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## Relationship between compaction levels (bulk density) and chemical properties of different textured soil

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**Abstract**

The investigation entitled “Study of relationship between compaction level (bulk density) and chemical properties of different textured soil” was carried out using various research materials and analytical techniques during 2017-18 at department laboratory of Soil Science at Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut, UP, India. Results of study reveals that levels of compaction does not affects pH and EC significantly however soil OC was affected significantly. More impact was found in organic carbon as compare to pH and EC. Effect of compaction on amount of OC in different textured soil indicates that more organic carbon was found in sandy clay loam soil followed by sandy loam and minimum in loamy sand at same degree of compaction. A strong negative correlation of bulk density with pH ( $r = -0.912, -0.943$  and  $-0.943$ ) EC ( $r = -0.988, -0.991$  and  $-0.992$ ) and OC% ( $r = -0.993, -0.985$  and  $-0.989$ ) for loamy sand, sandy loam and sandy clay loam soil, respectively was observed. The available macro nutrients (N, P and K) of soil decreased significantly with an increase in the level of compaction. A strong negative correlation of bulk density with available N ( $r = -0.993, -0.995$  and  $-0.992$ ), available P ( $r = -0.985, -0.983$  and  $-0.980$ ) and available K ( $r = -0.925, -0.979$  and  $-0.984$ ) for loamy sand, sandy loam and sandy clay loam soil, respectively was found. Unlike available macro nutrient, the micro nutrient of soil also decreased with an increase in the level of compaction. A strong negative correlation between bulk density and available micronutrients Zinc  $r = -0.925, -0.944$  and  $-0.929$  and Iron  $r = -0.981, -0.974$  and  $-0.931$  for loamy sand, sandy loam and sandy clay loam soil, respectively was also recorded.

**Keywords:** Relationship, bulk density, chemical

**Introduction**

The ever-increasing population of the world necessitates the intensification of farming and cropping systems to cope with the demand for more food. As a result, more and heavier farm machinery and/or animals per land surface area have become common all over the world. This intensification of the farming system has led to soil compaction and deterioration in soil fertility. Soil compaction adversely affects soil physical properties, fertility, particularly storage and supply of water and nutrients through increasing soil bulk density, decreasing porosity, increasing soil strength, decreasing soil water infiltration and water holding capacity. These adverse effects reduce fertilizer efficiency and crop yield, increase water-logging, runoff and soil erosion with undesirable environmental pollution problems. Intensification of agriculture could be more worsen when heavy tillage is employed to manipulate soil conditions. Tillage operation consisting of primary and secondary tillage, employed to increase the soil's structural macro porosity, while excessive tillage operations over these freshly tilled soils cause soil compaction (Wang *et al.* 2004). It is hard to identify one single cause responsible for soil compaction rather, a combination of causes are responsible to develop the problem, compaction also govern the nutrient availability in soil. Laiho, *et al.* 2004<sup>[15]</sup> studied the variability in mineral nutrient concentrations (P, K, Ca, Mg, Fe, Mn, Zn) and bulk density within floristically described peat land sites. Reintam, *et al.* 2005<sup>[7]</sup> reported the impact of bulk density on nutrient (N, P, K) assimilation and on cell fluid pH of spring barley with distinct tiers of fertilization. Soil compaction reduces the availability of macro and micro nutrients because of changing the soil ecosystem through reduction in

organic carbon and porosity ultimately the degradation of soil. Soil compaction reduces the yield of many crops by 12-23% (Ishaq *et al.* 2001a) <sup>[10]</sup>. About 68 million ha of the soil worldwide are estimated to be affected by the soil compaction from the vehicular traffic. The soil compaction is responsible for 33, 18, 10 and 4 million ha soil degradation in Europe, Africa, Asia and Australia, respectively and some areas of North America (Flowers and Lal 1998; Hamza and Anderson 2003). Therefore regular monitoring of soil health particularly its compactness is highly required. Knowledge of soil bulk density is imperative for soil management, Keeping this in mind we conducted a study to find out relationship between compaction level (bulk density) and chemical properties of different textured soil.

### Materials and Methods

The investigation entitled "Study of relationship between compaction level (bulk density) and chemical properties of different textured soil" was carried out using various research materials and analytical techniques during 2017-18 at department laboratory of soil science at Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut, UP, India. The study area falls in the district of Meerut from 29°04' N latitude and 77°42' E longitude at an altitude of 237 meter above the mean sea level (MSL). Climate of study area are sub tropical and semi arid climate with hot desiccating summers and cold winters.

