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Influence of Soil Properties on Compactability Behavior of Alluvial Soils under Different Cropping Systems in Haryana

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Abstract

Intensive cropping, increased mechanization and different tillage practices used for higher production in the state of Harayana have caused gradual compaction of soils. In this paper, the soil properties and the indices of soil compactability identified for predicting the soil compactability of alluvial soils of the state were used to determine the compactability behavior of soils and the level of compaction existing under different cropping systems. Soil samples were collected from five different locations from each of rice-wheat, cotton-wheat, bajra-wheat/mustard, and fallow-gram/mustard cropping systems of the state. The samples were grouped according to the cropping systems and their textures. The differences in soil properties between each group were compared with the mean differences analysis test. The relative bulk density was used to assess the existing level of soil compaction under different cropping systems. The texture was the major determinant of the compaction behavior of soils under different cropping systems. The level of compaction was highest in soils of rice-wheat cropping system followed by cotton-wheat, bajra-wheat/mustard and fallow-gram/mustard. The variation in the level of compaction was, however, quite large in each cropping system.
Key words : Compaction, Physical properties, Alluvial soils, Cropping systems, Haryana.

It has been realized after a gap of almost more than three decades that the intensive cropping and increased mechanization used for higher production in the state of Haryana have, in general, resulted in gradual compaction of soils. The susceptibility of soils to compaction is also arising due to imbalance use of inorganic fertilizers and over tilling that contributes to a gradual reduction in organic matter under different cropping systems. Cropping system followed primarily depends upon the texture, organic carbon content, the availability of water for irrigation and the size of land holding, apart from the domestic need of

Table 1. Variation in soil properties and indices of soil compaction for different cropping systems.

Soil property/compaction index (g/100 g)	Cropping system			
	Rice-wheat	Cotton-wheat	Pearl millet-wheat/mustard	Fallow-gram/mustard
Sand	41.6—77.6	62.7—92.3	51.1—87.2	74.2—94.3
Silt	9.2—26.1	2.6—18.2	5.3—17.4	1.0—10.2
Clay	12.6—34.1	5.9—19.1	8.0—33.4	4.2—15.6
Silt + Clay	22.4—58.4	7.7—37.3	12.8—48.9	5.7—25.8
Particle density (Mg/m^3)	2.46—2.66	2.58—2.66	2.51—2.64	2.57—2.65
Liquid limit	19.2—32.1	17.4—27.4	17.5—27.8	18.5—23.0
Plastic limit	11.2—17.6	9.8—12.7	11.4—16.4	–
Plastic index	8.0—14.8	6.5—11.9	10.8—12.9	–
Organic carbon	0.14—0.67	0.10—0.26	0.04—0.30	0.04—0.18
Field capacity moisture content	13.6—31.7	7.0—23.3	5.9—26.2	5.9—15.5
Maximum dry bulk density (Mg/m_3)	1.65—1.87	1.67—1.87	1.71—1.93	1.72—1.92
Critical water content	11.9—19.3	11.8—16.8	10.0—17.2	9.5—15.7
Susceptibility to compaction	0.021—0.036	0.008—0.024	0.014—0.022	0.007—0.024

Table 2. MBD, CWC, SC, organic carbon and textural parameters measured for soils in relation to their different cropping systems. The values in parentheses are standard deviations.

Cropping system	Sand	Silt	Clay	OC	MBD	CWC	SC
Rice-wheat	60.1	17.5	18.4	0.382	1.72	16.6	0.0268
	(5.0)	(2.2)	(3.4)	(0.07)	(0.04)	(1.0)	(0.0023)
Cotton-wheat	75.7	12.3	11.9	0.181	1.80	14.1	0.0196
	(4.0)	(2.5)	(2.0)	(0.02)	(0.03)	(0.8)	(0.0025)
Bajra-wheat/mustard	73.8	9.9	16.3	0.126	1.82	13.7	0.0194
	(5.3)	(2.0)	(3.5)	(0.03)	(0.03)	(0.8)	(0.0011)
Fallow-gram/mustard	85.4	4.9	9.6	0.099	1.83	13.1	0.0154
	(6.7)	(1.4)	(1.7)	(0.02)	(0.03)	(0.8)	(0.0021)

the farmers and the risk associated with the cropping system to be followed. The organic residue particles are reported to be more effective in separating single-grain particles in sandy soils than in fine textured soils due to the lower surface area of the former (1). Therefore, it becomes necessary to determine the soil conditions where organic matter may have optimum effect on soil compactability and the extent to which it can reduce it.

The measurement of soil compactability is time consuming, therefore, many researchers have attempted to predict soil compactability from the simpler, cheaper or more readily measurable soil compaction indices using soil properties including particle size distribution, organic matter or moisture of soil during tillage and other farm operations with varied degree of success (2—6). In the state of Haryana there is a substantial increase in the cropping intensity, and number of tractors and other tillage implements after green revolution. Due to increased use of canal and underground water for irrigation, the area under different cropping sequences is changing and farmers are adopting cropping systems which are more remunerative such as rice-wheat, without caring the soils to sustain crop production. Increased adoption of zero tillage technology for wheat in rice-wheat cropping system in recent past also requires knowledge regarding compactability behavior of the soils. The present study was, therefore, undertaken to determine the compactability behavior of soils under different cropping systems, and to assess the level of compaction existing under different cropping systems for planning management strategies to overcome the problem of soil compaction in the state.

