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EFFECT OF DIFFERENT TILLAGE IMPLEMENTS AND GYPSUM FOR FODDER PRODUCTION IN SALT AFFECTED SOILS USING HIGH RSC WATER

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ABSTRACT. Selection of suitable tillage implement, as well as amendments, is very important for the reclamation of salt affected soils. For this purpose, a field study was performed using the different rates of gypsum and tillage implements for the production of sorghum and berseem fodders in salt affected field using high RSC water. Treatments including were T_1: control (cultivator twice), T_2: modified chisel plough (twice), T_3: chisel plough (twice), T_4: modified chisel plough (twice) + gypsum application @ 100% GR of soil, T_5: modified chisel plough (twice) + gypsum application @ 50% GR of soil, T_6: chisel plough (twice) + gypsum application @ 100% GR of soil, T_7: chisel plough (twice) + gypsum application @ 50% GR of soil. A moderately salt affected field {EC_e = 5.37 (d Sm^{-1}), pH_s = 9.18, SAR = 34.01 (m mol $L^{-1})^{1/2}$ and GR 3.10 t $acre^{-1}$} was selected. Field was leveled, prepared and gypsum was applied according to treatment plan, followed by leaching. Tubewell water {EC_{iw}= 1.34 dS m^{-1}, RSC= 8.50 me L^{-1} and SAR= 12.72 (mmol $L^{-1})^{1/2}$} was used for irrigation. Gypsum was also applied before sowing of each crop on RSC basis of water. The trial was performed in the RCBD design with three replications. Pooled data of three years showed that maximum fodder yield of sorghum (38.44 t ha^{-1}) and berseem (60.21 t ha^{-1}) was recorded with modified chisel plough (twice) + gypsum @ 100% GR of soil. Data regarding the soil qualities revealed that soil pH_s, EC_e, SAR and BD decreased by 4.24, 30.72 and 31.37, respectively, while HC was increased by 130 % with use of modified chisel plough (twice) + gypsum @ 100% GR of soil, as compared to control.

Keywords: berseem; sorghum; brackish water; chisel plough; salinity

Abbreviations used: EC_e (electrical conductivity of soil extract); pH_s (pH of soil saturated past); SAR (sodium absorption ratio); BD (bulk density); HC (hydraulic conductivity).

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INTRODUCTION

Soil deterioration because of salinity is a major environmental threat to sustainable agriculture, which have damaging effects on soil properties and crop growth (Okur, 2002; Devkota *et al.,* 2015). Salt affected soils generally render hostile conditions for plant growth due to insufficient organic matter and excess of toxic soluble salts (Lodhi *et al.,* 2009; Bilandžija *et al.,* 2016). Physical and chemical properties of these soils are generally degraded due to presence of excessive soluble Na^+ and improvement in these soil's properties could be accomplished by different approaches, depending upon local conditions and available resources (Elsharawy *et al.*, 2008).

Compaction in salt affected is a well-recognized problem, which pose a prompt threat to crop growth and economic yields, in addition to a long-term hazard to future crop yields (Hamza and Anderson 2005; Singh *et al.,* 2014). Water permeability of salt affected soils is restricted as excess of Na^+ results dispersion, translocation and deposition of clay particles in conducting pores (Mari *et al*., 2011). One of the most economical and feasible approach to improve physical and chemical properties of salt prone soils is management by tillage practices (Mosaddeghi *et al*. 2009).

Gypsum is widely use as amendment for sodic-soil reclamation because of its economic, ease of handling and quick reaction. Gypsum removes the Na^+ from the root zone and decreases the pH of salt affected soils (Lim *et al.,* 2011) and improves the physical properties like, hydraulic conductivity, bulk density and macro-porosity (Emami and Astaraei, 2012; Singh *et al.,* 2014).

