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Studying the Soil Properties and Root Growth of Corn under Different Combination of Soil Bulk Densities

Mansoor, K.K* I. Haq
Department of Agricultural Mechanization, The University of Agriculture, Peshawar Pakistan.

Abstract
Research study was conducted on different level of bulk density combination in green house at NSDL –ARS – USDA, Auburn, Alabama, USA, on corn. The main objectives of this study were to find the impact of bulk density on corn root growth and different soil properties under sandy loam soil condition. In this research, total twenty seven (27) treatments and three replications were used under complete randomized design. The treatments included were AAA, AAB, ABA, ABB, AAC, ACA, ACC, ABC, ACB, BBB, BBA, BAB, BAA, BBC, BCB, BCC, BAC, BCA, CCC, CCA, CAC, CAA, CCB, CBC, CBB, CAB, and CBA. Corn was planted in a pot for about 40 days. The data were collected for different parameters i.e. corn root growth, Soil moisture content retain in the pot (%), retention of soil in the pot, Evapo-transpiration from soil surface. Mean highest depletion of soil 10.86 and 9.90 cm occurred in treatments AAA and AAB respectively; while the mean lowest depletion of soil 0.01,0.04, and 0.08 cm were recorded in treatments CCC, CCB and CBC respectively. Mean highest total amount of Evapo-transpiration was recorded 59.19% in treatment AAB and the mean lowest total amount of evapo-transpiration was noted 19.36% in CCC treatment. At Depths –I, II and III, Mean highest root length of 89.41, 104.05 and 142.87 m were noted in treatments AAC, BAC and ABA; dry root weight of 5.27, 2.39, and 2.78 g were observed in treatments AAC, AAA and BCA respectively; while the mean lowest root length of 1.27, 25.55 m was recorded in treatment AAA at depth I and II and 10.79 m was in CCC at depth III respectively; and the mean lowest dry root weight of 0.17 g was in treatment AAA at depth I, and 0.10 and 0.06 g were recorded in treatments CBC at depth II and III respectively.
Keywords: Corn, Root Growth, Dry Root Weight, Soil Evapo-transpiration, Root Growth.

Introduction

Soil particles must contain pores which allow the reassigning of water molecules and air, mixture of organic and inorganic components in proper amount. These pores may be finished by collapsing soil particles and termed as soil compaction, which is a main factor of limiting yield all over the world (Ball, et al., 2008). The soil of Southeastern Coastal Plains has a poor texture with low organic matter of about less than 1% (Novak, et al., 2009). The growth of any crop depends directly with the amount of organic matter and water content retain in the soil (Kawashima, et al., 2007).

Corn plays a major role in the economy of the USA. The country is one of the worldwide corn leaders with 96,000,000 acres (39,000,000 ha) of land reserved for corn production. Corn growth is dominated by west/north central Iowa and east-central Illinois. The US is ranked first in the world in corn production, and 20% of its annual yield is exported (*USDA Economic Research Service, 2013).* The total production of corn in the US for the year 2013-14 is reported to be 13.016 billion bushels of which the major use is for manufacture of ethanol and its co-product (Distillers' Dried Grains with Solubles) accounting for 37% (27% + 10%) or 4,845 million bushels (3,552 + 1,293) (*Iowa Corn organization, 2014).*

Plant Growth depends on the Properties of soil and moisture content within the soil. Bulk density may also revolutionize other properties of soil and plant growth (Jose, et al., 2009).

The particles of some soils are tightly bounded with each other naturally that they are strongly compacted. Poorly graded soils which are already having particular size are resistant to compaction while mixture of large and small particulates soil have more spaces and voids for enhancing the root growth of crops (lutzow, et al., 2006).

Water is the most essential factor for plant growth, and the plant do not take their food in any from, other than in liquid, so if there is no water, the plant will not take their food, resulting in to their complete failure or death. Sandy soil above the layer may hold only 1 inch of water per foot. Crops that are not able to root into the subsoil often do not have enough water to sustain plant growth for the frequent 5 to 20 day droughts that occur seasonally (Sadler and Camp, 1986). The use of insufficient water will restricted root volume (Lowry et al., 1970) and the soil water content of 70% field capacity enhanced higher root proliferation in the top layer, but as root penetrates the hardpan some physical and morphological change made it possible for the level of water content affects root growth in the Southern Coastal Plain of the USA (Duruoha et al., 2006).

Optimal bulk density for plant growth is different in each soil. In general, low bulk density leads to poor soil – root contact, and high bulk density reduces aeration and increases penetration resistance. Cotton plant growth and yield were associated with increased soil bulk density, penetration resistance and shallow hard pans (Lowry et al., 1970). The increased bulk density affects plant growth in many ways. Air and water movement and storage is restricted, causing shortages. Roots will not develop nor penetrate well in compacted soil due to lack of this elements. It was speculated that spatial variation of soil bulk density and resistance and temporal variation of soil water content allowed the roots to find weather path ways to across the compacted layer (Cooper et al., 1969; McConnell et al., 1989; Mullins et al., 1992). Subsoil compaction reduce both water and nutrient use efficiencies of wheat 24%; sorghum 18% and also reduce fodder yield (Ishaq et al., 2001). Bulk density affects all the properties of soil which result the decline growth of crop (Stirzakir, et al., 1996).