Texture of soils collected from three locations (1.Crop research centre Chitori Meerut, 2.Horticulture research centre SVPUAT Campus and 3.Basmati export development foundation modipuram Meerut) was determined using hydrometer method. Different level of compaction was created by maintaining different bulk density (1.1 to 1.8 Mg/m<sup>3</sup>) in 12 inch long plastic pipe of 4 inch diameter through adopting the formula of bulk density equals to mass of soil divided by volume of soil. Different chemical properties of soil like pH, Ec, organic carbon, available nitrogen, phosphorus, potassium, zinc and iron were assessed in the laboratory and furthermore correlation were established using statistical procedure.

### Results and Discussions

Different chemical properties viz pH, Ec, organic carbon, available nitrogen, phosphorus, potassium, zinc and iron estimated from the soil filled in pipe at different level of compaction (1.1 to 1.8 Mg/m<sup>3</sup>) showing different bulk densities are presented in Table 1, 2 and 3. Texture of the soil sample collected from three locations were loamy sand (80% sand, 10% silt and 10% clay), sandy loam (58% sand, 24% silt and 18% clay) and sandy clay loam (50% sand, 22% silt and 28% clay). Data on correlation study (r) for different textured soil are presented in Table 1, 2 and 3.

#### Effect of different levels of compaction on pH, EC and Organic carbon:

Data presented in Table 1, 2 and 3 indicates effect of compaction levels on pH in different textured soil. The maximum pH (7.53), (8.41) and (8.29) for was found at bulk density 1.10, 1.20 and 1.30 Mg m<sup>-3</sup>, respectively for loamy sand sandy loam and sandy clay loam and minimum pH (7.50), (8.39) and (8.27) at bulk density 1.70 and 1.80 Mg m<sup>-3</sup> respectively for loamy sand, sandy loam and sandy clay loam soil. This may be due to compaction decreases porosity and induced anaerobic condition in soil which may produces carbonic acids responsible for lowering the pH. Chaudhary *et*

*al* 2013 also reported that the bulk density is dependent on calcareous and saline nature of soils but independent on whether the soil is acidic or alkaline. However, Shaffer (1998) observed highest correlation between pH and BD at 0 to 15 cm, but he did not indicate the reasons. Similarly Nath 2014 <sup>[13]</sup> also found a negative relationship of bulk density with soil pH, electrical conductivity, total organic matter and macronutrients.

Compaction levels does not resulted any significant effect on EC although the maximum EC (0.290), (0.221) and (0.210) dSm<sup>-1</sup> for loamy sand, sandy loam and sandy clay loam soil, respectively was found at 1.10 Mg m<sup>-3</sup> bulk density while minimum EC (0.274), (0.189) and (0.175) dSm<sup>-1</sup> with 1.80 Mg m<sup>-3</sup> bulk density. It was observed that the bulk density is independent of whether the soil is acidic or alkaline. Compaction levels does not resulted any significant effect on EC although the more EC was found at low compaction while low EC was recorded at high compaction. The similar findings were also recorded by Chaudhary *et al.* 2013. They reported that high EC was found with low compaction. Similarly Nath 2014 <sup>[13]</sup> also found a negative relationship of soil bulk density with soil pH, electrical conductivity, total organic matter and macronutrients.

The bulk density differ with several factors such as compaction, consolidation and amount of soil organic carbon present in the soil and among these it is highly related with organic carbon content. Level of organic carbon decreased as the levels of compaction increased. Data presented in Table 1, 2 and 3 showed that the maximum organic carbon content (0.65, 0.74 and 0.98 percent) was found where level of compaction was minimum (1.10 Mg m<sup>-3</sup>) while minimum organic carbon content (0.47, 0.60, 0.75 percent) for loamy sand, sandy loam and sandy clay loam soil, respectively where level of compaction was maximum (1.80 Mg m<sup>-3</sup>). Our studies showed that the higher organic carbon content was found at low compaction while low organic carbon content was recorded at compaction high. Felton and Ali (1992) <sup>[9]</sup> reported that the addition of organic matter to B-horizon soils leads to an increase in the porosity and the water retention and to a decrease in bulk density determined by proctor test. The soil compaction affects concentration of carbon dioxide (Conlin and Van den Driessche 2000) <sup>[3]</sup> and mineralization of the soil organic carbon and nitrogen in the soil (De Neve and Hofman 2000) <sup>[5]</sup>.

