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Improving yield of barley grown on coarse textured soil by compaction and sulphur fertilization

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ABSTRACT

A field experiment was conducted in loamy sand at SKN College of Agriculture, Jobner to study the effect of different levels of compaction (i.e. 0, 2, 4 and 8 passes of 500 kg manually driven iron roller at proctor moisture) and sulphur (i.e. 0, 15, 30 and 45 kg S ha^{-1}) on soil physical properties, growth attributes and yield of barley (*Hordeum vulgare* L.). The soil compaction with 8 passes of 500 kg manually operated iron roller has increased maximum bulk density and moisture storage capacity besides, decrease in saturated hydraulic conductivity of soil. Soil compaction by 8 passing of iron roller increased the bulk density and moisture retention at both flowering and harvest stage of crop and decreased saturated hydraulic conductivity of soil having maximum values in 15-30 cm soil layer. Maximum increase in the growth attributes and yield was recorded under the treatment 8 passes of 500 kg iron roller and 45 kg S ha^{-1} application. However, 4 passes of 500 kg iron roller and 45 kg S ha^{-1} application was statistically at par with 8 passes of 500 kg iron roller and 45 kg S ha^{-1} application with respect to above parameters. In combined effects of compaction and sulphur, the yield of barley increased linearly up to 8 passes of iron roller with 30 kg S ha^{-1} application as compared to rest of the treatments.

Key words : *Saturated hydraulic conductivity, Bulk density, Moisture content, Loamy sand,*

Introduction

Barley is generally grown on marginal and sub marginal lands with low inputs where the conditions for wheat cultivation for wheat production are not favorable. It is grown on light textured soil with poor fertility status. Barley crop from sulphur deficient fields are occurring with greater frequency at various location in India. Leaching and depletion of soil sulphur due to maximum cultivation of cereal crops in cropping sequence, created a gap between supply and removal of sulphur. Use of sulphur free fertilizer in intensively cropped areas, depletion of organic matter in soil which is supposed to be a reservoir of sulphur are also important causes for sulphur deficiency. Loamy sand soils of Rajasthan are highly permeable and loss of water and soluble nutrients especially sulphur is quite high from these soil. Soil compaction improves the retention of these inputs by improving moisture storage in soil, creating a barrier of relatively high bulk density and minimizing percolation losses of nutrients. Looking to the interest of grower and constraints associated with highly permeable soils of Rajasthan. Hence, an attempt was made to assess the response to soil compaction and sulphur application on barley crop performance.

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Materials and Methods

A field experiment was conducted on loamy sand, classified as hypothermic family of Typic Ustipsamment at S.K.N. College of Agriculture, Jobner (Jaipur). Geographically, it is situated at 26° 06' North latitude and 75° 28' East longitude at an altitude of 427 meters above the mean sea level. The normal annual rainfall of this locality varies from 400 to 500 mm in arid and semi-arid region of Rajasthan. Experiment on barley was taken in a split-plot design. The treatment consists of four levels of compaction, i.e. no compaction (C_0) as practiced by farmer, two passing (C_2) and four passing (C_4) and eight passing (C_8) of 500 kg iron roller at proctor moisture in main plot, whereas four levels of sulphur i.e. no sulphur (S_0), 15 (S_{15}), 30 (S_{30}) and 45 (S_{45}) kg S ha^{-1} and were replicated four times. Barley seed (RD-2552) was sown with the help of plough at a depth 4-5 cm with row to row distance of 22.5 cm. A uniform basal dose of N @ 80 kg ha^{-1}, P @ 40 kg ha^{-1} and K @ 40 kg ha^{-1} through urea, diammonium phospahate and muriate of potash in all the plots were applied, respectively where as sulphur was applied through gypsum as per treatment at 21 days before sowing and incorporated in the soil. Various physical properties were determined by usual analytical procedures as described by Majumdar and Singh (2000).

The leaf area index was measured with the help of leaf area meter soil samples for root weight density and root length density at flowering and harvesting were collected from 0-15 cm depth with help of three soil cores. The sample was washed with water and made free from organic debris and soil particles. Root dry weight was divided by the volume of soil cores from which roots were extracted to obtain root weight density. The length of fresh root was measured by the line-intercept technique (Newman, 1966). The soil chemical parameters were analyzed following standard analytical procedures (Piper, 1950).

