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# Mitigating the salinity imposed impact of brackish water on chickpea (*Cicer arietinum* L.) through application of biogypsum and bioassimilable sulfur

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## Abstract

*Water scarcity is becoming an issue of concern which necessitates the use of underground brackish water for crop production. Poor quality underground water is harmful owing to its adverse effect on soil properties and crop growth. The effectiveness of biogypsum and bioassimilable sulfur prepared by inoculating sulphur and gypsum with bacteria was evaluated in a pot study to ameliorate the negative impact of brackish water on chickpea. The soil was mixed with biogypsum and bioassimilable sulphur alone and in combination. After filling the pots with treated and untreated soil, recommended dose of NPK was applied and five seeds of chickpea were sown in each pot. Two sets of pots with three replications were arranged according to completely randomized design. The pots were irrigated with brackish water and in case of control canal water was applied. To maintain uniform population, two plants per pot were maintained after germination. Nodulation data was collected from one set at flowering stage and data regarding growth and yield parameters was collected at maturity from second set. Results revealed that biogypsum and bioassimilable sulfur positively reduced the negative impacts of brackish water on chickpea growth and yield. Although both biogypsum and bioassimilable sulfur improved chickpea growth in the presence of brackish water whether applied alone or in combination however, significant increase in nodulation and yield was observed when both were applied in combination. The application of biogypsum and bioassimilable sulfur also improved the physicochemical properties (pH, $EC_e$ and bulk density) of soil. From present work it can be concluded that application of biogypsum and bioassimilable sulfur, could be an effective approach to mitigate the negative effect of brackish water.*

**Keywords:** Brackish water, Amendments, Biogypsum, Bioassimilable sulfur, Chickpea

## Introduction

Rise in temperature and low rainfall in arid and semi-arid areas, as well as increasing cropping intensity are some factors related to shortage of good quality canal water for crop production. This shortage of water necessitates the use of underground water. However, due to high electrical conductivity (EC), sodium adsorption ratio (SAR) and/or residual sodium carbonate (RSC), the underground water quality in most of the areas is not up to the mark (Qamar *et al.*, 2011).

The continuous use of poor quality brackish water is causing salinity/sodicity problems (Hussain *et al.*, 1993). The use of such water causes an adverse effect on soil–water–plant relations and severely restricting the normal physiological activity and productive capacity of the crops (De Pascale *et al.*, 2013, Plaut *et al.*, 2013). The use of brackish water increases root zone salinity (Patel *et al.*, 2000) and its long term use affect the physico-chemical properties of soil negatively and ultimately decrease plant growth (Farooq *et al.*, 2008). Salt accumulation in the root zone hazards to plant growth and development (Tedeschi and Dell'Aquila, 2005; Silva *et al.*, 2011, Wang *et al.*, 2011). Poor quality water is harmful for plants in many ways, but the most common impacts include nutritional and hormonal imbalances (Nadeem *et al.*, 2010; Hussain *et al.*, 2019) as well as osmotic effect that reduces water uptake by plant (Malash *et al.*, 2005).

Nutrient imbalances in plants cause disruption in normal nutrient uptake, transport, and partitioning, ultimately it effects the plant growth and development (Grattan and

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Grieve, 1994; Niste *et al.* 2014). Cucci *et al.* (2013) studied the impact of saline-sodic water on physical and chemical properties of soil. They observed that application of saline-sodic water increased the ECe, SAR and exchangeable Na and decreased the exchangeable K, Ca and Mg. Phosphorus availability is reduced in saline soil and phosphorus concentration in plant tissue decreased in response to salinity stress (Sharpley *et al.*, 1992).

With proper management practices such brackish water can be used efficiently (Qadir *et al.*, 2001). The use of chemical amendments like gypsum is one of the economical strategies for amelioration of salinity/sodicity problem (Feizi *et al.*, 2010). The SAR and/or RSC of irrigation water can be decreased by decreasing its carbonate and bicarbonate contents, either with the addition of acids (Ghafoor *et al.* 1997; Amrhein 2000) or by increasing the concentration of calcium with chemical amendments like gypsum (Gupta and Gupta 1997; Hussain *et al.* 2000). Similarly, sulfuric acid is generally recommended for the treatment of water having high RSC values. There are certain drawback/concerns about the use of these chemical amendments. For example, the solubility of gypsum at 20°C is 2.531 g $L^{-1}$ or 14 mM $L^{-1}$, which is roughly 140 times lower than the solubility of common salt. According to US Salinity Lab. Staff (1954) gypsum has a low solubility of 0.30 g per 100 mL water at 25◦C. Similarly, the use of mineral acids has been found five to seven times expensive than that of gypsum (Ghafoor *et al.*, 2002) and its handling is also difficult/dangerous. Therefore, there is a need to develop a cost effective technology to reduce the negative impact of brackish water and to promote plant growth by providing conducive environment on sustainable basis.