#### Effect of different levels of compaction on available macro nutrient

The available N content of soil decreased significantly with an increase in the level of compaction. Data presented in Table 1, 2 and 3 showed that the maximum available N (189.41, 170.45, and, 284.84 kg ha<sup>-1</sup> for loamy sand, sandy loam and sandy clay loam soil, respectively was recorded at 1.10 Mg m<sup>-3</sup> bulk density while minimum available N (164.87, 146.89 and 263.99 kg ha<sup>-1</sup> where level of compaction was maximum (1.80 Mg m<sup>-3</sup>). Tan *et al.* (2008) <sup>[20]</sup> also reported the same observations. They found that the soil compaction reduces the available N and efficiency of N use by the crops decreases (Douglas and Crawford 1991) <sup>[6]</sup>, which can increase the fertilizer requirements. In case of lower bulk density porosity will be more which will favour aerobic condition in soil and consequently more mineralization of organic matter and thereby more availability of nitrogen and phosphorus.

Alike available nitrogen, available P in soil decreased with an increase in the level of compaction. Data presented in Table 1,

2 and 3 showed that the maximum available P (15.15, 19.35 and 49.40 kg ha<sup>-1</sup> for loamy sand, sandy loam and sandy clay loam soil, respectively at low compaction (1.10 Mg m<sup>-3</sup>) while minimum available P (14.91, 19.13 and 49.27 kg ha<sup>-1</sup> for where level of compaction was maximum (1.80 Mg m<sup>-3</sup>). Mathan *et al.*, (1994) [12] reported significantly higher accumulation of P in the surface soil (top 2.5 cm) occurred in no-till soil, owing to deposition of P by residue on the soil surface Chaudhary *et al.* (2013) [2] have also concluded that as the bulk density decreases the total primary and secondary macronutrient contents in the soil increases

The available K content of soil decreased with an increase in the level of compaction. Data presented in Table 1, 2 and 3 clearly showed that the maximum available K (62.08, 210.66 and 259.70 kg ha<sup>-1</sup> was found at 1.10 Mg m<sup>-3</sup> bulk density while minimum available K (58.97, 199.18 and 249.31 kg ha<sup>-1</sup> for loamy sand, sandy loam and sandy clay loam soil, respectively at maximum bulk density (1.80 Mg m<sup>-3</sup>). Agrawal (1991) [1] advocated that compaction of sandy soil favorably affects hydraulic parameters, viz, moisture retention, infiltration and saturated hydraulic conductivity, which are important for improving their water status and reducing the leaching losses of soluble nutrients. Rhoton *et al.*, (1993) [16] also observed the same results.

#### Effect of different levels of compaction on available micro nutrient

The available Zn content of soil decreased with an increase in the level of compaction. Data presented in Table 1, 2 and 3 showed that the maximum available Zn (0.98), (1.50) and (1.40) ppm for loamy sand, sandy loam and sandy clay loam soil, respectively was found in T<sub>1</sub> where level of compaction in term of bulk density was minimum (1.1 Mg m<sup>-3</sup>) while minimum available Zn (0.93), (1.42) and (1.34) ppm for loamy sand, sandy loam and sandy clay loam soil, respectively in T<sub>8</sub> where level of compaction in terms of bulk density was maximum (1.8 Mg m<sup>-3</sup>). Chaudhary *et al.* 2013 also recorded the similar observations. They noticed the available micronutrients (Fe + Mn + Zn + Cu) in the soil also varied with bulk density of the soil. It was found that the bulk density decreases as the total micronutrient contents in the soil increases

The available Fe content of soil decreased significantly with an increase in the level of compaction. Data presented in Table 1, 2 and 3 showed that the maximum available Fe (13.29), (16.05), (18.54) ppm for loamy sand, sandy loam and sandy clay loam soil, respectively was found in T<sub>1</sub> where level of compaction in term of bulk density was minimum (1.10 Mg m<sup>-3</sup>) while minimum available Fe (12.62), (15.25) and (17.80) ppm for loamy sand, sandy loam and sandy clay loam soil, respectively in T<sub>8</sub> where level of compaction in term of bulk density was maximum (1.80 Mg m<sup>-3</sup>). The available micronutrients (Zn + Fe) in the soil also differ with bulk density of the soil. Similar results were also recorded by Laiho, *et al.* 2004 and Chaudhary *et al.* 2013 [15].

**Relationship between compaction level (bulk density) and pH, EC & organic carbon of soil:** Data presented in Table 4, 5 and 6 indicated that, pH and EC decreases as the bulk density increases. Statistical correlation studies showed a strong negative correlation  $r = -0.912$ ,  $-0.943$  and  $-0.943$

among bulk density and pH of soil for loamy sand, sandy loam and sandy clay loam soil, respectively. We also found a strong negative correlation  $r = -0.988$ ,  $-0.991$  and  $-0.992$  among bulk density and EC for loamy sand, sandy loam and sandy clay loam soil, respectively. Statistical correlation studied by Chaudhary *et al.*, 2013 between bulk density and, pH & EC showed negative correlations. Bulk density showed negative correlation with CaCO<sub>3</sub> ( $r = -0.4952$ ) content and electrical conductivity ( $r = -0.6611$ ).

