INNSPUB

**International Journal of Biosciences | IJB |**
**ISSN: 2220-6655 (Print), 2222-5234 (Online)**
**http://www.innspub.net**
**Vol. 11, No. 2, p. 1-10, 2017**

RESEARCH PAPER OPEN ACCESS

# Integrated use of inorganic and organic amendments for reclamation of salt affected soil

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**Key words:** Integrated nutrient management, Gypsum, Press mud, Poultry manure, Rice-wheat

http://dx.doi.org/10.12692/ijb/11.2.1-10 Article published on August 20, 2017

## Abstract

Salt affected soils are the menace of 21$^{st}$ century agriculture. The issue has been more alarming for the present agriculture due to water scarcity. Water scarcity limits the intensive cropping pattern and ultimately reduced the yields. The issue of salinity/sodicity and water scarcity needs to be addressed precisely. Incorporation of organic content has positive impact on soil properties and crop yield and gypsum proved economical amendments for reclamation. Studies were planned following rice-wheat cropping system for the consecutive three years to assess the role of gypsum with and with organic sources i.e. press mud and poultry manure on the yield of rice and wheat crops. Studies were conducted at Soil Salinity Research Institute, Pindi Bhattian with treatments viz. $T_1$-control, $T_2$- gypsum @ 100 % GR, $T_3$- gypsum @ 50 % GR, $T_4$- gypsum @ 25 % GR + poultry manure @ 5 t ha$^{-1}$, $T_5$-gypsum @ 25 % GR + poultry manure @10 t ha$^{-1}$, $T_6$-gypsum @ 25 % GR + pressmud @ 5 t ha$^{-1}$, $T_7$-gypsum @ 25 % GR + pressmud @10 t ha$^{-1}$. Initial soil analysis showed that selected field has $pH_s$, 9.43, $EC_s$, 6.30 dS m$^{-1}$, SAR, 38.49 (mmol L$^{-1}$)$^{1/2}$, GR, 2.48 t acre$^{-1}$, bulk density, 1.73 Mg m$^{-3}$ and infiltration rate, 0.12 cm hr$^{-1}$.Two rates of gypsum i.e. 50% and 100% of GR while press mud and poultry manure @ 5 and 10 t ha$^{-1}$with gypsum @ 25% GR were applied. Results revealed that gypsum application @ 100% of GR proved best treatment followed by gypsum @ 25% GR with organic sources i.e. poultry manure and press mud. Application of gypsum at both rates 100% and 50% of GR reduced the ECe and SAR and integration of gypsum @ 25%GR with poultry manure and press mud also healthy effect on soil health and soil properties.

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## Introduction

Food production needs to be amplified for the burgeoning population of the world. In this regard arid and semi-arid regions may play vital role. On global spectrum, the most critical issues of the 21stcentury are food security, economic stability, and poverty alleviation (Falkenmark and Rockstrom, 2005a, b: Eickhout *et al.,* 2006; Rasmussen *et al.*, 2017). Continuous use of poor quality or high EC/RSC water for irrigation coupled with traditional practices is more threatening for an agro-based country like Pakistan. Their chemical and physical deterioration needs efficient water and nutrient management strategies to secure sustainable crop production.

Addition of excessive salts through irrigation damaged the chemical, physical and biological health of soil (Darwish *et al.,* 2005; Lakhdar *et al.,* 2008).Increasing incidence of soil salinization/sodification due to high EC/RSC irrigation ground water resulted in soil deterioration and aggravated the reduced crop yields (Zhang, 2006; Harmona and Daigh, 2017; Picaa *et al.,* 2017). High ESP (exchangeable sodium percentage) and pH promote clay dispersion and disintegration of soil aggregates by lessening of soil permeability, infiltration rate and available water content (Tejada*et al.,* 2006). The reliance on agriculture inputs has been increased due to land degradation. Nutrient availability is minimized due to poor soil conditions in salt affected soils of arid and semi-arid regions. Proper nutrient management should be opted to soil-plant-water relationships for optimal crop yield under adverse conditions (Silvertooth *et al.,* 2002).Extensive utilization of poor quality brackish water for raising crops not only enhanced the soil deterioration but also worsened the nutritional disorders causing poor yield. An integrated nutrient management/approach by incorporation of inorganic and organic sources along with inorganic and organic reclamants, is the need of present agriculture.