Tilling is a fundamental practice that's manipulate the soil for good seed bed preparation and change the soil environment for root penetration and make it favorable for plant growth. Conventional tillage not only alter the bulk density of top soil but also considerably increased water permeability and introduce minimum resistance to root growth (Ji *et al.,* 2013), but at some depth below the top soil a hard layer, commonly called plow sole develops and is characterized by high bulk density and low infiltration rate. This plow sole limits the water movement and gaseous exchange. According to Ahmed and Maurya (1988), under such circumstances, deep tillage by such as chiseling is beneficial for crop production and improve the soil physical and chemical properties. Therefore, selection of a specific tillage package is a necessary that sustains and improves the soil properties required for successful crop growth (Jabro *et al*., 2009).

Azhar *et al.* (2001) studied the effect of different tillage implements (subsoiler, chisel plough, disc plough and narrow tin cultivator) with two rates of gypsum (50 and 75% GR) in salt affected soils. They reported that wheat emergence was maximum in subsoiler plot followed by chisel plough. Gypsum application 75% GR proved more superior over 50% GR in improving soil properties. Soil EC_e was decreased by (85%), pH_s (8.27%) and ESP (84.34%) over its initial value with application of gypsum @ 75% GR. Similarly, Singh *et al.* (2011) reported that deep tillage, combined with gypsum and green manuring, improved the grain and straw yield of wheat. In this context, Ahmed *et al.* (2015) showed that gypsum and FYM with chiseling, improved pH_s, EC_e, SAR, soil organic matter, hydraulic conductivity, bulk density and increase fodder beet root and shoot biomass. Islam *et al.* (2015) concluded that deep tillage with gypsum and organic manure should be right choice for managing silty-loam soils in Bangladesh. Costa *et al.* (2016) also reported that tilling with disc harrow and application of gypsum increased porosity, infiltration rate and bulk density. Numerous other researchers stated that deep tillage by plowing or loosening with fertilizer combination (Rahman, 1997; Jeyasree and Rao, 2005; Xiong *et al.,* 2012; Meng *et al.,* 2016), or with combination of straw mulch (Zhao *et al.,* 2014) also showed positive results on remediation of saline-sodic soils and improvement in grain yields.

Keeping the above facts in view a study was planned to develop the best reclamation strategy with tillage implements and different rates of gypsum for improving the physical and chemical properties of salt affected soils and obtaining maximum fodder yield of sorghum and berseem crops.

MATERIAL AND METHODS

A field experiments was conducted from 2012 to 2015 at research farm of Soil Salinity Research Institute, Pindi Bhattian, Pakistan, to find out the best tillage implement and rate of gypsum for obtaining maximum fodder yield of sorghum and berseem crops in salt affected soil.

The treatments tested were T_1: control (cultivator twice), T_2: modified chisel plough (twice), T_3: chisel plough (twice), T_4: modified chisel plough (twice) + gypsum application @ 100% GR of soil, T_5: modified chisel plough (twice) + gypsum application @ 50% GR of soil, T_6: chisel plough (twice) + gypsum application @ 100% GR of soil, T_7: chisel plough (twice) + gypsum application @ 50% GR of soil. Modified chisel plough is designed at the engineering division of Soil Salinity Research Institute Pindi Bhattian. It is modified form of sub soiler which have a mole at the tip of sub soiler. It can penetrate up to a depth of 18-21 inches and its mole cut the soil and make a sub-surface drain to leach down the salts.

A moderately salt affected field, as described in *Table 1*, was selected, leveled and prepared and gypsum was applied thirty days before sowing of Kharif crop according to treatment plan, followed by leaching. Tube-well water EC_{iw} = 1.34 dS m^{-1}, RSC = 8.50 me L^{-1} and SAR = 12.72 (mmol $L^{-1})^{1/2}$ was used for irrigation. Gypsum was also applied before sowing of each crop on RSC basis of water. Experimental design was RCBD with three repeats having plot size 8 m × 8 m. Different tillage implements were used according to treatment plan for sowing of

