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Effect of Compaction on Soil Physical Properties and Nitrogen Utilization by Wheat and Pearl Millet Crops in Loamy Sand

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ABSTRACT

Field experiments were conducted during 1995 and 1996 on highly permeable loamy sand to evaluate the effect of compaction and nitrogen on change in soil physical properties, yield and nitrogen utilization efficiency by wheat and pearl millet crops. The results indicated that sub-surface compaction decreased the saturated hydraulic conductivity and total porosity besides increasing the bulk density,moisture storage capacity and retention of applied N in the root zone during both the cropping seasons. The yield and N uptake by wheat and pearl millet increased significantly with increasing levels of compaction and N. The N use efficiency of wheat and pearl millet improved significantly with increasing levels of compaction at a given level of N application but it decreased significantly with increasing levels of N application at a given level of compaction.

Introduction

The agricultural production potential of highly permeable and light textured soils in arid and semi-arid regions of Rajasthan are low due to high water and nutrient losses from the effective root zone during rainy season or under heavy irrigation. More over, these soils have excessive non-capillary porosity at the cost of capillary porosity (Somani and Kumawat, 1986). Use of surface mulches to retard evaporation, artificial barriers of asphalt, bitumen and cement in the sub soil zone of sandy soils have been found to reduce the water and nutrient losses and improve crop yield, but their adoption on a large scale has been limited by the high cost of the technology. However, compaction of such soil was proposed to alleviate the physical property of excessive water loss so as to improve moisture and nutrient retentivity besides improving the crop yields.

Materials and Methods

Field experiments were conducted during *rabi* 1995-96 with wheat (cv. Raj. 3077) and during *kharif* 1996 with pearl millet (cv. MH 179) at the experimental farm of the College of Agriculture, Jobner on Chomu series (loamy sand, mixed hyperthermic family of typic Ustipsamment) to assess the effect of compaction on soil physical properties, NO_3-N distribution pattern and crop response. The soils of the experimental site (85 to 86% sand, 6 to 8% silt and 6 to 7% clay) have pH 8.0 to 8.2, EC 0.40 to 0.85 dSm^{-1}, organic carbon 0.15 to 0.16%, CEC 4.5 to 4.6 c mol (p+) kg^{-1}, NO_3-N 3.2 to 3.5 mg kg^{-1}, available N, P, K, 108 to 110, 24 to 25, 154 to 155 kg ha^{-1}, respectively. The bulk density and moisture content at 0.33 and 15 bar varied from 1.48 to 1.51 Mg m^{-3}, 10.8 to 11.2 and 2.3 to 2.5 per cent, respectively. The treatments consisted of three levels of compaction (0, 4 and 8 passings by 500 kg manually driven iron roller having 125 cm length and 75 cm diameter with 10 cm x 125 cm actual area of contact, creates pressure per unit area of 0.40 kg cm^{-2} in main-plots for both the crops) and four levels of N(0, 40, 80 and 120 kg N ha^{-1} for wheat and 0, 30, 60 and 90 kg N ha^{-1} for pearl millet) through urea in sub-plots of 3 x 2 m^2 size. The experiments were laid out in split plot design with four replications. The soil of the treatment plots were compacted at optimum moisture (Proctor, 1933) following pre sowing irrigation of 7 cm on November 13, 1995 and 134 mm rainfall received in the third week of June, 1996. The wheat and pearl millet seeds @ 120 and 4 kg ha^{-1} were sown on November 15, 1995 and June 25, 1996 at a row distance of 22.5 and 40 cm, respectively. Uniform basal dose of 40 kg P_2O_5 ha^{-1} and 30 kg K_2O ha^{-1} was applied through single super phosphate and muriate of potash for wheat and 30 kg P_2O_5 ha^{-1} as SSP for pearl millet. One third dose of N as per treatments through urea were applied at sowing and remaining dose of N were top dressed in two splits one and two months after sowing in both the crops. The cultural operations were performed as per recommended practice. Wheat crop received nine irrigations during its entire growth period whereas pearl millet was raised under rainfed condition.

Wheat and pearl millet crops were harvested on April 3, 1996 and October 5, 1996. The grain, straw and stover yields were recorded and their N content were determined by the micro-kjeldhal method. Soil physical properties and NO_3-N distributions were determined as per methods described by Singh (1980) and Black (1965), respectively.