Application of organic sources not only improves the salt tolerance mechanisms of plants but also provides an excellent source of nutrients in nutrient imbalance circumstances (Chun *et al.,* 2007; Munns and Tester, 2008).

Application of organic sources lessened the sodium, carbonates, and bicarbonates in soil solution and enhanced the essential nutrient availability (Chun *et al.,* 2007; Rajendran *et al.,* 2009). The improvement in physical/chemical conditions, due to addition of organic matter, largely depends on nature and composition of organic source (Tejada and Gonzalez, 2006; Melero *et al.,* 2007). Organic amendments enhance the cation exchange capacity of soil particles and thus results in removal of excess cations from the root zones by leaching (Clark *et al.,* 2007). Organic content improved the soil microbiota promoted the nutrient transformations that providemore suitable platform for raising crops (Ndiaye *et al.,* 2000; Madejon *et al.,* 2001). Salt affected soils are well characterized for their deteriorated physical conditions and restricted nutrients availability. Better soil granulation can be achieved by the application of organic amendments. Application of organic amendments endorsed better granulation, soil aggregation, and other physical parameters i.e. water holding capacity, hydraulic conductivity, infiltration rate and soil adsorption (Brady and Weil, 2005).Application of manures (farm yard manure, poultry manure), press mud and compost (municipal solid waste, food wastes) improved the soil physical conditions viz. bulk density, water holding capacity, hydraulic conductivity, infiltration rate and soil porosity (Hussain *et al.,* 2001; Yaghmaeian *et al.,* 2005; Zaka, 2005; Alidadi *et al.,* 2008; Qazi *et al.,* 2009; Tzortzakis *et al.,* 2012). The present study was designed to observe the effect of integrated use of organic manures and gypsum for soil reclamation and crop production.

## Materials and methods

### *Field Studies*

Field experiments were conducted on moderately salt affected soil at Soil Salinity Research Institute (SSRI), Pindi Bhattian following rice-wheat rotation and layout was randomized complete block design (RCBD). Standard cultural and plant protection measures were adopted. Fertilizer @ 110-90-60 and 120-110-70 kg ha$^{-1}$to were applied to rice and wheat, respectively.

The amendments (gypsum, poultry manure and press mud) were applied in the respective treatment plots followed by leaching. Composite soil samples were collected and analyzed for salinity/sodicity and GR. Tube-well water (EC 1.54 dS $m^{-1}$, SAR 7.60 (mmol $L^{-1})^{1/2}$ and RSC 4.8 me $L^{-1}$), was used for crop production. Treatment details are presented in tables of results. Biomass and paddy / grain yield data were recorded of rice and wheat. The initial soil status before start of the experiment showed that soil was sandy loam (Bouyoucos, 1962), bulk density: 1.73 (Blake and Hartge, 1986). Soil was moderately salt affected having $pH_s$: 9.43, $EC_e$: 6.30 dS $m^{-1}$, SAR: 38.49 (mmol $L^{-1})^{1/2}$, GR: 2.48 t $acre^{-1}$ and infiltration rate: 0.12 cm $hr^{-1}$ (U.S. Salinity Lab. Staff, 1954). Soil samples for chemical analyses were collected before sowing and after each crop harvest.

*Statistical Analysis*

Data regarding biomass /paddy/grains yield of rice and wheat were subjected to statistical analysis by following RCBD using analysis of variance test (ANOVA) (Steel *et al.,* 1997) and differences among the means were compared by applying the Duncan's multiple range tests (DMR) (Duncan, 1955).

## Results

*First Year*

Field studies conducted following rice-wheat system at Research Farm of SSRI, Pindi Bhattian to assess the integrated use of organic sources and gypsum for soil reclamation and crop production. Before start of the field studies, soil sampling was carried out to determine the existing soil conditions. Soil was salt affected having $pH_s$, 9.43, $EC_e$, 6.30 dS $m^{-1}$, SAR, 38.49 (mmol $L^{-1})^{1/2}$, GR, 2.48 t $acre^{-1}$, bulk density, 1.73 Mg $m^{-3}$ and infiltration rate, 0.12 cm $hr^{-1}$. The gypsum was applied @ 50% and 100% of GR while press mud and poultry manure @ 5 and 10 t $ha^{-1}$with gypsum @ 25% GR were applied.