Methods

Surface soil samples were collected from five different locations from each of rice-wheat, cotton-wheat, pearl millet-wheat/mustard, and fallow-gram/mustard cropping system, in triplicates, during January 2005. The most common texture was loam followed by sandy loam, sand, loamy sand and loam, although variation occurred within the cropping system. The

Table 3. MBD, CWC, SC, organic carbon and textural parameters measured for soils under different cropping systems in relation to their textures. The values in parentheses are the standard deviation.

Texture	Sand	Silt	Clay	OC	MBD	CWC	SC
Sand	91.4	2.3	6.3	0.113	1.75	14.4	0.0112
	(1.4)	(0.7)	(0.8)	(0.030)	(0.05)	(1.2)	(0.0020)
Loamy sand	81.2	9.6	9.2	0.119	1.80	13.6	0.0178
	(3.2)	(3.5)	(0.9)	(0.050)	(0.03)	(1.6)	(0.0022)
Sandy loam	77.6	8.5	13.8	0.137	1.86	12.9	0.0207
	(1.6)	(0.9)	(0.9)	(0.020)	(0.01)	(0.5)	(0.0008)
Loam	68.8	16.1	15.1	0.302	1.75	15.4	0.0241
	(1.5)	(1.3)	(0.8)	(0.064)	(0.03)	(0.9)	(0.0010)
Clay loam	49.1	19.7	31.2	0.275	1.70	16.3	0.0254
	(4.9)	(3.7)	(2.3)	(0.158)	(0.04)	(1.7)	(0.0080)

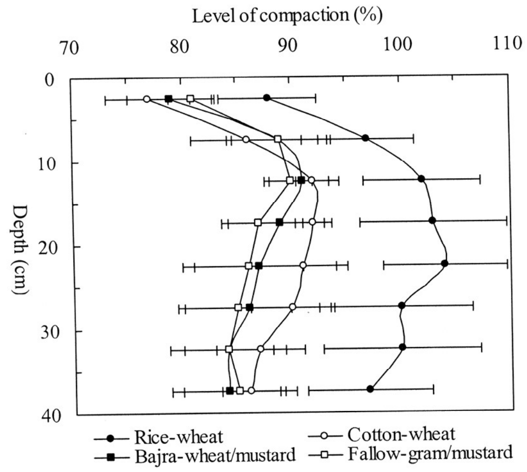

Figure 1. Level of soil compaction at different depths under different cropping systems.

compaction behavior of soils under different cropping systems was studied using the compaction indices i.e. maximum bulk density (MBD), critical water content (CWC) and susceptibility to compaction (SC) obtained using standard procedures. For measuring the level of soil compaction existing under different cropping systems, core samples from various depths (0—5, 5—10, 10—15, 15—20, 20—25, 25—30, 30—35 and 35—40 cm) from 20 different locations covering all the four cropping systems were collected for measurement of the field bulk density, in triplicate. The relative bulk density i.e. the ratio of actual bulk density of soil in the field to the maximum bulk density as obtained using standard proctor test, was calculated and used for assessing the level of soil compaction in the cropping systems.

The samples were also grouped according to cropping system and their texture. The differences in soil properties (variables) between each group were compared with the mean differences analysis test.

Results and Discussion

The soil properties of different cropping systems covered an almost entire range of values existing in the soils of Haryana (Table 1). The range of values obtained for sand was from 41.6 to 94.3%, silt from 1.0 to 26.1%, clay from 4.2 to 34.1% and silt + clay from 5.7 to 58.4%. The organic carbon content ranged from 0.04 to o.67%. The variations in soil properties and assiociated compactability indices show that soil samples were collected from areas having variation in texture (particle size distribution) and organic matter content.

For evaluating the compactability behavior of soils under different cropping systems, the soils were organized into different groupings based on their cropping systems and textured classes, and the mean values of compactability indices, organic carbon content and the textural parameters for cropping systems and textural classes are given in Tables 2 and 3, respectively. The content of silt, clay and OC was highest in soils under rice-wheat followed by cotton-wheat, bajra-wheat/mustard and least in fallow-gram/mustard dropping system. Similar trend was observed in the values of CWC and SC in the cropping system. This was because the rice-wheat system is generally followed in heavier textured soil and fallow-gram/mustard system in light (sandy soils). The heavier textured are relatively higher in their OC contents (Table 3). Since the compactability indices were better correlated with OC and silt contents, the coefficient of determinations for compactability indices and OC, silt and silt+OC are given separetely in Table 4 for cropping systems and in Table 5 for soil textures.

The significant relationship was found between

Table 4. Coefficients of determination (r^2 or R^2) between indices of soil compactability, and organic carbon content (OC), silt and silt + OC of soils in relation to their cropping system (n=15).