Statistical Analysis

The observation recorded for different aspects of crop *viz.*, growth and yield characteristics were subjected to analysis, statistical method as suggested by Fisher (1950) for split plot design. Significance of the treatment effect was tested through "F" test. To elucidate the nature and the magnitude of the effect found to be significant by "F" test summary tables along with appropriate standard error of mean (SEm±) and critical difference (CD) were prepared.

Results and Discussion

Characterization of experimental soil

Soil of experimental site, of which initial soil properties have been given in Table 1. The soil is loamy sand in texture with clay 6.2 and sand content as high as 85.7 per cent. Soil reaction was slightly alkaline, low in cation exchange capacity, organic carbon content, available nitrogen, potassium, sulphur whereas phosphorus content was moderate in soil.

Table 1. Physico-chemical properties of experimental soil

Soil properties	Soil depth (0-15 cm)
Coarse sand (%)	26.8
Fine sand (%)	58.9
Silt (%)	7.6
Clay (%)	6.2
Texture class	Loamy sand
Bulk density (Mg m^{-3})	1.49
Saturated hydraulic conductivity (cm hr^{-1})	10.2
Moisture content at 1/3 bar (%)	11.0
pH (1:2 soil water suspension)	8.0
ECe (dSm^{-1} at 25°C)	1.28
Organic carbon (%)	0.15
CEC [cmol (p$^+$) kg^{-1}]	5.2
Available N (kg ha^{-1})	128.2
Available P_2O_5 (kg ha^{-1})	16.8
Available K_2O (kg ha^{-1})	187.1
Available sulphur (mg kg^{-1} soil)	9.00

Soil Physical Properties

At flowering

Soil compaction was influenced the bulk density, saturated hydraulic conductivity and moisture content (weight basis) in loamy sand at flowering stage of barley crop (Table 2). The data revealed that maximum bulk density (1.61 Mg m^{-3}), moisture content (14.63%) and minimum hydraulic conductivity (7.74 cm hr^{-1}) of soil were obtained by 8 passing of 500 kg iron roller (C_8) in 15-30 cm soil layer at flowering stage. Data further indicate that the increase in bulk density, moisture content and highest decrease in hydraulic conductivity was obtained under C_8 in all the layers (i.e. 0-15, 15-30 and 30-45 cm depth) at flowering compared to that of no passing, two and four passing of 500 kg iron roller. Increase in bulk density due to compaction at flowering and harvest stage was noticed by Hirekurabar *et al.* (1991). Decrease in hydraulic conductivity due to compaction could be attributed to increase in bulk density and rearranging of soil particle leading to increase fractional capillary porosity. Majumdar *et al.* (2000) also reported after an exhaustive study on highly permeable soils that, crop raised after the compaction have shown remarkable increase in moisture content of soil as compared to un compacted plots.

At harvest

The uncompacted plots (C_0) showed minimum bulk density (1.48±0.02 Mg m^{-3}) and moisture content (4.23±0.02%) in 0-15 cm soil layer, which increased to maximum of 1.58±0.01 Mg m^{-3} and 7.60±0.02% in 15-30 cm soil layer under C_8, respectively (Table 3). Saturated hydraulic conductivity of soil in different soil layers was highest in uncompacted plots which decreased with the increase in the level of compaction and reached to minimum (7.40±0.02 cm hr^{-1}) under 8 passing of 500 kg iron roller (C_8) in 15-30 cm soil layer followed by 30-45 cm and 0-15 cm soil layer. The highest increase in bulk density in 15-30 cm soil layer showed that maximum compaction occurs not immediately below the pressing surface but at some distance below it. The decrease in bulk density of 0-15 cm soil layer was probably due to cultivation practices performed on soil surface layer after compaction. Bulk density and moisture retention of sub-surface layer also decreased with the lapse of time but at a slower rate and effect of compaction persisted even up to harvest of the crop. The magnitude of increase in bulk density was low at flowering and at harvest stage as compared to that of just after compaction. Decrease in hydraulic conductivity and increase in moisture retention due to compaction could be attributed to increase in bulk density and re-arrangement of soil particle leading to increase fractional capillary porosity which holds the more moisture by reducing hydraulic conductivity. These findings are in conformity with Majumdar *et al.* (2000).