It was observed a strong negative correlation between bulk density and total organic carbon content of the soil samples  $r = -0.993$ ,  $-0.985$  and  $-0.989$  for loamy sand, sandy loam and sandy clay loam soil, respectively, which indicate that as the organic carbon increases the bulk density of soil decreases. The bulk density bears an inverse relationship with the soil organic matter (White, 1987) [22]. Many researchers (Morisada *et al.* 2004 and Leifeld *et al.* 2005) [11] obtained the relationship between organic matter and bulk density of soils and showed strong correlation between them. Curtis and Post (1964) [4] stated a reverse correlation between organic matter and bulk density. E. Sakin (2011) [8] determined the strongest correlation between bulk densities and organic matter among the data attained from the analysis results. They obtained similar results with strong negative correlation ( $r = -0.8869$ ) between organic matter and bulk density of soil samples.

#### Relationship between compaction levels (bulk density) and macro nutrients of soil

The bulk density of the soil samples decides the available macronutrients in the soil. It was found that as the bulk density decreases the macronutrient contents in the soil increases. Data presented in Table 4, 5 and 6 showed a strong negative correlation  $r = -0.993$ ,  $-0.995$  and  $-0.992$  among the bulk density and available N for loamy sand, sandy loam and sandy clay loam soil, respectively. A strong negative correlation  $r = -0.985$ ,  $-0.983$  and  $-0.980$  was found between bulk density and available P for loamy sand, sandy loam and sandy clay loam soil, respectively. Similarly a strong negative correlation  $r = -0.925$ ,  $-0.979$  and  $-0.984$  was found between bulk density and available K for loamy sand, sandy loam and sandy clay loam soil, respectively. Chaudhary, *et al.* (2013) [2] also studied the statistical correlation and found strong negative correlation of bulk density with available total primary macronutrients ( $r = -0.8615$ ) in the soil.

#### Relationship between compaction levels (bulk density) and micro nutrients of soil

It was found that as bulk density decreases the total micronutrient contents in the soil increases. Statistical correlation studies showed (Table 4, 5 and 6) a strong negative correlation between bulk density and available micronutrients Zinc  $r = -0.925$ ,  $-0.944$  and  $-0.929$  for loamy sand, sandy loam and sandy clay loam soil, respectively and Iron  $r = -0.981$ ,  $-0.974$  and  $-0.931$  for loamy sand, sandy loam and sandy clay loam soil, respectively.

Correlation studies conducted by Chaudhary *et al.* 2013 also showed strong negative correlation between bulk density and available total micronutrients ( $r = -0.7089$ ) in the soil. Laiho, *et al.* 2004 [15] also reported that the total variances of Fe and Zn decreases with increase in bulk density.

**Table 1:** Chemical properties of loamy sand soil under different level of compaction (BD)

Treatment	Level of Compaction/ Bulk density ( $\text{Mg m}^{-3}$ )	pH	EC ( $\text{dsm}^{-1}$ )	OC (%)	Available Nutrient				
					N $\text{Kg ha}^{-1}$	P $\text{Kg ha}^{-1}$	K $\text{Kg ha}^{-1}$	Zn ppm	Fe ppm
T1	1.10	7.53	0.290	0.65	189.41	15.15	62.08	0.98	13.29
T2	1.20	7.53	0.290	0.64	187.65	15.13	62.05	0.98	13.29
T3	1.30	7.53	0.287	0.62	184.37	15.11	61.97	0.98	13.06
T4	1.40	7.52	0.285	0.58	180.33	15.08	61.75	0.97	12.98
T5	1.50	7.52	0.281	0.56	174.05	15.05	61.38	0.97	12.95
T6	1.60	7.52	0.280	0.53	171.28	15.01	60.75	0.96	12.88
T7	1.70	7.50	0.278	0.51	167.13	14.96	60.16	0.94	12.74
T8	1.80	7.50	0.274	0.47	164.87	14.91	58.97	0.93	12.62