Kharif (sorghum) and Rabi (berseem) crops. In Kharif season, sorghum crop was sown in last week of June and recommended dose of NP (60-60 kg ha^{-1}) was applied as urea and single super phosphate (SSP). Crop was harvested on second week of September, and fodder yield was recorded. In Rabi season, berseem crop was sown in last week of November and recommended dose of NP (45-115 kg ha^{-1}) was applied as urea and single super phosphate (SSP). Total fodder yield was obtained from three cuttings and final cutting was recorded in last week of April. Composite soil samples were collected before sowing and after the harvest of each crop in each season and were analyzed for soil parameters like pH_s, EC_e, SAR, hydraulic conductivity (HC) and bulk density (BD) by adopting the protocol as reported by the US Salinity Lab. Staff (1954). The data generated was subjected to analysis of variance (ANOVA) technique and the least significance difference (LSD) test was used to separate the differences among treatment means (Steel *et al*., 1997).

Table 1 - Physicochemical properties of soil before start of study

Parameter	Soil depth (0-15cm)
pH_s	9.18
EC_e (dS m^{-1})	5.37
SAR (mmol L^{-1})$^{1/2}$	34.01
GR (t acre^{-1})	3.10
BD (Mg m^{-3})	1.64
HC (cm hr^{-1})	0.20

RESULTS

Sorghum fodder yield

Data regarding fodder yield of sorghum showed that tillage implements had positive impact on fodder yield for three consecutive seasons and this effect was more pronounced when tillage implements were used in combination with gypsum (*Table 2*).

Mean value data for three seasons showed that maximum fodder yield (38.44 t ha^{-1}) was observed where modified chisel plough (twice) + gypsum@100% GR of soil, followed by chisel plough (twice) + gypsum@ 100% GR of soil were used, however, both the treatments were statistically (p<0.05) non-significant from each other.

Minimum average fodder yield (21.55 t ha^{-1}) was recorded in control where cultivator was used twice for the field preparation without any amendments.

Berseem fodder yield

Pooled data for three seasons showed that berseem fodder yield was also improved remarkably with conjunctive use of tillage implements and different rates of gypsum, however gypsum @ 100% GR was proved more superior than gypsum @ 50% GR (*Table 3*).

Maximum average fodder yield of 60.21 t ha^{-1} was obtained with modified chisel plough (twice) + gypsum @ 100% GR of soil, which was statistically (p<0.05) significant from chisel plough (twice) + gypsum@ 100% GR of soil.

Control (cultivator twice) recorded the minimum fodder yield of 43.22 t ha^{-1}.

Table 2 - Effect of tillage implements and gypsum on sorghum fodder yield (t ha^{-1})

Treatments	2012	2013	2014	Mean
T_1: Control (Cultivator twice)	22.67 C	20.00 E	22.00 E	21.55 D
T_2: Modified Chisel Plough (twice)	24.00 C	26.67 D	27.83 D	26.16 C
T_3: Chisel Plough (twice)	23.33 C	25.33 D	26.67 D	25.11 C
T_4: Modified Chisel Plough (twice) + Gypsum @ 100% GR of soil	36.67 A	38.33 A	40.33 A	38.44 A
T_5: Modified Chisel Plough (twice) + Gypsum @ 50% GR of soil	28.67 B	33.33 BC	36.17 BC	32.72 B
T_6: Chisel Plough (twice) + Gypsum @ 100% GR of soil	34.67 A	36.17 AB	38.17 AB	36.33 A
T_7: Chisel Plough (twice) + Gypsum @ 50% GR of soil	28.00 B	32.17C	34.17 C	31.44 B

Table 3 - Effect of tillage implements and gypsum on berseem fodder yield (sum of three cuttings) (t ha^{-1})