Table 2. Effect of compaction on the average bulk density, saturated hydraulic conductivity and moisture content at flowering stage of barley

Soil properties	Depth (cm)	Compaction levels			
		C_0	C_2	C_4	C_8
Bulk density (Mg m^{-3})	0-15	1.47 ± 0.02	1.52 ± 0.04	1.54 ± 0.02	1.55 ± 0.01
	15-30	1.58 ± 0.02	1.56 ± 0.03	1.59 ± 0.02	1.61 ± 0.01
	30-45	1.52 ± 0.03	1.55 ± 0.01	1.58 ± 0.01	1.59 ± 0.02
Saturated hydraulic	0-15	11.21±0.03	9.16 ± 0.02	8.70 ± 0.02	8.72 ± 0.01
conductivity (cm hr^{-1})	15-30	8.58 ± 0.01	8.49 ± 0.04	8.32 ± 0.01	7.74 ± 0.02
	30-45	9.08 ± 0.01	8.56 ± 0.04	8.50 ± 0.01	8.16 ± 0.02
Moisture content (%)	0-15	9.09 ± 0.02	11.19±0.01	13.00±0.02	13.99±0.02
	15-30	9.46 ± 0.02	12.13±0.02	13.85±0.04	14.63±0.03
	30-45	9.91 ± 0.05	11.56±0.01	13.51±0.02	14.57±0.02

Table 3. Effect of compaction on the average bulk density, saturated hydraulic conductivity and moisture content at harvest stage of barley

Soil properties	Depth (cm)	Compaction levels			
		C_0	C_2	C_4	C_8
Bulk Density (Mg m^{-3})	0-15	1.48±0.02	1.52±0.01	1.53±0.01	1.54±0.01
	15-30	1.51±0.01	1.56±0.00	1.58±0.01	1.58±0.01
	30-45	1.50±0.01	1.54±0.01	1.56±0.01	1.57±0.01
Saturated hydraulic conductivity	0-15	10.67±0.01	9.75±0.01	9.18±0.02	8.65±0.02
(cm hr^{-1})	15-30	9.81±0.01	8.52±0.01	7.85±0.02	7.40±0.02
	30-45	8.80±0.01	8.60±0.02	8.20±0.03	7.78±0.01
Moisture content (%)	0-15	4.23±0.02	5.24±0.02	6.19±0.01	6.95±0.02
	15-30	4.40±0.01	5.83±0.02	6.79±0.04	7.60±0.02
	30-45	4.80±0.01	5.51±0.03	6.36±0.03	7.11±0.04

Growth attributes

Compaction significantly increased the growth attributes of barley crop (Table 4). The maximum leaf area index (3.76), root length density (1.58 cm cm^{-3}) and root weight density (373µg cm^{-3}) were recorded under C_8 (i.e. compaction by 8 passes of 500 kg iron roller) and minimum leaf area index (3.06), root length density (1.21 cm cm^{-3}) and root weight density (274 µg cm^{-3}) were observed under C_0 (no compaction) treatment, respectively. The percent increase in leaf area index, root length density and root weight density by 8, 4 and 2 passing of 500 kg iron roller were of in order of 22.87, 17.28 and 11.76; 30.79, 24.79 and 14.05; 36.13, 26.18 and 12.41, respectively over that of control. Data further reveals that the treatment C_4 was found to be statistically at par with that of C_8 treatment with respect to leaf area index and root length density.

Table 4. Effect of compaction and sulphur on growth attributes of barley at flowering stage

Treatments	Leaf Area Index	Root Weight Density (µg cm^{-3})	Root Length Density (cm cm^{-3})
Compaction levels			
C_0	3.06	274	1.21
C_2	3.42	308	1.38
C_4	3.65	346	1.51
C_8	3.76	373	1.58
SEm±	0.07	5.31	0.03
CD (P=0.05)	0.22	17.00	0.12
Sulphur levels			
S_0	3.01	293	1.26
S_{15}	3.40	319	1.38
S_{30}	3.64	337	1.48
S_{45}	3.84	352	1.56
SEm±	0.07	5.27	0.016
CD (P=0.05)	0.19	15.08	0.083

The above observations indicate that the compaction treatment has improved the physical condition of soil that led the better availability of moisture increase in nutrient content per unit volume of soil due to increase in bulk density and more contact between the root and soil particle consequently higher availability of nutrients (Balai *et al.*, 2009).