**Table 1.** Effect of different treatments on biomass / paddy / grains and soil analysis at harvest during 1st year.

| Treatments | Rice-1st year | | | | | Wheat-1st year | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Paddy | Biomass | Soil analysis at harvest | | | Grains | Biomass | Soil analysis at harvest | | |
| | (t $ha^{-1}$) | | $pH_s$ | $EC_e$ (dS $m^{-1}$) | SAR (mmol $L^{-1})^{1/2}$ | (t $ha^{-1}$) | | $pH_s$ | $EC_e$ (dS $m^{-1}$) | SAR (mmol $L^{-1})^{1/2}$ |
| $T_1$-Control | 0.75 D* | 2.96 E | 9.19 | 5.00 | 40.95 | 0.66 E | 1.61 D | 9.12 | 4.90 | 33.67 |
| $T_2$-Gypsum@100% GR | 2.13 A | 8.40 A | 8.82 | 3.95 | 29.88 | 1.73 A | 4.66 A | 8.79 | 3.83 | 24.97 |
| $T_3$-Gypsum@50% GR | 1.65 B | 6.48 B | 8.95 | 4.22 | 35.57 | 1.48 B | 3.25 B | 8.89 | 4.01 | 26.85 |
| $T_4$-Gypsum@25% GR + P. manure* (5 t $ha^{-1}$) | 1.11 C | 4.28 D | 9.00 | 4.96 | 36.65 | 1.03 D | 2.66 C | 9.01 | 4.78 | 28.85 |
| $T_5$-Gypsum@25% GR+ P. manure (10 t $ha^{-1}$) | 1.55 B | 5.80 BC | 8.92 | 4.77 | 35.47 | 1.40 BC | 3.58 B | 8.85 | 4.63 | 28.10 |
| $T_6$-Gypsum@25% GR + P. mud* (5 t $ha^{-1}$) | 1.25 C | 4.80 CD | 9.00 | 4.76 | 36.69 | 1.20 CD | 3.25 B | 8.95 | 4.61 | 27.75 |
| $T_7$-Gypsum@25% GR +P. mud (10 t $ha^{-1}$) | 1.73 B | 6.28 B | 8.90 | 4.63 | 32.62 | 1.46 B | 3.66 B | 8.86 | 4.55 | 26.90 |

Data regarding the biomass, paddy and biomass, grains of rice-wheat system (Table 1) during 1st year showed that gypsum application @100% GR significantly enhanced the paddy, biomass of rice i.e. 8.40, 2.13;respectively while biomass, grains of wheat i.e. 4.66, 1.73 t $ha^{-1}$, respectively. Integrated application of gypsum @ 25% GR and poultry manure@ 5 and 10% t $ha^{-1}$ produced the biomass and paddy yield of rice i.e.4.28, 1.11 and 5.80, 1.55 t $ha^{-1}$ while with press mud produced i.e. 4.80, 1.25 and 6.28, 1.73, respectively. Similarly, integrated application of gypsum @ 25% GR with poultry manure and press mud @ 10 t $ha^{-1}$ produced wheat biomass and grains i.e.3.58, 1.40 and 3.66, 1.46 t $ha^{-1}$, respectively.

The maximum decrease in soil $EC_e$ and SAR after rice harvest with gypsum @100%GR i.e. 3.95 and 29.88 followed by gypsum application @ 50% GR i.e. 4.22 and 35.57 as compared to control i.e. 5.00 (dS $m^{-1}$) and 40.95 (mmol $L^{-1})^{1/2}$, respectively. Combined application of gypsum @ 25% GR with poultry manure and press mud at both levels also reduced the EC and SAR values but more reduction was observed at 10 t $ha^{-1}$after rice harvest. Similarly after harvest of wheat, the maximum decrease in soil $EC_e$ and SAR with 100% GR i.e. 3.83 and 24.97 followed by gypsum application @ 50% GR i.e. 4.01 and 26.85 as compared to control i.e. 4.90 dS $m^{-1}$ and 33.67 (mmol $L^{-1})^{1/2}$, respectively. After rice harvest, soil $EC_e$ and SAR were reduced with integration of 25%GR with poultry manure @ 10 t $ha^{-1}$ i.e. 4.77 and 35.47 while with press mud @ 10 t $ha^{-1}$ i.e. 4.63 and 32.62.