Results and Discussion

Soil physical properties : After sub-surface compaction, change in bulk density, saturated hydraulic conductivity, total porosity and moisture retention in loamy sands were recorded. Data in table 1 revealed that the maximum increase in bulk density (15-30 cm soil layer) just after compaction, at flowering and harvest stages of crops and moisture retention (cm/45cm) after 24 hours, 3 days after irrigation and 15 days after rainfall was obtained under 8 passings of 500 kg iron roller during both the cropping periods. Similarly, higher increase in saturated hydraulic conductivity and total porosity was found under 8 passings in all the soil layers (i.e. 0-15, 15-30 and 30-45 cm depths) during both the cropping periods as compared to that of no passing and 4 passings, respectively.

NO_3 - N in Soil : The increasing levels of compaction and N increased the retention of NO_3-N in the sub-surface 15-30 cm soil layers and then decreased gradually in the lower layers of 30-45 cm depths recorded at flowering stage of wheat and pearl millet crops (Table 2). Compaction by 8 passings with 120 kg N ha^{-1} in wheat and 90 kg N ha^{-1} in pearl millet retained 7.9, 8.0 and 5.3 and 7.4, 8.2 and 5.4 mg kg^{-1} more NO_3-N over control and 4.3, 4.7 and 5.1 and 3.9, 4.9 and 5.0 mg kg^{-1} NO_3-N over 4 passings at the same level of N, respectively in 0-15, 15-30 and 30-45 cm depths. The sub-surface soil layers of 15-30 and 30-45 cm depths were found to be the zone of higher NO_3-N retention mainly due to high bulk density layers which retained NO_3-N for longer duration (Agrawal, 1991)

Crop yield : Significant response to compaction by grain, straw and stover yields in wheat and pearl millet was observed (Table 3). Increasing levels of compaction from 4 to 8 passings resulted in 19 and 48 per cent higher grain and 14 and 34 per cent straw yield of wheat over control. Likewise, in pearl millet compaction from 4 to 8 passings gave 20 and 36 per cent more grain and 17 and 32 per cent stover yield over control. Progressive increase in crop yield due to compaction was attributed to decrease in percolation losses of nutrients and improvement in moisture storage in the soil (Gupta *et al.*, 1984).

The grain, straw and stover yield of wheat and pearl millet increased significantly with increasing application of N. Increasing levels of N from 40 to 120 kg ha^{-1} in wheat gave 29, 50 and 66 and 20, 32 and 42 per cent more increase in grain and straw yield over control. Similarly, increasing levels of N from 30 to 90 kg ha^{-1} in pearl millet resulted in 49, 84 and 105 and 44, 77 and 93 per cent higher grain and stover yield over control. Increase in yields of wheat and pearl millet crops due to application of N is attributed to very low available N status of the soil. Plants adequately supplied with N had more number of functional leaves and photosynthesising area and this consequently contributed to better growth and development of individual plant. This, in turn, resulted in production of grain, straw and stover yields.

Significant interaction effect of compaction and N was observed on grain, straw and stover yields of wheat and pearl millet (Table 3). The grain yield of wheat under treatment combination of 8 passing with 80 kg N ha^{-1} was superior than that obtained with 120 kg N ha^{-1} in uncompacted plot. Thus a saving of 40 kg N ha^{-1} resulted due to compaction. Similarly, in case of pearl millet, grain yields obtained under treatment combinations of no passing with 60 kg N ha^{-1} and 4 passings with 30 kg N ha^{-1} as well as no passing with 90 kg N ha^{-1} and 8 passings with 30 kg N ha^{-1} were found at par. However, maximum grain and stover yield was obtained under treatment combination of 8 passings with 90 kg N ha^{-1}. Moreover, response to N significantly increased due to compaction at all the levels of N application. Such high response to N application due to compaction of sandy soil was also reported by Mathan and Natesan (1993) who ascribed it to decrease in leaching of N after soil compaction in light textured soils besides improving the crop yields.

Nitrogen uptake : The total uptake of N by wheat and pearl millet increased significantly with increasing levels of compaction (Table 3). The per cent increase in N uptake by wheat was 24 and 49 while in pearl millet it was of the order of 14 and 43 over control due to compaction by 4 and 8 passings, respectively.