Increasing levels of sulphur significantly influenced the growth attributes (Table 4) of barley crop. The maximum leaf area index (3.84), root weight density (352 µg cm^{-3}) and root length density (1.56 cm cm^{-3}) were observed under 45 kg S ha^{-1} treatment, where as minimum leaf area index (3.01), root weight density (293 µg cm^{-3}) and root length density (1.26 cm cm^{-3}) were recorded under no sulphur treatment. Application of 45, 30 and 15 kg S ha^{-1}produced 27.57, 20.93 and 12.96; 20.14, 15.02 and 8.87; 23.81, 17.46 and 9.52 per cent more leaf area index, root weight density and root length density respectively over that of control (S_0). Perusal of data further indicate that increase in leaf area index, root weight density and root length density observed under S_{30} was found to be statistical at par with application of 45 kg S ha^{-1} (S_{45}) treatment.

The above observation indicates that increasing levels of sulphur significantly increased the growth attributing character. This is probably due to better nutritional environment for plant growth. Increase content of sulphur in plant also helped in better development and thickening of xylem, sulphur helped in better uptake of nutrients, the results so obtained get support from findings by Wani and Refique (2000). Sulphur being a constituent of succnyl *COA* which involves in chlorophyll formation (Pirson, 1965) by creating a balanced nutritional environment for root growth as well as plant system in keeping the micro-nutrient physically active has been very instrumental in increased chlorophyll synthesis in plant leaves. Ultimately, plant metabolism and photosynthetic activity enhanced the resulting into better growth and development of plant root.

Grain Yield

Grain yield of barley was significantly affected by compaction and sulphur as well as their interaction (Table 5). Maximum grain yield (41.61 q ha^{-1}) obtained under C_8 (compaction by 8 passes of 500 kg iron roller), whereas minimum grain (28.40 q ha^{-1}) was observed under C_0 (no compaction) treatment. The percent increase in grain yield under C_8, C_4 and C_2 were in order of 46.51, 40.04 and 18.42, respectively over that of control. Data further reveal that the treatment C_4 was found to be statistically at par with that of C_8 treatment with respect to grain yield. The above observation indicate that compaction treatment has improved the physical condition of soil that led the better availability and uptake of nutrient and ultimately enhanced the growth and yield attributing character of barley crop. Our results confirm the findings of Balai *et al.,* (2009).

An application of 45 kg S ha^{-1} resulted higher grain yield (39.96 q ha^{-1}) compared to no sulphur application. Grain yield obtained under application of 30 kg S ha^{-1} was found to be statistically at par with the application of 45 S kg ha^{-1} treatment. Sulphur is also essential for chlorophyll formation and improve nutritional environment for root growth. Supply of sulphur in adequate and appropriate amounts helps in flower primordial initiation for its reproductive parts (Dwivedi *et al.*, 2002).

The significant interactive effect of compaction and sulphur indicated that synergistic effect on grain yield of crop. The significantly higher grain yield was observed under the treatment combination of four passes of 500 kg iron roller with the application of 30 kg S ha^{-1} than rest of the treatment combination. This might be due to two fold effect of compaction on crop, first is the compaction improves the physical condition of soil and be get the congenial condition for more contact between nutrients and roots, while other hand compaction checks the leaching losses of nutrients in light textured soils. Majumdar and Das (1997) also reported similar results for guar and pearl millet.

Straw yield

Straw yield of barley was also significantly affected by compaction and sulphur as well as their interaction (Table 6). The mean value of straw yield (63.77 q ha^{-1}) was highest under C_8 and minimum in control (44.01 q ha^{-1}). But C_4 was found to be statistically at par with C_8 treatment. The percent increase in straw yield under C_8, C_4 and C_2 was of in order of 44.90, 37.92 and 15.86, respectively over that of control. The straw yield might be increased by compaction due to increase in storage and availability of moisture, besides decreased losses of nitrogen and other nutrient through leaching and percolation. The above statement corroborate with the findings made by Yadav and Jakhar (2001).

Significant increase in mean value of straw yield (58.94 q ha^{-1}) was obtained under application of 30 kg S ha^{-1} given through gypsum as compared to rest of treatment. This might be due to sulphur itself

Table 5. Effect of compaction and sulphur levels on grain yield (q ha^{-1}) of barley

Treatments	Sulphur levels				
	S_0	S_{15}	S_{30}	S_{45}	Mean
Compaction levels					
C_0	24.52	27.40	30.04	31.64	28.40
C_2	29.00	33.24	35.08	37.20	33.63
C_4	33.08	38.40	43.60	44.00	39.77
C_8	33.08	39.84	46.50	47.00	41.61
Mean	29.92	34.72	38.81	39.96	
SEm±	I=1.53	II=1.63	C=0.68	S=0.54	
CD (P=0.05)	I=3.09	II=3.43	C=2.16	S=1.55	