METHODOLOGY

Research Site

The experiment was conducted on the impact of different level of bulk density combination on plant growth and nutrients uptake under sandy loam soil condition during corn growing season. The study was conducted in the green house for 40 days in the southern coastal plain area of USDA- ARS – NSDL, Auburn, Alabama, USA (32˚ 24' N, 85˚ 54' W). The soil for the experiment was brought from the Alabama Agricultural Experiment Station's E.V. Smith Research Center. Soil was fine and fine loamy, kaolinitic, thermic Typic and Aquic Paleudults.

Experimental Design

A complete randomized design (CRD) was used in the experiment.

Treatments Description

Bulk Density	Ranged from	Depth Level	Ranged from
A:	1.00 – 1.30 g cm^{-3}	Depth 1:	0.00 – 15.24 cm
B:	1.30 - 1.60 g cm^{-3}	Depth 2:	15.24 – 30.48 cm
C:	1.60 – 1.90 g cm^{-3}	Depth 3:	30.48 – 45.72 cm

The combination of above mentioned three different levels of bulk densities were considered individually as well as combined with each other in the above mentioned three depths and treatments were made from their combination for conducting an experiment as shown in Table 1. There were a total of 27 different combinations of bulk density; and all these 27 combination means individual treatment. Each combination/treatment was replicated 3 times. Hence, there were a total of 81 subplots for the experiment.

Table-1. Description of treatments

Treat	Depth- 1	Depth- 2	Depth- 3	Treat	Depth- 1	Depth- 2	Depth- 3	Treat	Depth- 1	Depth- 2	Depth- 3
S.No	0-15 cm	15 - 30 cm	30 - 45 cm	S.No	0-15 cm	15 - 30 cm	30 - 45 cm	S.No	0-15 cm	15 - 30 cm	30 - 45 cm
1	A	A	A	10	B	B	B	19	C	C	C
2	A	A	B	11	B	B	A	20	C	C	A
3	A	B	A	12	B	A	B	21	C	A	C
4	A	B	B	13	B	A	A	22	C	A	A
5	A	A	C	14	B	B	C	23	C	C	B
6	A	C	A	15	B	C	B	24	C	B	C
7	A	C	C	16	B	C	C	25	C	B	B
8	A	B	C	17	B	A	C	26	C	A	B
9	A	C	B	18	B	C	A	27	C	B	A

Description of PVC Pots

- PVC Pots: Pots were constructed from PVC pipes (≥50 cm lengths, ≥20.32 cm internal diameter with a bottom cover to prevent losses of soil from the base of pot). Pipes were divided into three subsections: top section was ≥20.32 cm and middle and bottom sections were made 15.24 cm each internally

Table 2. Calculation of materials for the experiment

	Bulk dens.	Dia. of pot	Rad. of pot	Area of pot	Depth of pot	Vol. of pot	Soil wt.	Water (10%)	Water (15%)	Fertilizer (N+K+ Lime)	Total wt. (10% basis)	Total wt. (15% basis)
S.No	(g/ cm^{-3})	(cm)	(cm)	(cm^{-2})	(cm)	(cm^{-3})	(kg/ pot)	(kg/ pot)	(g/pot)	(kg/ pot)	(kg/ pot)	(kg/ pot)
1	1.00	20.32	10.16	324	15.24	4939.7	4.9	0.49	0.74	0.0044	5.438	5.69
2	1.30	20.32	10.16	324	15.24	4939.7	6.4	0.49	0.74	0.0058	6.921	7.17
3	1.60	20.32	10.16	324	15.24	4939.7	7.9	0.49	0.74	0.0071	8.405	8.65

Procedure

First of all, as per calculation, soil (50 kg) dry soil, water (10% by weight basis i.e. 5 kg) and fertilizer (N = 1.25g/50kg, P_2O_5 = 2 g/50 kg, Lime = 45.40 g/50kg) were mixed in the rotary machine and machine was driven for 15 minutes, so that all the materials were mixed thoroughly in the machine. After that, all samples were kept in enclosed plastic boxes for three days. After 3 days, again, all samples were taken and put in the rotary machine for 10 minutes, so that moisture content and fertilizer were mixed uniformly in the whole sample. Next day, three samples were taken from each box and placed in oven for 48 hour at 55˚ to determine the moisture content in each individual box. Moisture content was recorded in each boxes and was recorded average moisture content 9.50 – 12.00 % in all boxes. By varying the bulk density level combination, three different bulk density levels was created for each subsection of pot separately (i.e. 0 – 15.24, 15.24 – 30.48 and 30.48 – 45.72 cm depths) by an Electromechanical Test System. For different level of bulk densities, soil was weighed by electronic balance (such as 5.40 kg for 1.00 g/cm^{-3}, 7.07 kg for 1.30 g/cm^{-3} and 8.70 kg for 1.60 g/cm^{-3}) and then soil was poured in each subsection of the pots and each subsection pot was placed before the Electromechanical Test System for obtaining the required level of bulk density.

