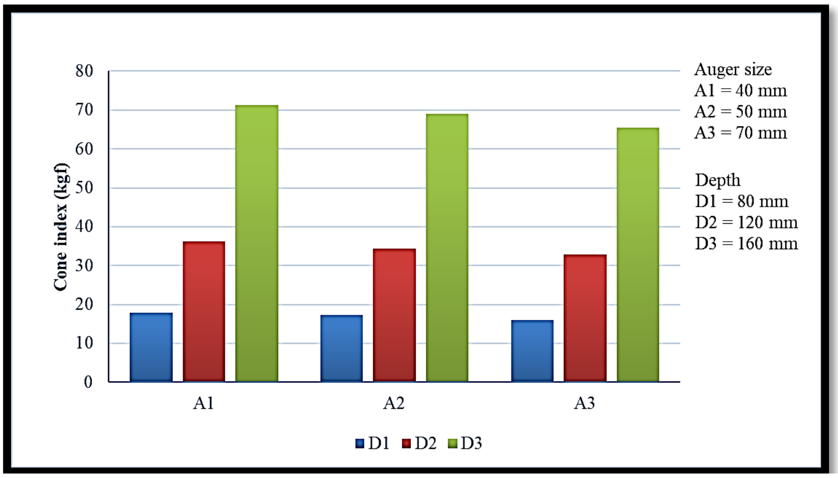

Fig. 6 Effect of auger size and depth on cone index

The ANOVA Table6Shows the effect of auger size and depth of operation on cone index. The effect of auger size and depth on cone index is not significant (p>0.05). Similarly, the interaction between auger size and depth of operation on cone index is not significant (p>0.05).

Table 6 ANOVA for effect of auger size and depth on cone index

Source of Variation	SS	df	MS	F	P-value	F crit
Auger size	62.84	2	31.42	0.046	0.95	3.55
Depth of operation	3.31	2	1.65	0.002	0.99	3.55
Interaction	6.80	4	1.70	0.002	0.99	2.93
Error	395.49	18	88.64			
Total	**468.43**	**26**				

3.3 Effect of Auger Size and Depth of Operation for Maize Crop

3.3.1 Effect on seed germination

The laboratory test was assessed for seed germination of maize crop and result showed that seed germination for maize crop obtained was 92% respectively. The effect of different augers and depths on germination percentage for maize which was sown at recommended depth of 50 mm on field. The data obtained for seed germination of maize for different treatments combinations of operation is given in Table 7.

Table 7Data obtained forseed germination of maize

Auger size (mm)	Seed germination (%)		
	Depth 80mm (D_1)	Depth 120mm (D_2)	Depth 160mm (D_3)
40 (A_1)	89	89	89
50 (A_2)	89	90	89
70(A_3)	90	91	90
Control	90		

The data from the graph (Fig.7) revealsspecific values for germination percentage of maize crop corresponding to different combinations of treatments. seed germination percentages at different depths (80mm, 120mm, and 160mm) and auger sizes (40, 50, and 70mm), alongside a control group. Germination rates generally ranged between 89% and 91%, with slight variations based on the auger size and depth. The "Control" group, representing traditional planting, also exhibited a 90% germination rate.This suggests that using these auger sizes and depth of operation did not significantly impact on seed germination. These results indicate that the combinations of all treatments had comparable effects on the germination percentage of maize, as there were no substantial variations observed among the different combinations of the treatment.

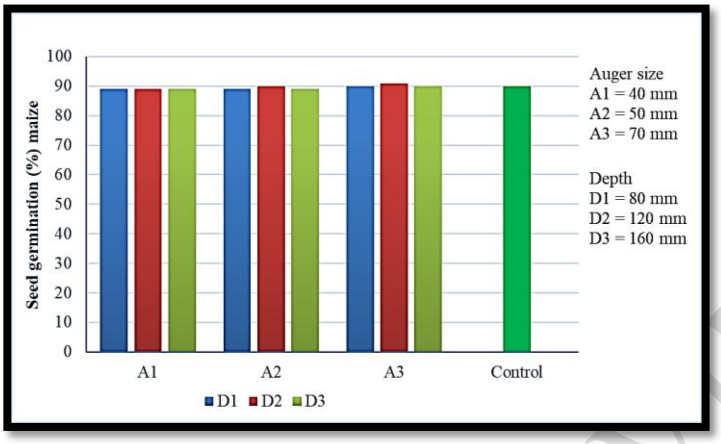

Fig. 7 Effect on germination for maize

The ANOVA Table 8 shows the effect of auger size, depth of operation and their interaction on seed germination. The effect of auger size and depth of operation variation on germination is not significant ($p>0.05$). The interaction between the auger size and depth of operation on germination is not significant ($p>0.05$). therefore, no significant effects were observed for auger size and depth of operation on seed germination.