Cropping system	Maximum bulk density (MBD, Mg/m^3)			Critical water content (%)			Susceptibility to compaction (%)		
	OC	Silt	Silt+OC	OC	Silt	Silt+OC	OC	Silt	Silt+OC
Rice-wheat	0.37	0.48	0.50	0.58*	0.62*	0.68**	0.47	0.80**	0.80**
Cotton-wheat	0.02	0.33	0.35	0.03	0.06	0.16	0.07	0.77**	0.79**
Bajra-wheat/mustard	0.01	0.40	0.42	0.05	0.09	0.11	0.13	0.04	0.26
Fallow-gram/mustard	0.01	0.63*	0.64*	0.18	0.20	0.39	0.07	0.60*	0.69**

Table 5. Coefficients of determination (r^2 or R^2) between indices of soil compactability, and organic carbon content (OC), silt and silt+OC of soils in relation to their textures.

		Maximum bulk density (MBD, Mg/m³)			Critical water content (%)			Susceptibility to compaction (%)		
Texture	n	OC	Silt	Silt+OC	OC	Silt	Silt+OC	OC	Silt	Silt+OC
Sand	10	0.02	0.61	0.62	0.20	0.61	0.77**	0.74**	0.08	0.79**
Loamy sand	8	0.11	0.11	0.12	0.36	0.27	0.36	0.40	0.57	0.57
Sandy loam	17	0.01	0.01	0.01	0.00	0.00	0.00	0.01	0.40	0.46
Loam	19	0.42	0.18	0.45	0.60**	0.43	0.61**	0.76**	0.50*	0.76**
Clay loam	6	0.99**	0.62	0.99**	0.97**	0.64	0.97**	0.86*	0.86*	0.97**

MBD and silt in fallow-gram/mustard cropping system, CWC with OC and silt in rice-wheat system and SC and silt in all the cropping system except bajra-wheat/mustard. The poor influence of OC on the estimation of soil compactability in different cropping systems may be attributed primarily to the reason that individual cropping system was spread over in areas where the textural variation of soils was large and the soils of some textural classes were under different cropping systems. For example, rice-wheat system was followed in soils which were sandy loam, loam and clay loam in texture and bajra-wheat/mustard on loamy sand, sandy loam, loam and clay loam soils. Loam soils were under rice-wheat, cotton-wheat and bajra-wheat/mustard cropping systems. Secondly, the soils were not sufficiently high in their organic carbon contents and thirdly, the small number of data sets (15) may not be sufficient to explain the variation in the values of compaction indices under different cropping systems. The highest coefficients of determination observed ($r^2 = 0.38$) in rice-wheat system as compared to other systems may be due to the reason that rice-wheat system is usually followed on relatively heavier textured soils and OC is usually associated with these soils. In the state, due to scarcity of water, the heavier textured soils are also used for less water requiring crops or cropping systems. When data were arranged according to their textural classes (Table 5), the OC was found to be related to MBD in clay loam soil as the OC content was expectedly lower in soils of lighter textured. The CWC and SC were found to be related to OC in loam and clay loam soil emphasizing the role of OC and silt in estimation of these compaction indices. These results may not be of desired accuracy as the number of samples in each textural class was less, e.g. number of samples in clay loam soil was as low as six. The results thus, show that the soil texture determines the compaction behavior of soil rather than the cropping system, and addition of organic matter content may play the key role in covering the risk of excessive compaction of the alluvial soils.

The level of soil compaction found to exist was highest in rice-wheat cropping system as compared to other systems although the variation in soil compaction was quite large in each cropping system (Fig. 1). This was because of relatively heavy textured soils under rice-wheat system which is compaction sensitive as compared to coarse textured soils. In each cropping system, the highest compaction was found to be at a depth of 10—20 cm which emphasizes that intensive cropping and mechanization used for higher production in the state has gradually caused the development of plough sole below the usually tilled soil layer (0—10 cm). More than 100% compaction in some of the soils in rice-wheat cropping system was due to the procedure followed for calculation of the level of compaction. Some of the clay loam soils in rice-wheat system were of swelling type, the MBD of these soils could not be measured accurately by using proctor test while the field bulk density values were quite high. These results suggest that it is necessary to monitor the bulk density of soils at different depths so that the effects of current agricultural practices on soil compaction may be assessed and measures to correct/avoid excessive compaction may be undertaken.

Conclusion

It is concluded that the soil compactability in different cropping systems was not found to be related to organic carbon contents of soils because of low organic matter content of soils and individual cropping system was spread over in areas where the textural variation of soils was large. Soil texture was the major determinant of the compaction behavior of soils under different cropping systems. The level of soil compaction was highest in rice-wheat cropping system as compared to other systems although the variation in soil compaction was quite large in each cropping system. In each cropping system, the highest compaction was found to be at a depth of 10—20 cm indicating that intensive cropping and mechanization used for higher production in the state have gradually caused the development of plough sole below the usually tilled soil layer. Addition of organic matter may play an important role in covering the risk of excessive compaction of the alluvial soils of the state in the present era of intensive agriculture.

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