After that, all the three subsections of pots were joined together by plastic tap and made one whole pot. By creation of these various combination levels of bulk densities, there was a little bit changes occurred in each level of combination; however, it was not exceeded the required range of bulk density. Before the sowing of seed in the pot, addition 5% water was added to whole pot. Moisture content level was kept 10 – 15% in the whole experiment in all the treatments throughout the growing season. In each pot, three seeds were planted at 2 cm depth and then pots were placed in the green house. Cultural practices of pruning the weeds were undertaken as needed. Pruning process was done manually to avoid re-arranging the soil particle on the top layer.

Physical Properties of Soils:

Data on the following physical properties of soil was collected:

Soil moisture content Retain in the pot

Soil moisture content retaining data was recorded within three days intervals during the crop growing period.

Depletion/Compaction of soil in the pot

Surface depletion of soil in the pot data was recorded within three days intervals during the crop growing period.

Evapo-transpiration Moisture Content (%age) from the pot surface

Evapo-transpiration data was recorded within three days intervals during the crop growing period.

Crop Physiology

The following physiological parameters were recorded:

Root Length, Diameter and Volume

Root length data will be collected after the harvest of the crop in each subsection of pot. Soil will be removed by using different size of sieves and also by washing of water carefully. So that soil and crop residues may be separated from the roots. Root length density (cm^{-3}), root volume (cm^{-3}) and average root diameter (mm) will be scanned by WinRHIZO ™ analysis software measured (Arsenault et al., 1995; Regent Instruments, Canada).

Dry Root Weight

The dry weight of root will be taken after scanning and will placed at 55 ˚C in the oven.

Cumulative Growing Degree Days

Crop was stand in the pot for 35 days after emergence of seed. The temperature was kept maximum (85 ˚F) and minimum (80 ˚F) throughout the growing season. Cumulative growing degree days were determined by total days into daily growing degree days.

Statistical Package

The statistical package SAS (SAS Institute Inc, 1999) was used for the analysis of data. This analysis of variance automatically provided the standard error difference (SED) and also the application of Fisher's tests for the comparison of treatments.

Results and Discussion

In this section, detail analysis of the data was described.

Physical Properties of Soil

Soil Moisture Content Retaining in the Pot (%)

Soil moisture content retaining was recorded approximately within three days interval in each individual treatment during the crop growing season (Fig. I). Mean soil moisture content ranged from 9.07 – 13.05 %. There was a statistical significant difference among all the treatments. Mean highest soil moisture content 13.05% retained by CCC treatment and mean lowest soil moisture content 9.07% by AAB. As seem in the figure, CCC treatment is significantly difference from all the treatments except CBC treatment.

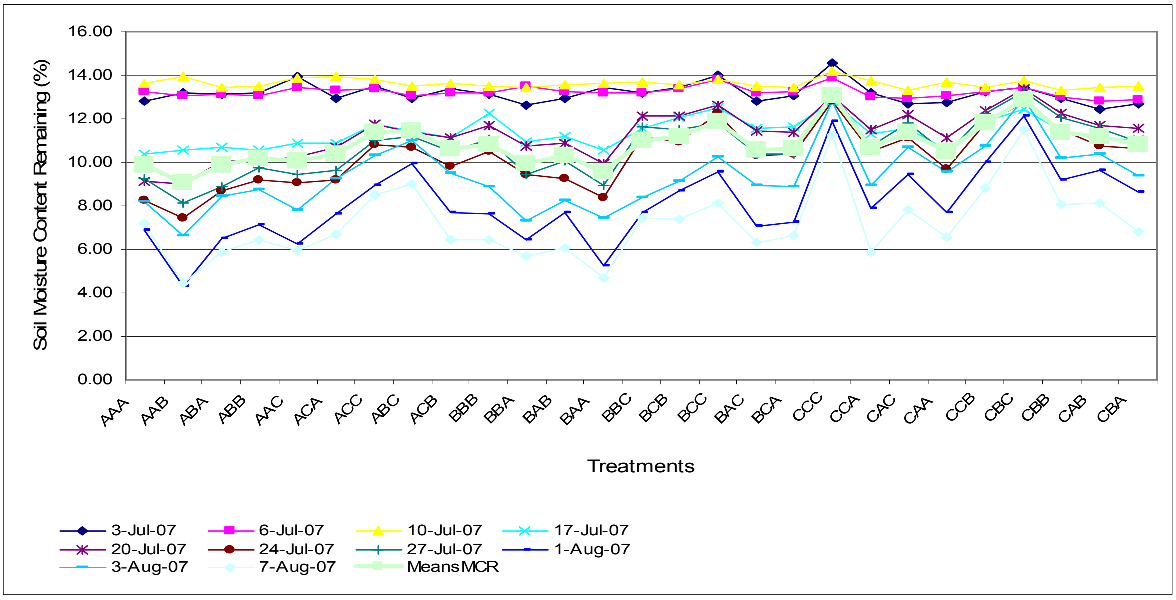

Fig.I. Mean moisture content retaining in the pot during crop growing season.

Highly soil moisture content retained by CCC and CBC treatments was may be due to highly compaction, due to which plant was not able to take enough water from the soil. The ultimate result may be less evapo-transpiration occurred from the soil.