Table 8 ANOVA for effect on germination for maize

Source of Variation	SS	df	MS	F	P-value	F crit
Auger size	6.74	2	3.37	0.59	0.56	3.55
Depth of operation	6.74	2	3.37	0.59	0.56	3.55
Interaction	1.93	4	0.48	0.08	0.98	2.93
Error	103.33	18	5.74			
Total	**118.74**	**26**				

3.3.2 Effect on root length

The effect of different augers and depths on root length measurements for maize were measured as per different treatments combinations. For auger A_1, the combinations of A_1 D_1, A_1 D_2&A_1 D_3, for auger A_2, the combinations of A_2 D_1, A_2 D_2&A_2 D_3 and for auger A_3, the combinations of A_3 D_1, A_3 D_2&A_3 D_3 respectively. The root length measured for maize crop is given in the Table 9.

Table 9 Data obtained for root length of maize

Auger size (mm)	Root length (cm)		
	Depth of 80mm (D_1)	Depth of 120mm (D_2)	Depth of 160mm (D_3)
40 (A_1)	21	35	37
50 (A_2)	23	33	36
70 (A_3)	25	30	33
Control	27		

The results indicated that auger size (70mm) was associated with shorter root lengths at all depths as shown in Fig. 8. At a depth of 80mm, the root lengths for 40mm, 50mm, and 70mm augers were 21cm, 23cm, and 25cm, respectively. Similarly, at a depth of 120mm, the corresponding root lengths were 35cm, 33cm, and 30cm, and at a depth of 160mm, the root lengths were 37cm, 36cm, and 33cm, respectively. In comparison, the control root length was 27cm. The length of root was found more in spot tillage operation as compared to control may be due to availability of less lateral tilled space in holes as compared to control. Due to this the root might have developed more vertically downwards.

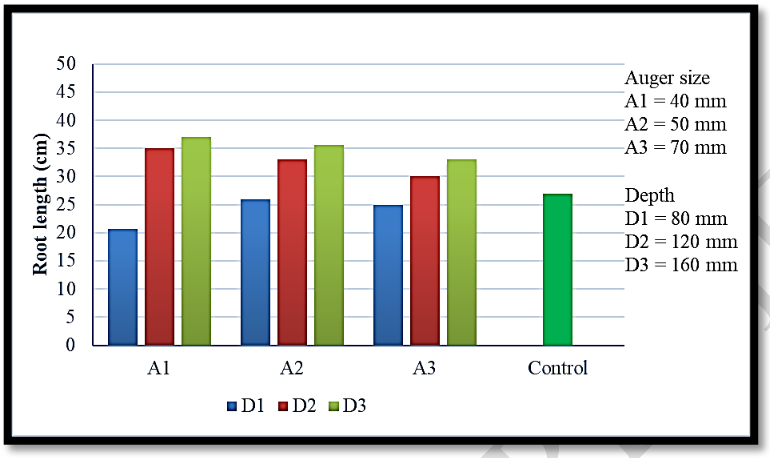

Fig. 8 Effect on root length for maize

The ANOVA Table 10 shows the effect of auger and depth on root length. The effect of auger on root length is significant ($p<0.05$). It may be due to different size of augers significantly impact on root length. Similarly, the effect of depth on root length is significant ($p<0.05$). It may be happened by varying depths significantly influence root length. Additionally, the interaction between auger and depth on root length is significant ($p<0.05$). The reason for increase in root length with respect to depth of operation may be due to more depth tilled soil with increase in depth of operation. The finding showed that increasing the tillage depth resulting greater root development as root length increased significantly with greater tillage depths (Varsa, *et al.*, 1997).