After wheat harvest, application of gypsum @ 25%GR with poultry manure @ 10 t $ha^{-1}$ in combination reduced $EC_e$ to 4.63 and SAR to 28.10 while with press mud $EC_e$ and SAR were reduced to 4.55 and 26.90, respectively. Slight reduction of $pH_s$ was observed with the application of gypsum and integrated application of gypsum and organic amendments.

**Table 2.** Effect of different treatments on biomass/paddy/grains and soil analysis at harvest during 2nd year.

| Treatments | Rice-2nd year | | | | | Wheat-2nd year | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Paddy | Biomass | Soil analysis at harvest | | | Grains | Biomass | Soil analysis at harvest | | |
| | (t $ha^{-1}$) | | $pH_s$ | $EC_e$ (dS $m^{-1}$) | SAR (mmol $L^{-1})^{1/2}$ | (t $ha^{-1}$) | | $pH_s$ | $EC_e$ (dS $m^{-1}$) | SAR (mmol $L^{-1})^{1/2}$ |
| $T_1$-Control | 0.71 D | 3.25 E | 9.00 | 4.25 | 35.49 | 0.68 F | 1.50 F | 8.98 | 4.12 | 32.57 |
| $T_2$-Gypsum@100% GR | 2.46 A | 8.58 A | 8.59 | 3.63 | 23.27 | 3,17 A | 6.97 A | 8.55 | 3.54 | 20.36 |
| $T_3$-Gypsum@50% GR | 1.90 B | 6.66 B | 8.63 | 3.73 | 25.40 | 2.66 B | 6.46 B | 8.58 | 3.67 | 23.16 |
| $T_4$-Gypsum@25% GR + P. manure* (5 t $ha^{-1}$) | 1.36 C | 4.41 D | 8.90 | 4.29 | 28.35 | 2.10 DE | 4.62 D | 8.86 | 4.19 | 26.39 |
| $T_5$-Gypsum@25% GR+ P. manure (10 t $ha^{-1}$) | 1.66 B | 6.00 BC | 8.75 | 4.01 | 29.10 | 2.03 E | 4.40 E | 8.58 | 3.91 | 25.14 |
| $T_6$-Gypsum@25% GR + P. Mud* (5 t $ha^{-1}$) | 1.40 C | 5.25 CD | 8.65 | 4,13 | 27.15 | 2.26 C | 4.84 C | 8.62 | 4.22 | 24.12 |
| $T_7$-Gypsum@25% GR +P. mud (10 t $ha^{-1}$) | 1.71 B | 6.73 B | 8.80 | 3.93 | 28.95 | 2.16 CD | 4.75 C | 8.74 | 3.89 | 26.12 |

LSD (paddy)= 0.2544; LSD (biomass) = 1.1606; LSD (grains) = 0.1492; LSD (biomass) = 0.1757. *Means sharing the same letter(s) in a column do not differ significantly at $p<0.05$ according to Duncan's Multiple Range Test.* P. manure = Poultry manure; P.mud* = Pressmud.

*Second Year*

Data regarding the biomass, paddy and biomass, grains of rice-wheat system (Table 2) during 2nd year clearly indicated that gypsum application @100% GR significantly enhanced the paddy, biomass of rice i.e. 8.58, 2.46 while biomass, grains of wheat i.e. 6.97, 3.17 t $ha^{-1}$, respectively. Integrated application of gypsum @ 25% GR and poultry manure @ 5 and 10% t $ha^{-1}$ produced the biomass and paddy yield of rice i.e. 4.41, 1.36 and 6.00, 1.66 t $ha^{-1}$ while with press mud produced i.e. 5.25, 1.40 and 6.73, 1.71, respectively. Integrated application of gypsum @ 25% GR with poultry manure and press mud @ 10 t $ha^{-1}$ produced wheat biomass and grains i.e. 4.40, 2.03 and 4.75 and 2.16 t $ha^{-1}$ as compared to control i.e. 1.50, 0.68 t $ha^{-1}$, respectively.