Significant increase in mean uptake of N was

Table 1. Effect of compaction on soil physicsl properties

Stage of sampling	Depth (cm)	Compaction levels (passings by roller)					
		Wheat			Pearl millet		
		0	4	8	0	4	8
(a) Bulk density (Mg m^{-3})							
Just after compaction	0-15	1.49	1.54	1.57	1.49	1.56	1.60
	15-30	1.52	1.56	1.64	1.52	1.59	1.65
	30-45	1.54	1.53	1.61	1.54	1.57	1.62
At flowering	0-15	1.49	1.53	1.55	1.49	1.54	1.57
	15-30	1.52	1.56	1.63	1.52	1.56	1.63
	30-45	1.53	1.55	1.58	1.53	1.55	1.60
At harvest	0-15	1.49	1.53	1.54	1.48	1.53	1.55
	15-30	1.53	1.55	1.58	1.52	1.55	1.59
	30-45	1.53	1.54	1.56	1.53	1.54	1.57
(b) Saturated hydraulic conductivity (x 10^{-5} ms^{-1})							
Just after compaction	0-15	2.80	2.43	2.24	2.92	2.44	2.08
	15-30	2.62	2.22	1.57	2.68	1.97	1.64
	30-45	2.39	2.33	1.85	2.43	2.03	1.69
At flowering	0-15	2.85	2.42	2.37	2.96	2.56	2.26
	15-30	2.53	2.32	1.73	2.69	2.04	1.68
	30-45	2.43	2.37	2.21	3.00	2.59	2.33
At harvest	0-15	2.87	2.46	2.41	3.00	2.59	2.33
	15-30	2.46	2.37	2.15	2.75	2.14	1.72
	30-45	2.46	2.41	2.35	2.47	2.18	1.91
(c) Total porosity (%)							
Just after compaction	0-15	43.77	41.88	40.75	43.78	41.13	39.62
	15-30	42.64	40.75	38.11	42.64	40.00	37.74
	30-45	41.88	41.13	39.24	41.89	40.75	38.87
At flowering	0-15	43.77	42.26	41.50	43.78	41.89	40.76
	15-30	42.64	41.13	38.49	42.64	41.13	38.49
	30-45	42.26	41.50	40.37	42.27	41.51	39.63
At harvest	0-15	43.77	42.26	41.88	44.15	42.27	41.51
	15-30	42.26	41.50	40.37	42.64	41.61	40.00
	30-45	42.26	41.88	41.13	42.27	41.89	40.75

(d) Soil moisture retention (cm/45cm) after and before irrigation/rainfall

Compaction levels (Passings by roller)	After 24 hours of irrigation	After 3 days of irrigation Wheat	Before irrigation	After 15 days of rainfall Pearl millet
0	8.37	5.23	3.69	3.07
4	9.25	6.64	4.64	3.58
8	10.11	7.30	5.53	4.06

also observed with increasing levels of N from 43.79 kg ha^{-1} at zero level of N to 84.89 kg ha^{-1} at 120 kg N ha^{-1} in wheat whereas in pearl millet it was 32.46 kg ha^{-1} at zero level of N to 78.89 kg ha^{-1} at 90 kg N ha^{-1}. Increase in uptake of N was more pronounced when N application improved from sub-optimum level to optimum level (Lal, 1980).

An examination of data in table 3 showed that the total uptake of N by wheat and pearl millet was significantly affected due to levels of compaction and N. The maximum total uptake of N by wheat was observed under 8 passings with 120 kg N ha^{-1} whereas minimum total uptake of N was obtained under no compaction and without application of N

Table 2. Effect of compaction and nitrogen levels on retention of NO_3^-N (mg kg^{-1}) in soil at flowering stage of wheat and pearl millet

Compaction levels (Passings by roller)	Nitrogen levels (kg ha^{-1})	Wheat Soil depth (cm)			Nitrogen levels (kg ha^{-1})	Pearl millet Soil depth (cm)		
		0-15	15-30	30-45		0-15	15-30	30-45
0	0	3.1	4.4	4.9	0	3.3	4.5	5.1
	40	3.9	5.1	6.4	30	4.0	5.3	6.6
	80	4.6	6.3	6.9	60	4.8	6.5	7.0
	120	5.2	6.6	7.4	90	5.5	6.8	7.5
4	0	3.6	5.8	5.2	0	3.7	6.0	5.4
	40	5.7	8.0	6.7	30	5.9	8.0	6.9
	80	7.0	8.9	7.3	60	7.1	9.1	7.6
	120	8.8	9.9	7.6	90	9.0	10.1	7.9
8	0	4.5	7.7	6 5	0	4.7	7.9	6.8
	40	7.2	12.0	9.1	30	7.5	12.2	9.3
	80	10.6	13.8	11.0	60	10.9	14.1	11.1
	120	13.1	14.6	12.7	90	12.9	15.0	12.9

Table 3. Effect of compaction and nitrogen levels on yield, total nitrogen uptake and nitrogen use efficiency of wheat and pearl millet