Depletion of soil in the pot

Mean depletion of soil were varies from 34.86 to 45.71 cm (Fig. II). There was a significant difference among the treatments. The highest depletion of soil 34.86 and 35.82 cm occurred in treatments AAA and AAB respectively; while the lowest depletion 45.71, 45.68 and 45.64 cm were recorded in the treatments CCC, CCB and CBC respectively. The reason of highest depletion of soil in the treatments AAA and AAB were may be due to lowest range of bulk density combination i.e. from 1.00 to 1.30 g cm^{-3} at the surface layer. The highest depletion of soil in the treatments AAA and AAB were 10.86 and 9.90 cm respectively, while the lowest depletion of soil in the treatments CCC, CCB and CBC was may be about 0.01, 0.04 and 0.08 cm respectively.

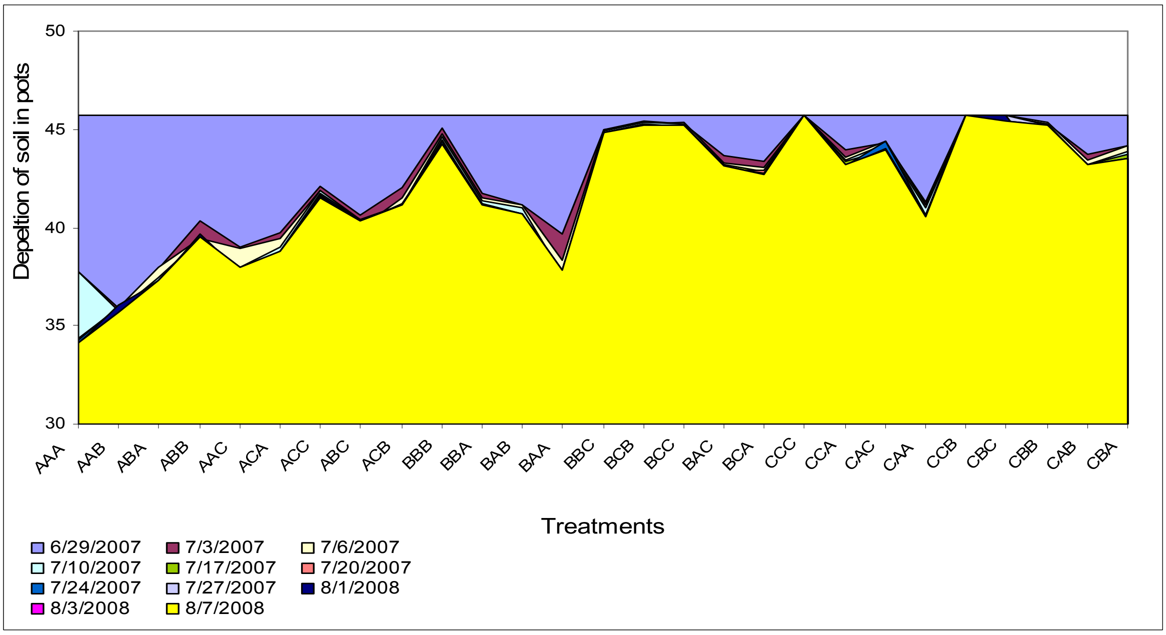

Fig. II. Depletion of soil by water application during corn growing season.

The finding of the study shows that both the conditions (i.e. too loose or compact) may not be favorable for plant growth. Soil with lowest bulk density combinations (≤1 g cm^{-3}) from 0- 30.48 cm depth may be suddenly depleted from 10 - 11 cm with one or two irrigation. The ultimate result will be affected plant growth. Similarly, the soil with highly compacted bulk densities combination may not provide favorable environment to plant growth.

Evapo-transpiration of MC (%)

Mean and total amount of Evapo-transpiration (MTT and TTT) data for all treatment was determined within three days interval as shown in Fig. III. Mean evapo-transpiration ranged from 1.94 - 5.92 % in all the treatments. There was a statistically significant difference in all the treatments. The highest amount of ET was 5.92 % in AAB treatment and the lowest EP was 1.94% in CCC treatment. The total evapo-transpiration varied from 19.36 – 59.19 % in all the treatments. The highest amount of evapo-transpiration was revealed 59.19% in AAB treatment and the lowest was noted 19.36% in CCC treatment. The results shown in the figure, that MET and TET from the AAB treatment was higher than any other treatments.