Treatments	2012-13	2013-14	2014-15	Mean
T_1: Control (Cultivator twice)	38.8 E	42.93 E	47.93 E	43.22 E
T_2: Modified Chisel Plough (twice)	44.23 D	48.87 CD	53.87 CD	48.99 D
T_3: Chisel Plough (twice)	43.40 D	47.47 D	52.47 D	47.780 D
T_4: Modified Chisel Plough (twice) + Gypsum@ 100% GR of soil	58.23 A	58.70 A	63.7 A	60.21 A
T_5: Modified Chisel Plough (twice) + Gypsum @ 50% GR of soil	52.23 B	52.80 B	57.8 B	54.27 B
T_6: Chisel Plough (twice) + Gypsum @ 100% GR of soil	53.07 B	54.77 B	59.77 B	55.87 B
T_7: Chisel Plough (twice) + Gypsum @ 50% GR of soil	49.67 C	50.70 C	55.7 C	52.023 C

Soil qualities

Soil physical and chemical properties were also substantially improved with application of gypsum and tillage implements and more positive effect was observed where gypsum and tillage implements were used in combination.

Data regarding the pH of soil showed that maximum decreased in soil pH at the end of study was noted in T_4 (modified chisel plough (twice) + gypsum @ 100 % GR of soil). In this treatment, soil pH at the end of study was 8.79 with 4.24% decrease, as compared to initial value (9.18) at the start of study (*Table 4*). While this reduction was 4.03 % over its initial value where chisel plough (twice) + gypsum @ 100 % GR of soil were used (T_6). Minimum reduction (0.98%) in soil pH was observed in control. Similar trend was observed in soil EC_e. This soil salinity indicator was also improved significantly with gypsum and tillage implements. Maximum reduction (30.72%) in soil EC_e at the end of study was observed where modified chisel plough was used with gypsum @ 100% GR (*Table 5*). On the other hand, minimum reduction (5.21%) in soil EC_e was observed in control. Soil sodicity index, *i.e.* SAR, was also decreased significantly where modified chisel plough (twice) was practiced with gypsum @ 100% GR with maximum reduction of 31.37% over its initial value at the start of study (*Table 6*). While control recorded the minimum reduction (9.23%) in soil SAR.

Table 4 - Effect of tillage implements and gypsum on soil pH

Treatments	2013	2014	2015	Percent decrease over initial value at end of study
T_1: Control (Cultivator twice)	9.12	9.11	9.09	0.98
T_2: Modified Chisel Plough (twice)	9.04	9.02	9.01	1.85
T_3: Chisel Plough (twice)	9.08	9.05	9.04	1.52
T_4: Modified Chisel Plough (twice) + Gypsum @ 100% GR of soil	8.85	8.85	8.79	4.24
T_5: Modified Chisel Plough (twice) + Gypsum @ 50% GR of soil	8.92	8.90	8.85	3.59
T_6: Chisel Plough (twice) + Gypsum @ 100% GR of soil	8.88	8.86	8.81	4.03
T_7: Chisel Plough (twice) + Gypsum @ 50% GR of soil	8.94	8.92	8.87	3.37

Table 5 - Effect of tillage implements and gypsum on soil EC_e ($dS\ m^{-1}$)

Treatments	2013	2014	2015	Percent decrease over initial value at end of study
T_1: Control (Cultivator twice)	5.19	5.12	5.09	5.21
T_2: Modified Chisel Plough (twice)	4.68	4.63	4.47	16.75
T_3: Chisel Plough (twice)	4.71	4.70	4.54	15.45
T_4: Modified Chisel Plough (twice) + Gypsum @ 100% GR of soil	4.18	3.85	3.72	30.72
T_5: Modified Chisel Plough (twice) + Gypsum @ 50% GR of soil	4.34	4.11	4.01	25.32
T_6: Chisel Plough (twice) + Gypsum @ 100% GR of soil	4.23	3.92	3.83	28.67
T_7: Chisel Plough (twice) + Gypsum @ 50% GR of soil	4.42	4.23	4.08	24.02

Table 6 - Effect of tillage implements and gypsum on soil SAR (mmol $L^{-1})^{1/2}$