Table 10 ANOVA for effect on root length for maize

Source of Variation	SS	df	MS	F	P-value	F crit
Auger size	23.41	2	11.70	8.32	0.002768	3.55
Depth of operation	636.07	2	318.04	225.97	1.77E-13	3.55
Interaction	87.70	4	21.93	15.58	1.14E-05	2.93
Error	25.33	18	1.41			
Total	**772.52**	**26**				

3.3.3 Effect on root weight

The effect of different auger size and depth of operation on root weight measurements for maize were measured as per different treatments combinations. For auger A_1, the combinations of A_1 D_1, A_1 D_2&A_1 D_3, for auger A_2, the combinations of A_2 D_1, A_2 D_2&A_2 D_3 and for auger A_3, the combinations of A_3 D_1, A_3 D_2&A_3 D_3 respectively. The root weight measured for maize crop is given in the Table 11.

Table 11 Data obtained for root weight of maize

Auger size (mm)	Root weight (g)		
	Depth of 80mm (D_1)	Depth of 120mm (D_2)	Depth of 160mm (D_3)
40 (A_1)	28	45	67
50 (A_2)	30	57	85
70 (A_3)	32	73	94
Control	77		

The data reveals that as the auger size increases, the root weight generally tends to increase as well. At a depth of 80mm, auger of 40mm size resulted in a root weight of 28g, while a 70mm auger had a higher root weight of 32g. Similarly, at depths of 120mm and 160mm, the auger of 70mm size had higher root weights compared to other two augers. In control, the root weight obtained was 77g. Thus, the results show that both the auger type and the depth significantly impact on root weight as shown in Fig. 9. This might be due to increasing in auger size the loosening of soil will be more which may cause for higher root volume.

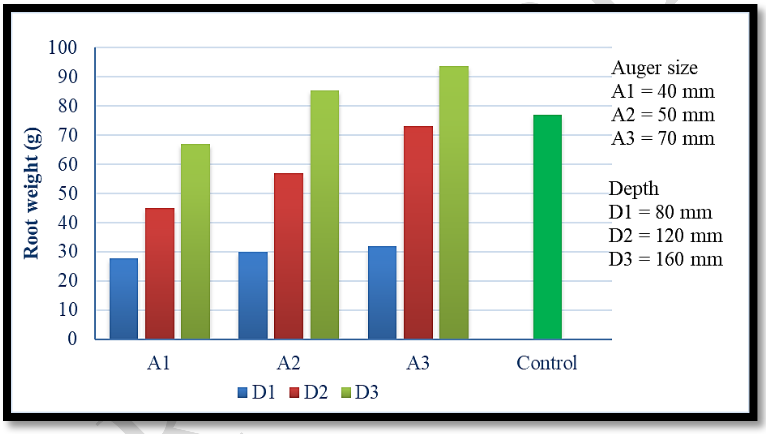

Fig. 9 Effect on root weight for maize

The ANOVA Table 12 shows the effect of auger and depth on root weight. The effect of auger on root weight is significant ($p<0.05$) it may be due to different auger dia that significantly impact root weight. Similarly, the effect of depth on root weight is significant ($p<0.05$) it may be happened that varying depths have a significant influence on root weight. Furthermore, the interaction between auger type and depth on root weight is significant ($p<0.05$). It may be due to different auger size for tillage as larger dia. auger loosening more soil which may cause for higher root volume. As stated, that loosening the soil allows roots to grow more easily and deeply, which can improve water and nutrient uptake (Weil & Brady, 2017).

Table 12 ANOVA for effect on root weight for maize

Source of Variation	SS	df	MS	F	P-value	F crit
Auger	1747.18	2	873.59	302.40	1.41E-14	3.55
Depth	12254.3	2	6127.15	2120.94	4.29E-22	3.55
Interaction	581.70	4	145.43	50.34	1.56E-09	2.93
Error	52	18	2.89			
Total	**14635.19**	**26**				

3.3.4 Effect on cob weight

The effect of different augers and depths on root length measurements for maize were measured as per different treatments combinations (A_1D_1, A_1D_2&A_1D_3, A_2D_1, A_2D_2&A_2D_3 & A_3D_1, A_3D_2&A_3D_3) of operation after harvesting were measured as shown Table 13.