I= CD at 5% for compaction at same levels and sulphur at different levels
II= CD at 5% for compaction at different levels and sulphur at same levels or both

Table 6. Effect of compaction and sulphur levels on straw yield (q ha^{-1}) of barley

Treatments	Sulphur levels				
	S_0	S_{15}	S_{30}	S_{45}	Mean
Compaction levels					
C_0	38.72	42.04	46.96	48.32	44.01
C_2	44.40	50.64	53.40	55.52	50.99
C_4	50.36	58.40	65.56	68.48	60.70
C_8	50.60	60.32	69.84	72.02	63.77
Mean	46.02	52.85	58.94	61.66	
SEm±	I=2.82	II=3.14	C=1.39	S=1.01	
CD (p=0.05)	I=5.70	II=6.62	C=4.44	S=2.86	

I= CD at 5% for compaction at same levels and sulphur at different levels
II= CD at 5% for compaction at different levels and sulphur at same levels or both

important for vegetative growth. Similar interactive effect of compaction and sulphur (C_4S_{30}) was also observed for straw yield as observed in case of grain yield. These results are in agreement with Majumdar and Das (1997).

Conclusion

It is concluded from that investigation that the compaction at proctor moisture content increased bulk density and decreased saturated hydraulic conductivity as a result of reduction in macrospores increased the moisture retention in soil and the retention was more in 15-30 cm soil layer followed by 30-45 and 0-15 cm in coarse textured soils. Soil compaction with 8 passing of 500 kg iron roller was not significantly increased the crop growth. Moderate levels of soil compaction with 4 passing of roller were generally beneficial for improving soil environment for roots of barley. Compaction by making 4 passing of 500 kg iron roller and application of 30 kg S ha^{-1} through gypsum was found beneficial in increasing the growth parameters and yield of barley under rainfed condition of semi-arid region of India on loamy sand soils.

References

Balai, C.M., Yadav, K.K. and Majumdar, S.P. 2009. Effect of Compaction on bulk Density, saturated hydraulic conductivity and moisture content of Soil. *Hydrology Journal*. 32 : 87-95.

Dwivedi, S.K., Singh, R.S., Dwivedi, K.N. 2002. Effect of sulphur and zinc nutrition on yield and quality of maize in typic ustocrept soil of Kanpur. *Journal of the Indian Society of Soil Science.* 50 : 70-74.

Fisher, R.A. 1950. *Sataistically Method for Research Workers. Oliver and Boyd.*, Edinburgh, London.

Hirekurabar, B.M., Doddamani, V.S. and Satyanarayana, T. 1991. Effect of soil compaction on physical properties and crop growth. *Journal of the Indian Society of Soil Science.* 39 : 348-350.

Majumdar, S.P. and Singh, R.A. 2000. *Analysis of Soil Physical Properties,* Pub. Agrobios Ltd. Jodhpur, India.

Majumdar, S.P., Meena, R.L. and Bhagel, G.D.S. 2000. Effect of levels of compaction and potassium on yield and quality of tomato and chilli crop grown on highly permeable soil. *Journal of the Indian Society of Soil Science.* 48 : 215-220.

Majumdar, S.P. and Das, D.K. 1997. Management of coarse textured soil of arid ecosystem for sustaining crop production. Paper presented in *Symposium in Recent Advanced in Management of Arid Ecosystem held at Jodhpur*, March 3rd- 5th, 1997.

Newman, E.I. 1966. A method of estimating the length of root in a sample. *Journal of Applied Ecololgy.* 3 : 139-145.

Piper, C.S. 1950. *Soil and Plant Analysis*. The University of Adelaide, Australia.

Pirson, A. 1965. Functional aspects of mineral nutrition og green plants. *Annual Review of Plant Physiology.* 6: 71-144.

Wani, M.A. and Rafique, M.M. 2000. Effect of different levels of sulphur on yield and nutrient uptake rice (*Oryza sativa*). *Advance in Plant Science.* 13(1): 139-143.

Yadav, B.L. and Jakhar, S.R. 2001. Effect of tillage and phosphorus fertilization on yield and water expense efficiency of rainfed mungbean. *Journal of the Indian Society of Soil Science.* 49 : 193-194.