Treatments	2013	2014	2015	Percent decrease over initial value at end of study
T_1: Control (Cultivator twice)	31.75	31.34	30.87	9.23
T_2: Modified Chisel Plough (twice)	29.83	28.67	27.99	17.70
T_3: Chisel Plough (twice)	29.52	29.12	28.82	15.26
T_4: Modified Chisel Plough (twice) + Gypsum @100 % GR of soil	26.88	24.81	23.34	31.37
T_5: Modified Chisel Plough (twice) + Gypsum @ 50 % GR of soil	27.74	26.18	25.61	24.69
T_6: Chisel Plough (twice) + Gypsum @ 100% GR of soil	27.21	25.26	24.96	26.60
T_7: Chisel Plough (twice) + Gypsum @ 50% GR of soil	28.07	27.05	26.45	22.22

Table 7 - Effect of tillage implements and gypsum on soil HC (cm hr^{-1})

Treatments	2013	2014	2015	Percent increase over initial value at end of study
T_1: Control (Cultivator twice)	0.29	0.37	0.38	90
T_2: Modified Chisel Plough (twice)	0.34	0.40	0.42	110
T_3: Chisel Plough (twice)	0.33	0.41	0.38	90
T_4: Modified Chisel Plough (twice) + Gypsum @ 100% GR of soil	0.48	0.53	0.46	130
T_5: Modified Chisel Plough (twice) + Gypsum @ 50% GR of soil	0.48	0.45	0.43	115
T_6: Chisel Plough (twice) + Gypsum @ 100% GR of soil	0.51	0.47	0.45	125
T_7: Chisel Plough (twice) + Gypsum @ 50% GR of soil	0.46	0.44	0.42	110

Soil physical properties were also remarkably improved by all applied treatments and effect was more pronounced with combined use of tillage implements and gypsum application. Maximum increase in soil hydraulic conductivity was recorded in T_4 (modified chisel plough (twice) + gypsum @ 100% GR of soil).

It was 0.46 cm hr^{-1} at the end of study, as compared to its initial value of 0.20 cm hr^{-1} at the start of study with maximum increase of 130% (*Table 7*). In the case of soil bulk density maximum reduction (20.73) was also observed with modified chisel plough (twice) + gypsum @ 100% GR of soil and minimum reduction of 3.65% was observed in control (cultivator twice) (*Table 8*).

Table 8 - Effect of tillage implements and gypsum on soil BD (Mg m^{-3})

Treatments	2013	2014	2015	Percent decrease over initial value at end of study
T_1: Control (Cultivator twice)	1.60	1.58	1.58	3.65
T_2: Modified Chisel Plough (twice)	1.53	1.52	1.51	7.926
T_3: Chisel Plough (twice)	1.54	1.52	1.50	8.53
T_4:Modified Chisel Plough (twice) + Gypsum @100% GR of soil	1.38	1.36	1.30	20.73
T_5: Modified Chisel Plough (twice) + Gypsum @ 50% GR of soil	1.42	1.39	1.37	16.46
T_6: Chisel Plough (twice) + Gypsum @ 100% GR of soil	1.39	1.37	1.32	19.51
T_7: Chisel Plough (twice) + Gypsum @ 50% GR of soil	1.44	1.41	1.35	17.68

DISCUSSION

Arid to semi-arid climate is very favorable for formation of saline soils and such soils are characterized by the presence of excessive soluble salts and exchangeable Na^+ or both. These saline conditions deteriorated the physical and chemicals properties of soil, causing a retard growth and development of plants and ultimately decline the soil productivity. Hence, remediation of such problematic soil is challenging. Different remedial strategies are available to combat the salinity problem but most striving concern is to choose the most economical and environment friendly technology with objective to restore original values and features of the soil properties required for crop production purposes or to slow down and limit the further degradation.

Use of gypsum is widespread technology for reclamation of salt affected soil because of its economics, effectiveness, ease in availability and handling. It is a direct source of Ca^{2+}, which reinstate the adsorbed Na^+ and removed it from root zone. Suitable tillage practice is one of the main soil operations (Lal *et al.,* 2007), which affect the soil physical, chemical and biological properties of soil. Therefore, in our study we used the different types of tillage implements with gypsum to evaluate their effects on reclamation process and can be used at farmers levels.