Table 13 Data obtained for cob weight of maize

Auger size (mm)	Cob weight (g)		
	Depth of 80mm (D_1)	Depth of 120mm (D_2)	Depth of 160mm (D_3)
40 (A_1)	134.67	167.77	181.00
50 (A_2)	167.77	172	189.33
70 (A_3)	162.27	172	221
Control	190		

The data from the graph reveals specific values for cob weights of maize crop corresponding to different combinations of treatments. The results indicate that as the auger size increases with increase in depth, the cob weight also increase. The data obtained at a depth of 80mm, for 40mm auger size resulted cob weight of 134.67g (Fig.10) while the weight increased to 167.77g and 181.00g with 50mm and 70mm augers, respectively. Similarly, the cob weight showed variations with auger size at depths of 120mm and 160mm ranging from approximately 2.53% to 36.18%. Comparatively, the cob weight for control was 190g.

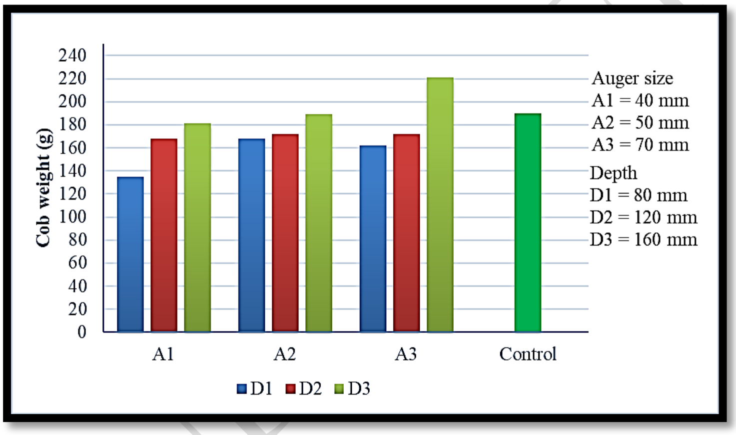

Fig. 10 Effect on cob weight for maize

The ANOVA Table 14 shows the effect of auger size and depth on cob weight. The effect of auger size and depth on cob weight is significant ($p<0.05$). It may be due to loosening of soil that improves water infiltration and movement in the soil which can enhance root growth development which increases the production. As stated, that soil loosening progressively enhanced root length density for each increase in tillage depth and resulted in correspondingly increased yield (Varsa, *et al.*, 1997). However, the interaction between the auger and depth on cob weight is not significant ($p>0.05$).

Source of Variation	SS	df	MS	F	P-value	F crit
Auger size	2616.51	2	1308.25	11.60	0.000579	3.55
Depth of operation	10366.82	2	5183.41	45.97	8.46E-08	3.55

Interaction	1244.61	4	311.15	2.76	0.059747	2.93
Error	2029.68	18	112.76			
Total	**16257.62**	**26**				

Table 14 ANOVA for effect on cob weight for maize

4. Conclusions

- The effect of auger size and depth of operation on bulk density was found significant as bulk density of the soil increased with depth. A 70mm auger size resulted in lower bulk density values because more soil was removed, leaving less behind to compact. The interaction between auger size and depth of operation on bulk density was not significant.
- The results showed that higher values of cone index indicated stronger and more compacted soil, while lower values indicated looser and less compacted soil. The statistical analysis revealed that neither auger size nor depth of operation had a significant effect on cone index and the interaction between auger size and depth was also not significant.
- The seed germination percentage for maize was consistently around 90% for all treatment combinations of auger size and depth of operation. No significant effects of auger size and depth on seed germination were observed.
- Auger size and depth significantly impacted root length. Larger auger sizes were associated with shorter root lengths, and increasing depth resulted in greater root development in small size augers (40 & 50mm), leading to longer roots.
- Auger size and depth significantly influenced root weight. Larger auger sizes and deeper depths generally resulted in higher root weights.
- Cob weight increased with larger auger sizes and deeper depths. Auger size and depth significantly impacted cob weight.It may be due to loosening of soil that improves water infiltration and movement in the soil which can enhance root growth development which increases the production.

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