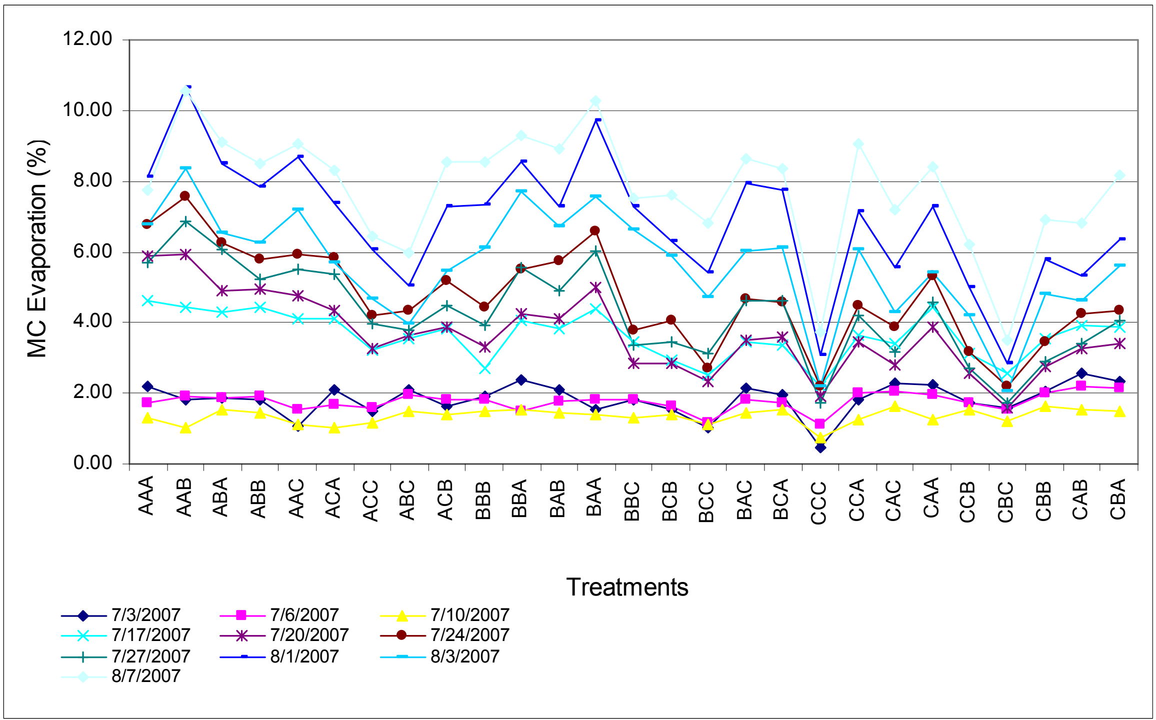

Fig. III. Evapo-transpiration of moisture content from surface of pot during corn growing season.

Crop Physiology

The following physiological parameters were recorded:

Root Length

Root length was determined at three depths I, II and III and is given in Table 3. At Depth –I (0.00 – 15.24 cm), the root length was varied from 1.27 – 89.41 m (Table 3). There was a statistically significant difference among all the treatments. The highest root length of 89.41 m was noted in treatment AAC; while the lowest root length of 1.27 m was recorded in treatment AAA. At depth –II (15.24 – 30.48 cm), root length data was recorded and ranged from 25.55 – 104.05 m (Table 3). There was no statistically significant difference among all the treatments. However, the higher root length was observed 104.05 m in treatment BAC and the lower root length was noted 25.55 m in treatment AAA. At depth –III (30.48 – 45.72 cm), the data for root length was also recorded and varied from 10.79 – 142.87 m (Table 3). The highest root length of 142.87 m was noted in treatment ABA and the lowest root length of 10.79 was found in treatment CCC. There was a statistically significant difference in all the treatments.

In the combination of all the three depths I, II and III (i.e. from 0.00 – 45.72 cm), the total root length was determined and was varied from 55.71 – 237.67 m (Table 3). There was a statistically significant difference among various treatments. The highest root length was found 237.67 m in treatment BAB and the lowest root length was 55.71 m in treatment CBC. Overall, the results show that that treatment, which was a bulk density in the range A & B at depth-1, was showing better results as compared to bulk density more than C.

Table 3. Root length in different Depths of pots during corn growing season.

S.No	Treatments	Depth-I (m)	Depth-II (m)	Depth-III (m)	Total Length (m)
1	AAA	1.27 i	25.55	84.17 bcde	110.99 cdefg
2	AAB	20.73 fghi	42.09	112.89 abc	175.71 abcde
3	ABA	16.53 hi	63.65	142.87 a	223.05 ab
4	ABB	37.48 cdefgh	55.49	67.84 cdefg	160.82 abcdefg
5	AAC	37.85 cdefgh	57.75	48.29 defgh	143.89 abcdefg
6	ACA	39.40 cdefgh	40.41	74.89 bcdef	154.71 abcdeg
7	ACC	50.36 bcd	39.98	19.11 gh	109.46 defg
8	ABC	23.02 efghi	58.35	19.88 gh	101.25 efg
9	ACB	45.88 cde	53.77	68.33 cdefg	167.98 abcdef
10	BBB	51.21 bcd	56.15	92.78 abcd	200.14 abcde
11	BBA	32.45 defgh	79.70	107.46 abc	219.60 ab
12	BAB	34.09 defgh	89.34	114.25 abc	237.67 a
13	BAA	23.98 efghi	67.45	125.91 ab	217.35 abc
14	BBC	58.81 bc	87.16	39.10 efgh	185.07 abcde
15	BCB	73.15 ab	61.15	83.32 bcde	217.61 abc
16	BCC	89.41 a	55.95	27.94 fgh	173.30 abcde
17	BAC	59.88 bc	104.05	48.53 defgh	212.46 abcd
18	BCA	45.37 cde	60.06	113.85 abc	219.28 ab
19	CCC	26.87 defgh	25.87	10.79 h	63.53 fg
20	CCA	42.77 cdefg	45.15	77.96 bcdef	165.89 abcdef
21	CAC	44.74 cdef	59.49	27.55 fgh	131.78 abcdefg
22	CAA	30.69 defgh	69.17	111.35 abc	211.21 abcd
23	CCB	36.56cdefgh	30.19	53.99 defgh	120.74 bcdefg
24	CBC	18.72 ghi	25.97	11.02 h	55.71 g
25	CBB	36.12 cdefgh	56.91	54.06 defgh	147.08 abcdefg
26	CAB	25.63 efghi	30.47	40.76 efgh	96.86 efg
27	CBA	39.63 cdefgh	65.16	92.22 abcd	197.01 abcde