**Table 2:** Chemical properties of sandy loam soil under different level of compaction (BD)

Treatment	Level of Compaction/ Bulk density ( $\text{Mg m}^{-3}$ )	pH	EC ( $\text{dsm}^{-1}$ )	OC (%)	Available Nutrient				
					N $\text{Kg ha}^{-1}$	P $\text{Kg ha}^{-1}$	K $\text{Kg ha}^{-1}$	Zn ppm	Fe ppm
T1	1.10	8.41	0.221	0.74	170.45	19.35	210.66	1.50	16.05
T2	1.20	8.41	0.219	0.73	168.83	19.35	210.56	1.50	16.05
T3	1.30	8.41	0.214	0.71	163.41	19.32	209.91	1.50	16.00
T4	1.40	8.40	0.206	0.70	160.11	19.29	207.81	1.48	15.87
T5	1.50	8.40	0.200	0.68	157.33	19.26	205.70	1.48	15.74
T6	1.60	8.40	0.199	0.66	155.38	19.22	203.48	1.46	15.52
T7	1.70	8.39	0.193	0.63	150.93	19.18	201.85	1.43	15.44
T8	1.80	8.39	0.189	0.60	146.89	19.13	199.18	1.42	15.25

**Table 3:** Chemical properties of sandy clay loam soil under different level of compaction (BD)

Treatment	Level of Compaction/ Bulk density ( $\text{Mg m}^{-3}$ )	pH	EC ( $\text{dsm}^{-1}$ )	OC (%)	Available Nutrient				
					N $\text{Kg ha}^{-1}$	P $\text{Kg ha}^{-1}$	K $\text{Kg ha}^{-1}$	Zn ppm	Fe ppm
T1	1.10	8.29	0.210	0.98	284.84	49.40	259.70	1.40	18.54
T2	1.20	8.29	0.205	0.97	283.92	49.40	259.61	1.40	18.54
T3	1.30	8.29	0.199	0.95	280.47	49.39	258.43	1.40	18.49
T4	1.40	8.28	0.193	0.91	278.82	49.37	257.09	1.40	18.40
T5	1.50	8.28	0.188	0.87	274.31	49.34	254.83	1.38	18.33
T6	1.60	8.28	0.186	0.84	270.55	49.32	252.97	1.37	18.25
T7	1.70	8.27	0.183	0.80	267.76	49.30	250.76	1.35	18.12
T8	1.80	8.27	0.175	0.75	263.99	49.27	249.31	1.34	17.80

**Table 4:** Simple correlation coefficient (r) between bulk densities with soil (Loamy sand) chemical parameters:

Related soil parameters	Correlation Coefficient (r)	Level of Significance
Bulk density—pH	-0.912	Negative but not significant
Bulk density -Electrical conductivity	-0.988	
Bulk density—Organic matter (%)	-0.993	
Bulk density—N	-0.993	Strong negative
Bulk density—P	-0.985	Strong negative
Bulk density—K	-0.925	Strong negative
Bulk density—Zn	-0.925	Strong negative
Bulk density—Fe	-0.981	Strong negative

**Table 5:** Simple correlation coefficient (r) between bulk densities with soil (Sandy loam) chemical parameters

Related soil parameters	Correlation Coefficient (r)	Level of Significance
Bulk density—pH	-0.943	Negative but not significant
Bulk density -Electrical conductivity	-0.991	
Bulk density—Organic matter (%)	-0.985	
Bulk density—N	-0.995	Strong negative
Bulk density—P	-0.983	Strong negative
Bulk density—K	-0.979	Strong negative
Bulk density—Zn	-0.944	Strong negative
Bulk density—Fe	-0.974	Strong negative



**Table 6:** Simple correlation coefficient (r) between bulk densities with soil (Sandy clay loam) chemical parameters:

Related soil parameters	Correlation Coefficient (r)	Level of Significance
Bulk density—pH	-0.943	Negative but not significant
Bulk density -Electrical conductivity	-0.992	
Bulk density—Organic matter (%)	-0.989	
Bulk density—N	-0.992	Strong negative
Bulk density—P	-0.980	Strong negative
Bulk density—K	-0.984	Strong negative
Bulk density—Zn	-0.929	Strong negative
Bulk density—Fe	-0.931	Strong negative

## Conclusions

Results of study reveals that levels of compaction does not affects pH & EC significantly but affect soil OC significantly. More impact was found in organic carbon as compare to pH and EC. Effect of compaction on amount of OC in different textured soil indicates that more organic carbon was found in sandy clay loam soil followed by sandy loam and minimum in loamy sand at same degree of compaction. The available macro nutrient of soil decreased significantly with an increase in the level of compaction. Alike available macro nutrient, the micro nutrient of soil also decreased with an increase in the level of compaction. Statistical correlation studies showed a very strong negative correlation between compaction levels and soil chemical properties.

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