A number of microbes that are present in soil environment play important key role in plant growth promotion and improving soil quality. Among these microbial populations, plant growth promoting rhizobacteria (PGPR) are considered as one of the most important agents of plant growth promotion. These microbes by virtue of number of their growth promoting traits like phosphate solubilization, phytohormones and siderophores production, activity of enzymes and production of exopolysaccharides and osmolytes promote plant growth under normal and stressed conditions (Nadeem *et al.*, 2010, Glick *et al.*, 2010).

Bacterial strains that produce extracellular polymeric substance (exopolysaccharides) bind cations including $Na^+$ and decrease the content of $Na^+$ available for plant uptake, thus help alleviating salt stress in plants growing in saline environments (Geddie *et al.* 1993).

The application of sulfur along with sulfur oxidizing bacteria enhances the availability of nutrient particularly phosphorus and micronutrients in calcareous soil (Yang *et al.*, 2010). Microbial oxidation produces sulfuric acid (Vidyalakshmi *et al.*, 2009) which is responsible for nutrient solubility. Enhanced solubility of phosphorus, zinc and iron by the application of sulfur plus sulfur oxidizing bacteria has been reported by Heydrarnezhad *et al.* (2012). The effect of microbial application on saturated hydraulic conductivities of four different saline–sodic soils which were being ameliorated with gypsum was studied by Sahin *et al.* (2011). They observed that application of bacterial strain with gypsum caused a significant positive impact on hydraulic conductivity of saline-sodic soil. Andrade *et al.* (2018) demonstrated that application of sulfur with gypsum mitigating the negative impact of saline water by reducing the soil salinity and promoting the growth of sorghum. Similarly, to study the impact of sulfur on yield of wheat grown on soil irrigated with saline water Mohamed e al. (2019) observed that electrical conductivity (EC), sodium adsorption ratio (SAR) and soil pH increased with increasing salinity levels in the irrigation water however the application of sulfur reduced the value of these parameters. Recently, Kozminska *et al.* (2024) investigated the role sulful oxidizing bacteria to ameliorate the negative impact of salinity. They demonstrated that sulfur oxidizing bacteria enhanced the salt stress tolerance of *Plantago coronopus* L.

The above-mentioned work shows that the application of PGPR with gypsum or sulfur could be an effective approach to overcome the problem of negative impact of salinity on plant growth and development. However, there is no information about the use of bacteria in combination with gypsum or sulphur for reducing the effect of poor quality brackish water for plant growth and soil properties. Therefore, this preliminary work was conducted to evaluate the impact of gypsum and sulphur enriched with effective strain of bacteria on the physiological parameters, growth and yield of chickpea irrigated with brackish water. Moreover the comparative effectiveness of biogypsum and bioassimilable sulfur was also evaluated to mitigate the negative impact of brackish water.

## Materials and Methods

A pot experiment was conducted at the University of Agriculture, Faisalabad (UAF) Sub-Campus Burewala. Soil was collected from the research area of the Sub-Campus. It was air dried, ground, sieved. A composite sample of soil was collected for analysing physico-chemical properties of soil (Table 1) by using standard procedure according to US Salinity Lab Staff (1954). Biogypsum and bioassimilable

sulphur were obtained from the Institute of Soil & Environmental Sciences, University of Agriculture, Faisalabad. These were prepared by enriching the gypsum and sulfur through biological processes, often by bacteria.

There were seven treatments including $T_1$ (canal water), $T_2$ (brackish water), $T_3$ (brackish water + gypsum), $T_4$ (brackish water + bio gypsum), $T_5$ (brackish water + bioassimilable sulfur), $T_6$ (brackish water + bio gypsum + bioassimilable sulfur) and $T_7$ (brackish water + gypsum + bioassimilable sulfur).

**Table 1. Analysis of brackish water used to irrigate chickpea**

| Characteristics | Unit | Value |
|---|---|---|
| pH | - | 7.35 |
| EC | dS $m^{-1}$ | 5.65 |
| TSS | meq $L^{-1}$ | 60.2 |
| $CO_3^{-2}$ | dS $m^{-1}$ | - |
| $HCO_3^{-1}$ | meq $L^{-1}$ | 14.2 |
| $Cl^-$ | meq $L^{-1}$ | 68 |
| $SO^{-2}$ | | |
| $Na^+$ | | |
| $Ca^{+2}$+$Mg^{+2}$ | meq $L^{-1}$ | 2.2 |
| SAR | - | 65.3 |
| RSC | mmol $L^{-1}$ | 12 |

## Soil sample collection and application of treatments

Prior to filling the pots with soil, gypsum powder, bio gypsum and bioassimilable sulfur was mixed with soil @2% each. Gypsum, biogypsum and bioassimilable sulfur, was applied alone and in combination according to treatment plan.