Means bearing the same letters are not statistically different from one another with $P<0.05$.

Root Length per Volume

Root length per volume was determined at three depths I, II and III and is given in Table 4. At Depth –I, the root length per volume was ranged from 257 – 13922 m/m^{-3}. The data was a statistically significant difference among all the treatments. The highest root length per volume of 13922 m/m^{-3} was noted in treatment BCC, while the lowest root length per volume of 257 m/m^{-3} was recorded in treatment AAA. At depth –II, root length per volume data was recorded and is shown in Table 4. There was no statistically significant difference among all the treatments. However, the higher root length per volume was noted 20294 m/m^{-3} in treatment BAC and the lower root length per volume was recorded 5172 m/m^{-3} in treatment AAA.

Table 4. Root length per volume in different Depths of pots during corn growing season.

S.No	Treatments	Depth-I (cm/m^3)	Depth-II (cm/m^3)	Depth-III (cm/m^3)	Total Length per volume (cm/m^3)
1	AAA	257 j	5172	17039 bcdef	22468 bcdefgh
2	AAB	4196 fghij	8520	17579 bcdef	30295 abcdef
3	ABA	3346 hij	10267	28920 a	42533 a
4	ABB	7588 bcdefg	9402	10564 efghijk	27554 abcdef
5	AAC	7661 bcdefg	11691	6111 hijk	25463 abcdefh
6	ACA	7977 bcdef	6079	15160 cdefgh	29216 abcdef
7	ACC	10195 abc	6446	2419 k	19059 efgh
8	ABC	4660 fghi	9356	2516 k	16533 fgh
9	ACB	9287 bcde	7618	10640 efghijk	27546 abcdef
10	BBB	7974 bcdef	8744	14446 cdefgh	31164 abcdef
11	BBA	5054 fghi	12410	21752 abcd	39215 abc
12	BAB	5308 efghi	17460	17790 bcdef	40558 ab
13	BAA	3734 ghij	13165	25489 ab	42388 a
14	BBC	9157 bcde	13572	4948 ijk	27677 abcdef
15	BCB	11390 ab	8726	12974 defghij	33091 abcdef

16	BCC	13922 a	7959	3536 jk	25416 abcdefgh
17	BAC	9325 bcd	20294	6140 hijk	35759 abcde
18	BCA	7064 cdefgh	8026	23047 abc	38137 abcd
19	CCC	3399 hij	3273	1366 k	8039 gh
20	CCA	5412 defghi	5713	15781 cdefg	26907 abcdefg
21	CAC	5661 defghi	10962	3486 jk	20109 defgh
22	CAA	3884 ghij	13117	22540 abcd	39541 abc
23	CCB	4626 fghi	3820	8407 fghijk	16853 efgh
24	CBC	2369 ij	3927	1394 k	7690 h
25	CBB	4570 fghi	8509	8417 fghijk	21496 cdefgh
26	CAB	3244 hij	5581	6347 ghijk	15171 fgh
27	CBA	5015 fghi	9905	18668 bcde	33589 abcdef

Means bearing the same letters are not statistically different from one another with $P<0.05$.

At depth –III, the root length per volume was determined and varied from 1366 – 28920 m/m^{-3} (Table 4). There was a statistically significant difference in all the treatments. The highest root length per volume of 28920 m/m^{-3} was found in treatment ABA, and the lowest root length per volume of 1366, 1394, 2419 and 2516 m/m^{-3} were noted in treatments CCC, CBC, ACA and ABC respectively.

In the combination of all the three depths I, II and III, the total root length per volume was determined and is shown in Table 4. The data was varied from 7690 – 42533 m/m^{-3}. There was a statistically significant difference among all the treatments. The highest root length per volume were found 42533 and 42388 m/m^{-3} in treatments ABA and BAA respectively, and the lowest root length per volume was observed 7690 m/m^{-3} in treatment CBC.

Root Diameter

Root diameter was determined at three depths I, II and III and is given in an Appendix-A.

At all the three depths, the data was a statistically no significant difference among all the treatments. On overall mean basis of the three depths, the bigger root diameter of 0.45 mm was observed in treatment ABB and the smaller root diameter of 0.21 mm was noted in treatment AAA.