N levels (kg ha^{-1})	Wheat Compaction levels				N levels (kg ha^{-1})	Pearl millet Compaction levels			
	0	4	8	Mean		0	4	8	Mean
	Grain yield (q ha^{-1})					Grain yield (q ha^{-1})			
0	15.85	17.83	20.68	18.12	0	9.13	11.13	12.35	10.87
40	20.52	23.10	26.93	23.52	30	14.03	16.18	18.33	16.18
80	23.23	26.95	31.77	27.31	60	16.58	20.20	23.10	19.96
120	25.75	29.43	35.30	30.23	90	18.58	22.45	25.65	22.23
Mean	21.34	24.33	28.72		Mean	14.58	17.49	19.86	
	Straw yield (q ha^{-1})					Stover yield (q ha^{-1})			
0	27.25	28.43	31.93	29.20	0	28.08	35.55	38.75	34.13
40	33.18	35.35	36.98	35.17	30	42.05	48.45	57.23	49.24
80	35.50	38.13	42.38	38.67	60	52.93	59.68	69.10	60.57
120	37.98	39.75	46.68	41.47	90	56.90	67.38	73.18	65.82
Mean	33.48	35.42	39.49		Mean	44.99	52.76	59.56	
	N uptake (kg ha^{-1})					N uptake (kg ha^{-1})			
0	36.46	42.47	52.43	43.79	0	24.15	33.98	39.27	32.46
40	51.37	57.67	69.96	59.67	30	42.25	50.76	61.74	51.58
80	61.07	70.44	87.74	73.08	60	54.92	65.96	80.79	76.22
120	70.28	80.88	103.52	84.89	90	63.55	78.86	94.26	78.89
Mean	54.80	62.87	78.41		Mean	46.22	57.39	69.02	
	N use efficiency (kg grainkg^{-1} N)					N use efficiency (kg grain kg^{-1} N)			
40	11.69	13.19	15.63	13.50	30	16.33	16.83	19.92	17.69
80	9.22	11.41	13.87	11.50	60	12.42	15.13	17.92	15.15
120	8.10	8.67	12.35	10.04	90	10.50	12.58	14.78	12.62
Mean	9.67	11.42	13.95		Mean	13.08	14.85	17.54	
CD (P=0.05)		C	N	CxN		C	N	CxN	
Grain		2.39	0.67	2.58		1.51	0.41	1.63	
Straw/stover		3.14	1.00	3.47		3.54	1.65	4.31	
N uptake		6.42	2.13	7.16		4.31	1.55	4.89	
N use efficiency		3.09	0.62	NS		1.66	0.70	1.93	

C = Compaction, N = Nitrogen, CxN = Compaction x Nitrogen

treatment. Similarly, maximum total uptake of N in pearl millet was obtained under treatment 8 passings with 90 kg N ha^{-1} while minimum total uptake of N was recorded under uncompacted and without N treatment. The observed increase in total uptake of N following compaction may probably be due to good soil to seed contact, root to soil contact and growth stand during growing period resulting in better utilization of the available water and plant nutrients from the soil.

Nitrogen use efficiency : The N use efficiency of wheat and pearl millet improved significantly with successive increase in compaction levels (Table 3). The per cent increase in N use efficiency in wheat was 18 and 44 whereas in pearl millet it was of the order of 13 and 34 over control due to compaction by 4 and 8 passings, respectively. The increase in N use efficiency following compaction may be attributed to the fact that it improved the soil physical properties so favourable for plant while minimizing leaching of N from the root zone (Gupta *et al.*, 1984). The N use efficiency consistently decreased significantly in both the crops with increasing levels of N. Decreased N use efficiency with increasing application of N was associated with diminishing returns with increasing inputs. This was due to the fact that the fraction of N recovered through plant decreased progressively as the amount of N application increases (Agrawal, 1991). Interactive effect of compaction and N levels on N use efficiency was found significantl in pearl millet crop but non-significant in case of wheat. The highest N use efficiency resulted at lower level of N of 30 kg N ha^{-1} while the lowest N use efficiency was found at highest dose of N of 90 kg N ha^{-1}. These results suggest that N use efficiency can be improved by compaction.

From the study, it can be concluded that subsurface compaction at proctor moisture content decreased the saturated hydraulic conductivity and total porosity, besides, increasing the bulk density, moisture storage capacity and retention of applied N in loamy sand. Compaction resulted in higher crop yield, N uptake and N use efficiency by 8 passings of roller without any adverse effect on crop yields. Nitrogen application also increased the yield and N uptake upto 120 and 90 kg N ha^{-1} in wheat and pearl millet crops, respectively.

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