The experiment was laid out according to completely randomized design (CRD) with two sets of pots with three replications.

## Sowing of chickpea and collection of data

Five seeds of chickpea (Variety; Bittal-2021) were sown in each pot. After germination, uniform population of two plants per pot was maintained. Recommended dose of NPK @20-40-20 kg $ha^{-1}$ was applied in the form of urea, diammonium phosphate and potassium sulphate, respectively. Irrigation requirement of crop was fulfilled by applying canal water and underground brackish water as per treatment plan.

Leaf samples were collected at vegetative stage and analyzed for physiological parameters i.e chlorophyll content, membrane stability (electrolyte leakage) and relative water content. Chlorophyll content was measured according to Arnon (1949). For this purpose, 0.5g leaf sample was homogenised with 80% acetone. After filtration the absorbance was measured at wavelength of 663, 645 and 480 for chlorophyl a, b and carotenoids. Electrolyte leakage was measured according to the method described by Lutts *et al.* 1996. Plant leaves were collected and washed. Then samples were placed in closed vials with deionized water and incubated for 24 h at 25 ∘C on a rotary shaker. The electrical conductivity of the solution (*Lt*) was determined and then samples were autoclaved at 120 ∘C. After autoclaving, the electrical conductivity of solution (*L0*) was determined again. The electrolyte leakage by the following formula.

Electrolyte leakage (%) = (*Lt*/*L*0) × 100

Relative water content (RWC) was measured by using following formula Mayak *et al.* (2004).

RWC (%) = (Fresh mass – dry mass /Fully turgid mass – dry mass) x 100

Data regarding nodulation was collected at flowering stage from one set of replications. At maturity, data regarding growth and yield parameters was collected from second set of replications. Plant height, root length, fresh and dry weight of root and shoot and yield per pot was collected by using standard procedure. Soil samples from each pot was also collected after crop harvesting and was analyzed for physico-chemical characteristics i.e pH, electrical conductivity (ECe) and bulk density according to US Salinity Laboratory Staff (1954). Data was analysed by using Statistix (version 8.1) (Analytical software, 2005, Florida, USA) and means were measured by Duncan's multiple range test at 5% probability (Steel *et al.* 1997).

## Results

The application of treatments effectively ameliorated the negative impacts of brackish water and caused significant effect on nodulation (Table 2). The maximum number of nodules was observed in $T_6$ (brackish water + Biogypsum + Bioassimilable sulfur) that was up to 72% more compared to $T_1$ (canal water). Treatments $T_5$ (brackish water + Bioassimilable sulfur) and $T_7$ (brackish water + gypsum + bioassimilable sulfur) were statistically similar with $T_6$. Brackish water ($T_2$) showed negative response and decreased the number of nodules up to 45% as compared to canal water treatment ($T_1$). The highest nodules fresh weight was recorded in $T_6$ and was up to 69% more compared to canal water treatment. Minimum nodule fresh weight was recorded in case on brackish water. Compared to canal water treatment, 70% more increase in nodule dry weight was observed in case of $T_5$. It was statistically similar with $T_6$ and $T_7$.

**Table 2: Impact of treatments on number of nodule, nodule fresh weight and nodule dry weight**

| Treatment | No. of nodules per plant | Nodule fresh weight (g) | Nodule dry weight (g) |
|---|---|---|---|
| $T_1$= Canal water | 22b | 1.66d | 0.141b |
| $T_2$= Brackish water | 12c | 1.01e | 0.065c |
| $T_3$= BW + gypsum | 25b | 2.11cd | 0.170b |
| $T_{4=}$ BW + Biogypsum | 26b | 2.13cd | 0.150b |
| $T_5$= BW + Biosulfur | 36a | 2.81a | 0.240a |
| $T_6$= BW+BioGYP+BioS | 38a | 2.55ab | 0.211ab |
| $T_7$= BW+GYP+BioS | 33ab | 2.33ab | 0.20 ab |

**Table 3: Impact of treatments on relative water content, membrane stability, chlorophyll a, b and carotenoids**

| Treatment | Relative water content (%) | Membrane stability (%) | Chlorophyll a | Chlorophyll b | Carotenoids |
|---|---|---|---|---|---|
| $T_1$=Canal water | 19d | 73.2c | 28.5d | 12c | 8.4b |
| $T_2$=Brackish water | 6f | 61d | 7.9f | 2.5e | 6.2c |
| $T_3$=BW+ GYP | 26.6c | 72.2c | 23.9e | 9.6c | 8.7b |
| $T_4$=BW+ BioGYP | 10.9e | 72.5c | 29.5d | 13.4b | 8.2b |
| $T_5$=BW+ BioS | 30.4b | 83a | 44.5a | 17.3a | 11.9a |
| $T_6$=BW+BioGYP+BioS | 34.9a | 82.7a | 43.1b | 17.5a | 11.1a |
| $T_7$=BW+GYP+BioS | 31.2b | 78.6b | 32.2c | 14.3b | 10.1ab |