Roots Volume

Root volume was determined at three depths I, II and III and is given in an Appendix-B. At all the three depths, the root volume data was a statistically no significant difference among all the treatments. On overall mean basis of the three depths, the higher root volume of 38.50 cm^{-3} was recorded in treatment BCA and lower root volume of 3.47 cm^{-3} was observed in treatment CBC.

Dry Root Weight

Dry root weight was determined at three depths I, II and III and is given in Table 5. At Depth –I, the dry root weight was varied from 0.173 – 5.270 g. The data was a statistically significant difference among the treatments. The highest dry root weight was noted 5.270 g in treatment AAC, and the lowest dry root weight was recorded 0.173 g in treatment AAA. While in the remaining treatments, there was no significant difference except AAB treatment.

At depth –II, there was no statistically significant difference among all the treatments (Table 5). However, the higher dry root weight of 2.390 g was observed in treatment AAA, while the lower was 0.097 g in treatment CBC.

At depth –III, the dry root mass was determined and was found a statistically significant difference among all the treatments. Dry root mass weight was ranged from 0.063 – 2.783 g (Table 5). The highest dry root weight was attained 2.783 g in treatment BCA, and the lowest dry root weight was recorded 0.063 g in treatment CBC.

Table 5. Dry root mass in different Depths of pots during corn growing season.

S.No	Treatments	Depth-I (g)	Depth-II (g)	Depth-III (g)	Total dry root mass wt. (g)
1	AAA	0.173 c	2.390	1.163 bcd	3.73 bc
2	AAB	1.840 b	1.013	0.900 bcd	3.75 bcdef
3	ABA	0.897 bc	0.650	0.630 bcd	2.18 bcdef
4	ABB	1.750 bc	0.523	0.450 bcd	2.72 bcdef
5	AAC	5.270 a	1.030	0.427 bcd	6.73 a
6	ACA	1.240 bc	0.437	0.427 bcd	2.10 bcdef
7	ACC	1.603 bc	0.487	0.097 d	2.19 bcdef
8	ABC	0.500 bc	0.323	0.163 d	0.99 def
9	ACB	1.900 b	0.653	0.410 bcd	2.96 bcdef
10	BBB	1.377 bc	0.557	0.823 bcd	2.76 bcdef
11	BBA	1.437 bc	0.730	1.113 bcd	3.28 bcde
12	BAB	1.540 bc	0.860	1.080 bcd	3.48 bcd
13	BAA	1.667 bc	0.893	1.230 bcd	3.79 bc
14	BBC	1.473 bc	0.680	0.387 d	2.54 bcdef
15	BCB	1.303 bc	0.280	0.613 bcd	2.20 bcdef
16	BCC	1.507 bc	0.543	0.267 d	2.32 bcdef
17	BAC	1.677 bc	0.947	0.400 cd	3.02 bcdef
18	BCA	1.500 bc	0.417	2.783 a	4.70 ab
19	CCC	0.440 bc	0.177	0.083 d	0.70 ef
20	CCA	1.150 bc	0.377	0.807 bcd	2.33 bcdef
21	CAC	1.097 bc	0.480	0.140 d	1.72 cdef
22	CAA	1.077 bc	0.653	1.573 bc	3.30 bcde
23	CCB	0.920 bc	0.133	0.277 d	1.33 cdef
24	CBC	0.300 bc	0.097	0.063 d	0.46 f
25	CBB	0.922 bc	0.350	0.343 d	1.62 cdef
26	CAB	0.730 bc	1.640	0.337 d	2.71 bcdef
27	CBA	1.340 bc	0.580	1.577 b	3.50 bcd

Means bearing the same letters are not statistically different from one another with $P<0.05$.

In the combination of all the three depths I, II and III, total dry root mass weight is shown in Table 5. The data was a statistically significant difference among all the treatments. The dry root weight data ranged from 0.46 – 6.73 g. The total highest dry root weight of 6.73 g was possessed by treatment AAC and the lowest dry root weight of 0.460 g was recorded in treatment CBC. Overall, the results show that those treatments, which were a bulk density in the range from 1.00 – 1.30 g cm^{-3} at depth-1, were showing good results as compared to others treatments.

Cumulative Growing Degree Days

A cumulative growing degree day was noted 1768 hrs growing degree days from emergence to harvesting of the crop.

Conclusion

Based on one corn growing season, a combination of different level of bulk densities experiments was conducted on sandy loam soil in the Green House, National Soil Dynamic Laboratory, ARA, USDA, Auburn, Alabama, USA. Mean highest depletion of soil 10.86 and 9.90 cm occurred in treatments AAA and AAB respectively; while the mean lowest depletion of soil 0.01,0.04, and 0.08 cm were recorded in the treatments CCC, CCB and CBC respectively. Highest total amount of Evapo-transpiration was recorded 59.19% in treatment AAB and the lowest total amount of evapo-transpiration was noted 19.36% in CCC treatment.