Results of our study depicted that application of gypsum as amendments significantly increased the fodder yield of sorghum and berseem crops and gypsum @ 100 % GR proved more superior over gypsum @ 50% GR. Furthermore, reclamation process was also affected by the type of tillage implements and was accelerated by modified chisel plough, as compared to chisel plough and cultivator. Increased fodder yield of sorghum and berseem in gypsum receiving treatments may be explained by ameliorating effects of gypsum as it supplies the Ca^{2+}, which replaces the adsorbed Na^{+} from exchange site and this excessive toxic Na^{+} is accumulated in sub surface drain made by modified plough and leaching water removed it from the root zone (Mohamed *et al*., 2012). Crop was also benefited by improved soil chemical and physical properties in these treatments (*Tables 4 - 8*). Our results are in good agreements with findings of Ahmed *et al.* (2015) that application of FM and gypsum along with chiseling increased the productivity of fodder beet in saline-sodic soil. Among tillage implements used, modified chisel proves more efficient, as compared to other tillage implements. It may be due to reason that modified chisel cut the soil to deeper depth, which facilitate the leaching of salts out of root zone and speed up the reclamation process. Significant effect of tillage implements for rice-wheat production in salt affected soil was also reported by Sadiq *et al.* (2002), which reinforced the findings of our study.

After three years at the end of study, soil qualities were also remarkably improved by use of gypsum and tillage implements. Data regarding the chemical properties revealed that soil pH_s, EC_e and SAR decreased by 4.24%, 30.72% and 31.37%, respectively, with use of modified chisel plough (twice) + gypsum @ 100% GR of soil. This significant decrease in soil pH_s was due to availability of Ca^{2+} from gypsum, which replaces the exchangeable Na^{+} (Abdel-Fattah, 2012). Furthermore, deep chiseling by modified chisel plough helps to leach the salts and accelerated the reclamation process. Consequently, this decrease in pH_s values, results a decline in other salinity indices, *i.e.* EC_e and SAR (Gaffar *et al*., 1992; Qadir and Oster, 2002). Beneficial effects of gypsum and tillage implements on reclamation process has been reported by several researchers (Ahmed *et al.,* 2015; Rizwan *et al.,* 2018).

Soil physical properties, like hydraulic conductivity and bulk density, were also positively influenced by the gypsum and the implements used. Maximum increase of 130% in hydraulic conductivity was observed where modified chisel plough was used with gypsum @ 100 GR. This increased hydraulic conductivity may be ascribed due to more permeability of surface soil due to use of modified chisel plough. Increased hydraulic conductivity in modified chisel plough plots than cultivator or chisel plough was due to reason that modified chisel plough penetrate deeper into subsoil thus making the soil more porous. Similar results are reported by earlier scientist that chiseling increases the water infiltration rate of soil (Azhar *et al.,* 2001: Raza and Rafique, 2001). Soil bulk density is a very important physical property, which greatly influence the germination, emergence and growth of a seedling. Among tillage implements, soil bulk density was least with modified chisel plough

+ gypsum @ 100 GR, as compared to other implements used in this study. This may be justified due to more porous soil in these plots because modified chisel plough penetrates relatively to a greater depth. According to Sweeney *et al*. (2005), deep tillage, chiseling in particular, is often helpful in lowering the soil penetration resistance, bulk density and hydraulic conductivity, and improving infiltration rate of salt-affected soils, which is in accordance to our findings.

CONCLUSION

So, it can be concluded from the results of our study that combination of suitable rate of gypsum and tillage implements accelerated the reclamation process of salt affected soils. Modified chisel plough proved more effective tillage implements as it goes to deeper soil surface and make a drain which facilitate the leaching of soluble salts. Reclamation rate was greater in plots receiving the gypsum @ 100 GR than gypsum application @ 50% GR. Therefore, combination of modified chisel plough with gypsum @ 100 GR seem as a potential agro ecological innovation that promote the productivity of salt affected soils through improved soil physical and chemical properties.

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