Post-harvest soil analysis (Table 2) revealed that $EC_e$ and SAR of soils were reduced owing to application of gypsum at both rates i.e. 100% GR, 50% GR and poultry manure/press mud at both rates i.e. 5 and 10 t $ha^{-1}$with gypsum @ 25%GR. The highest reduction in soil $EC_e$ and SAR after rice harvest with gypsum @100%GR i.e. 3.63 and 23.27 followed by gypsum application @ 50% GR i.e. 3.73 and 25.40 as compared to control i.e. 4.25 dS $m^{-1}$ and 35.49 (mmol $L^{-1})^{1/2}$, respectively. After wheat harvest, soil $EC_e$ and SAR were reduced with gypsum @100%GR i.e. 3.54 and 20.36 followed by gypsum application @ 50% GR i.e. 3.67 and 23.16 as compared to control i.e. 4.12 dS $m^{-1}$ and 32.57 (mmol $L^{-1})^{1/2}$, respectively. After harvest of rice, application of gypsum @ 25%GR with poultry manure @ 10 t $ha^{-1}$ reduced $EC_e$ to 4.01 and SAR to 29.10 while with press mud $EC_e$ and SAR were reduced to 3.93 and 28.95, respectively. While after harvest of wheat, integrated application of gypsum @ 25%GR with poultry manure @ 10 t $ha^{-1}$ reduced $EC_e$ to 3.91 and SAR to 25.14 while with press mud $EC_e$ and SAR were reduced to 3.89 and 26.12, respectively.

*Third Year*

Data regarding the biomass, paddy and biomass, grains of rice-wheat system (Table 3) during 3rd year demonstrated that gypsum application @100% GR significantly enhanced the paddy, biomass of rice i.e. 9.20, 3.53 while biomass, grains of wheat i.e. 5.56, 3.26 t $ha^{-1}$, respectively.

Application of gypsum @ 25% GR and poultry manure @ 5 and 10% t ha$^{-1}$ produced the biomass and paddy yield of rice i.e. 7.50, 2.83 and 7.93, 3.21 t ha$^{-1}$ while with press mud produced i.e. 7.40, 2.92 and 8.21, 2.94, respectively. Integration of gypsum @ 25% GR with poultry manure @ 5 and10 t ha$^{-1}$ produced wheat biomass and grains i.e. 4.74, 2.54 and 5.05 and 2.85 t ha$^{-1}$ while with press mud produced i.e. 4.81, 2.61 and 4.97, 2.77 as compared to control i.e. 3.23, 1.02 t ha$^{-1}$, respectively. Post-harvest soil analysis (Table 3) showed that $EC_e$ and SAR of soils were reduced due to application of gypsum at 100% GR, 50% GR, integration of gypsum @ 25%GR and poultry manure / press mud at both rates i.e. 5 and 10 t ha$^{-1}$. After rice harvest, soil $EC_e$ and SAR with gypsum @100% GR i.e. 3.00 and 17.12 followed by gypsum application @ 50% GR i.e. 3.48 and 19.53 as compared to control i.e. 4.11 dS m$^{-1}$ and 31.18 (mmol L$^{-1}$)$^{1/2}$, respectively.

After wheat harvest, soil $EC_e$ and SAR were also reduced with gypsum @100% GR i.e. 2.40 and 14.56 followed by gypsum application @ 50% GR i.e. 3.00 and 16.40 as compared to control i.e. 4.00 dS m$^{-1}$ and 28.90 (mmol L$^{-1}$)$^{1/2}$, respectively. After harvest of rice, application of gypsum @ 25%GR with poultry manure @ 10 t ha$^{-1}$ reduced $EC_e$ to 3.70 and SAR to 20.00 while with press mud $EC_e$ and SAR were reduced to 3.42 and 22.51, respectively. While after harvest of wheat, integration of gypsum @ 25%GR with poultry manure @ 10 t ha$^{-1}$ reduced $EC_e$ to 2.98 and SAR to 16.98 while with press mud $EC_e$ and SAR were reduced to 2.76 and 17.50, respectively. The soil pHs was also reduced slightly with the application of gypsum at both rates and integration of organic sources and 25% GR. Soil analysis showed that $pH_s$ was under the safe limits in $T_2$ (gypsum @ 100 % GRand@ 50% GR) $T_5$ (gypsum @ 25 % GR+ poultry manure @ 10 t ha$^{-1}$)and gypsum @25%GR with press mud at both rates.