At Depths –I, II and III, Mean highest root length of 89.41, 104.05 and 142.87 m were noted in treatments AAC, BAC and ABA respectively; while the mean lowest root length of 1.27, 25.55 m was recorded in treatment AAA and 10.79 m was in CCC respectively. In the combination of all the three depths, the mean highest root length was found 237.67 m in treatment BAB and the lowest root length was 55.71 m in treatment CBC. At Depths –I, II and III, the mean highest root length per volume of 13922, 20294 and 28920 m/m^{-3} were attained in treatment BCC, BAC and ABA respectively, while the mean lowest root length per volume of 257, 5172 m/m^{-3} was noted in treatment AAA at depth II and 1366, 1394, 2419 and 2516 m/m^{-3} were noted in treatments CCC, CBC, ACA and ABC respectively at depth III. In the combination of all the three depths I, II and III, the highest root length per volume were found 42533 and 42388 m/m^{-3} in treatments ABA and BAA respectively, and the lowest root length per volume was observed 7690 m/m^{-3} in treatment CBC.

At all the three depths, mean maximum root diameter and root volume of 0.45 mm and 38.50 cm^{-3} were observed in treatment ABB and BCA respectively; and the mean minimum root diameter and root volume of 0.21 mm and 3.47 cm^{-3} were observed in treatment AAA and CBC respectively. At Depth –I, II and III, the mean highest dry root weight of 5.27, 2.39, and 2.78 g were observed in treatments AAC, AAA and BCA respectively; and the mean lowest dry root weight of 0.17 g was in treatment AAA at depth I, and 0.10 and 0.06 g were recorded in treatments CBC at depth II and III respectively. In the combination of all the three depths I, II and III, the mean total highest dry root weight of 6.73 g was attained by treatment AAC and the mean lowest dry root weight of 0.460 g was recorded in treatment CBC. In general, the finding of the results shows that these treatments (i.e. AAB, ABA, AAB, AAC, BBA, BAB, BAC and BCA) were more favorable as compared to other treatments. It is further concluded that on overall basis, the treatments BCA and AAC were shown excellent performance on all parameters.

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Appendices

Appendix A. Average Diameter of Root in different Depths of pots during corn growing season.

S.No	Treatments	Depth-I (mm)	Depth-II (mm)	Depth-III (mm)	Mean Length (mm)
1	AAA	0.270	0.110	0.240	0.210
2	AAB	0.550	0.300	0.270	0.380
3	ABA	0.450	0.310	0.430	0.400
4	ABB	0.560	0.480	0.310	0.450
5	AAC	0.350	0.320	0.310	0.320
6	ACA	0.370	0.340	0.310	0.340
7	ACC	0.290	0.320	0.290	0.300
8	ABC	0.370	0.290	0.320	0.330
9	ACB	0.340	0.310	0.270	0.310
10	BBB	0.300	0.310	0.300	0.300
11	BBA	0.370	0.310	0.340	0.340
12	BAB	0.380	0.290	0.310	0.330
13	BAA	0.340	0.280	0.300	0.310
14	BBC	0.320	0.290	0.390	0.330
15	BCB	0.290	0.320	0.320	0.310
16	BCC	0.290	0.350	0.360	0.330
17	BAC	0.310	0.310	0.370	0.330
18	BCA	0.330	0.310	0.460	0.370
19	CCC	0.380	0.320	0.290	0.330
20	CCA	0.310	0.280	0.290	0.300
21	CAC	0.400	0.330	0.330	0.350
22	CAA	0.410	0.340	0.410	0.390
23	CCB	0.370	0.340	0.260	0.320
24	CBC	0.340	0.250	0.240	0.280
25	CBB	0.370	0.290	0.300	0.320
26	CAB	0.370	0.320	0.280	0.320
27	CBA	0.380	0.310	0.300	0.330

Appendix B. Root volume in different Depths of pots during corn growing season.

S.No	Treatments	Depth-I (cm^3)	Depth-II (cm^3)	Depth-III (cm^3)	Total Root Volume (cm^3)
1	AAA	0.670	2.300	8.820	11.790
2	AAB	2.990	3.060	7.230	13.280
3	ABA	2.470	4.050	29.690	36.200
4	ABB	12.150	11.600	5.200	28.950
5	AAC	3.450	4.670	3.770	11.900
6	ACA	3.750	3.570	5.830	13.150
7	ACC	3.390	3.490	1.420	8.290
8	ABC	2.500	3.900	1.750	8.150
9	ACB	4.130	3.900	4.190	12.220
10	BBB	3.660	4.150	6.770	14.570
11	BBA	3.410	5.180	9.950	18.530
12	BAB	3.460	5.660	8.360	17.470
13	BAA	2.040	4.160	8.890	15.090
14	BBC	4.240	5.790	4.880	14.910
15	BCB	4.470	4.130	6.700	15.300
16	BCC	5.770	5.000	3.210	13.990
17	BAC	4.510	6.720	4.990	16.230
18	BCA	3.870	4.600	30.030	38.500
19	CCC	3.120	2.110	0.720	5.950
20	CCA	3.260	3.080	5.800	12.130
21	CAC	5.180	4.850	2.330	12.350
22	CAA	3.940	5.620	18.070	27.630
23	CCB	3.910	2.680	3.000	9.590
24	CBC	1.740	1.110	0.630	3.470
25	CBB	3.830	3.590	3.880	11.300
26	CAB	3.070	2.800	3.430	9.300
27	CBA	4.230	3.970	6.440	14.640