**Table 3.** Effect of different treatments on biomass/paddy/grains and soil analysis at harvest during 3rd year.

| Treatments | Rice-3rd year | | | | | Wheat-3rd year | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Paddy | Biomass | Soil analysis at harvest | | | Grains | Biomass | Soil analysis at harvest | | |
| | (t ha$^{-1}$) | | $pH_s$ | $EC_e$ (dS m$^{-1}$) | SAR (mmol L$^{-1}$)$^{1/2}$ | (t ha$^{-1}$) | | $pH_s$ | $EC_e$ (dS m$^{-1}$) | SAR (mmol L$^{-1}$)$^{1/2}$ |
| $T_1$-Control | 1.20 D | 3.03 E | 8.90 | 4.11 | 31.18 | 1.02 D | 3.23 E | 8.85 | 4.00 | 28.90 |
| $T_2$-Gypsum@100% GR | 3.53 A | 9.20 A | 8.52 | 3.00 | 17.12 | 3.26 A | 5.56 A | 8.50 | 2.40 | 14.56 |
| $T_3$-Gypsum@50% GR | 3.23 B | 8.25 B | 8.55 | 3.48 | 19.53 | 2.78 B | 4.98 B | 8.51 | 3.00 | 16.40 |
| $T_4$-Gypsum@25% GR + P. manure* (5 t ha$^{-1}$) | 2.83 C | 7.50 D | 8.82 | 3.98 | 23.83 | 2.54 C | 4.74 D | 8.72 | 3.46 | 19.52 |
| $T_5$-Gypsum@25% GR+ P. manure (10 t ha$^{-1}$) | 3.21 B | 7.93 C | 8.53 | 3.70 | 20.00 | 2.85 B | 5.05 B | 8.50 | 2.98 | 16.98 |
| $T_6$-Gypsum@25% GR + P. mud* (5 t ha$^{-1}$) | 2.92 C | 7.40 D | 8.59 | 3.76 | 21.22 | 2.61 B | 4.81 CD | 8.30 | 3.00 | 17.78 |
| $T_7$-Gypsum@25% GR +P. mud (10 t ha$^{-1}$) | 2.94 C | 8.21 B | 8.68 | 3.42 | 22.51 | 2.77 B | 4.97 BC | 8.57 | 2.76 | 17.50 |

LSD (paddy)= 0.2268; LSD (biomass) = 0.2211; LSD (grains) = 0.1041; LSD (biomass) = 0.1632. *Means sharing the same letter(s) in a column do not differ significantly at $p<0.05$ according to Duncan's Multiple Range Test. * P. manure = Poultry manure; P.mud* = Pressmud.

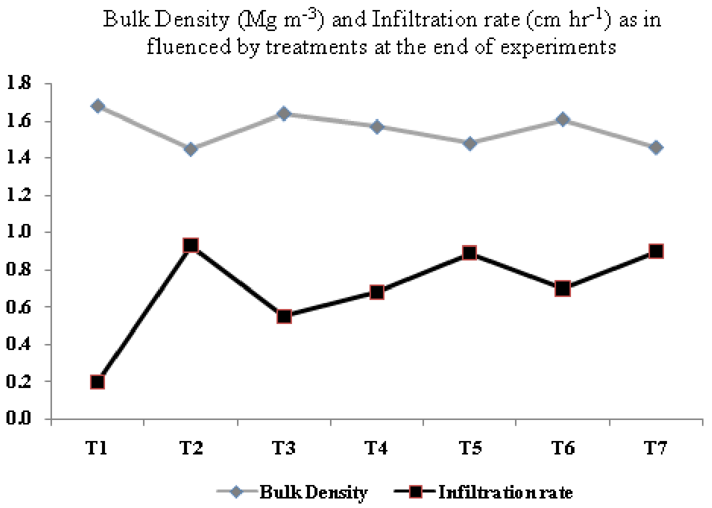
Data regarding the bulk density and infiltration rate recorded at the end of three year experiment (Fig. 1) revealed that application of gypsum @ 100% GR considerably improved the soil physical properties like infiltration rate and bulk density as compared to the 50@ GR. Integration of inorganic i.e. gypsum and organic sources at both levels improved the infiltration rate and bulk density. Application of poultry manure and press mud @ 10 tha$^{-1}$ has more assenting effect than 5 t ha$^{-1}$. Almost at par infiltration rate was observed with integrated application of gypsum @ 25% GR with poultry manure and press mud @ 10 t ha$^{-1}$. Similarly bulk density was also improved with gypsum and integration of gypsum and organic sources.

## Discussion

Increase in rice biomass/paddy yield and biomass/grains of wheat during 1st to 3rd year clearly demonstrated the role of gypsum in improvement of plant growth and ultimately the yield of rice and wheat and reduction of salinity and sodicity due to leaching of salts and promoting flocculation of dispersed soil.

Application of gypsum improved flocculation of dispersed soil and subsequent leaching removed the excessive $Na^+$ from the root zone (Qadir *et al.,* 2002; Zaka *et al.,* 2005; Muhammad and Khattak, 2011). Flocculation of dispersed soil by removal of $Na^+$ with $Ca^{2+}$ from gypsum promotes the hydraulic properties (Qadir *et al.,* 2002; Muhammad and Khattak, 2011).

The cultivation of rice submerged conditions results in leaching of soluble salts / excessive cations i.e. $Na^+$ might be the main cause of betterment in plant growth and yield and infiltration rate and hydraulic conductivity ultimately resulted in lowering of soil $EC_e$ and SAR (Ghafoor *et al.,* 2008). Results supported that salinity/sodicity parameters of soil were reduced than previous entries due to sole or combined application of gypsum with inorganic and organic sources (Qadir *et al.,* 2001; Ghafoor *et al.,* 2008; Qazi *et al.,* 2009; Nan *et al.,* 2016; Murtaza *et al.*, 2017). Our results are in accordance with Ghafoor *et al.* (2008) who reported that high leaching fraction in rice is implicitly attained resulting in leaching of soluble salts and hence reduce the EC of soil. Similarly, Muhammad and Khattak (2011) confirmed that reduction in SAR of soil was observed when gypsum was applied with organic amendments.




$T_1$-Control, $T_2$-Gypsum@100% GR, $T_3$-Gypsum@50% GR, $T_4$-Gypsum@25% GR + P. manure* (5 t ha$^{-1}$), $T_5$-Gypsum@25% GR+ P. manure (10 t ha$^{-1}$), $T_6$-Gypsum@25% GR + P. mud* (5 t ha$^{-1}$), $T_7$-Gypsum@25% GR +P. mud (10 t ha$^{-1}$).

**Fig. 1.** Bulk Density (Mg $m^{-3}$) and Infiltration rate (cm $hr^{-1}$) as influenced by treatments at the end of experiments**.**

Application of organic content improved the granulation, flocculation and aggregate stability indices owed to be the main factor for reduction of EC and SAR (Hussain *et al.,* 2001; Qadir *et al.,* 2001; Zia *et al.,* 2007). Improvement in soil health by lowering of soil EC and SAR, $pH_s$ with application of gypsum with poultry manure and press mud or other organic sources was also confirmed our findings (Qazi *et al.,* 2009;Mikanova*et al.,* 2012; Shaaban *et al.,* 2013).

The decline in soil $pH_s$, $EC_e$ and SAR after rice harvest owed to the fact that leaching from high $pH_s$ soil with application of gypsum and organic content alkaline soils resulted in decrease of soil $pH_s$ Blum *et al.,* 2004;Van-Camp *et al.,* 2004; Chitravadivu *et al.,* 2009). Integration of organic content with inorganic sources induced swift reclamation and nutrient availability resulted in more yield of crops (Matula and Pechová, 2007; Milosevic and Milosevic, 2009; Mikanova *et al.,* 2012; Shaaban *et al.,* 2013).

Previous studies demonstrated the positive correlation of organic content and grain yield of crops like rice, wheat, oat etc. (Hanč *et al.,* 2008;Khan *et al.,* 2012; Mikanová *et al.,* 2012; Verma *et al.,* 2012; Shaaban *et al.,* 2013).

Gypsum application with organic sources like farm yard manure, poultry manure, press mud etc. improved the soil physical properties like hydraulic conductivity, infiltration rate, aggregate stability, bulk density, and water holding capacity.

The decomposition of organic content enhanced soil carbon content especially $CO_2$ and discharged $H^+$ ion. Hydrogen ion released caused dissolution of calcium carbonate and provides more $Ca^{2+}$ ion for the replacement of $Na^+$ (Ullah and Bhatti, 2007; Ghafoor *et al.,* 2008; Zia-ur-Rehman *et al.,* 2016).

The present study demonstrated the role of gypsum in reclaiming salt affected soil and enhancing the crop yield. Integration of gypsum with poultry manure and press mud not only improved the soil salinity/sodicity parameters but also affected positive impact on physical properties.

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