The application of treatments effectively ameliorated the negative impacts of brackish water and caused significant effect on physiological parameters of chickpea as shown in Table 3. The highest gain in relative water content was noticed in case of $T_6$ (83% more compared to canal water treatment). $T_5$ and $T_7$ were statistically similar with $T_6$. A significant increase in relative water content was also observed in treatments where brackish water used with gypsum and sulfur. The more increase in membrane stability i.e. 83% was observed in case of $T_5$ where brackish water was used with bioassimilable sulfur. It was statistically similar with $T_6$. Maximum chlorophyll content (a, b and c) was recorded in case of $T_6$ followed by $T_5$ and $T_7$ (Table 3). Minimum chlorophyll content was observed where canal and brackish water used alone.

Data regarding growth and yield parameters of chickpea has been shown in Table 4. Data showed that application of brackish water with biogypsum and/or bioassimilable sulfur caused significant positive effect on growth and yield of chickpea. The maximum increase in the plant height (30.3 cm) was observed in case of $T_6$ (94% more than $T_2$) followed by $T_7$. $T_5$ was next effective treatment that was statistically similar with $T_7$. Treatments $T_3$ and $T_4$ also caused significant increase in plant height compared to $T_1$ and $T_2$. Similar results were also observed that in case of shoot fresh and dry weight. Data regarding root length, root fresh and dry weight showed that significant increase in these parameters was observed due to application of gypsum and bioassimilable sulfur compared to treatments where canal and brackish water was applied alone. Maximum root length was recorded with $T_5$ (21.6) that was statistically similar with $T_6$ (20.6) and $T_7$ (20.6). Similar results were obtained in case of root fresh and dry weight. Maximum root fresh weight (8.9) and root dry weight (1.90) was obtained with $T_5$ and $T_6$ respectively. Treatments $T_3$ and $T_4$ were statistically similar with $T_1$ and $T_2$ regarding root dry weight.

Data regarding yield parameters (Table 5) revealed that treatments effectively ameliorate the adverse impacts of brackish water and significantly enhanced yield of chickpea. Maximum number of pods per plant were recorded with $T_6$ (84) followed by $T_5$ (80.6) and $T_7$ (74). Treatments $T_3$ and $T_4$ were statistically similar with $T_1$ while minimum number of pods (39.2) were recorded in case where brackish water was applied without amendment. Similar results were obtained in case of grain yield. Application of brackish water with biogypsum and bioassimilable caused significant increase in chickpea yield.

The effect of treatments on soil pH, ECe and bulk density has been shown in Table 6. Data showed that all treatments caused significant effect on soil physico-chemical properties however the effect was more pronounced where brackish water was used alone. The maximum pH (8.75) was observed in case of $T_2$ (brackish water) followed by $T_3$ (brackish water + gypsum) and $T_4$ (Brackish water + biogypsum). Minimum (7.85) was noted in $T_6$ (brackish water + biogypsum + biosulfur) followed

**Table 4: Impact of treatments on plant height, root length, fresh and dry weight of shoot and root**

| Treatment | Plant height (cm) | Shoot fresh weight (g) | Shoot dry weight(g) | Root length(cm) | Root fresh weight(g) | Root dry weight(g) |
|---|---|---|---|---|---|---|
| T1=Canalwater | 22.3c | 5.6b | 2.7b | 17.0c | 4.8c | 1.40b |
| $T_2$=Brackish water | 15.6e | 2.6c | 1.4c | 14.3d | 4.7d | 1.05b |
| $T_3$=BW+GYP | 19.0d | 7.1b | 3.4b | 19.0bc | 6.6b | 1.52ab |
| $T_4$=BW+BioGYP | 19.3cd | 6.7b | 3.2b | 18.0c | 6.8b | 1.53ab |
| $T_5$=BW+BioS | 27.0b | 11.9a | 5.2a | 21.6a | 8.9a | 1.83a |
| $T_6$=BW+bioGYP+BioS | 30.3a | 12.1a | 5.4a | 20.6ab | 8.2a | 1.90a |
| $T_7$=BW+GYP+BioS | 29.3ab | 9.2ab | 3.9ab | 20.6ab | 8.1a | 1.71a |

**Table 5: Impact of treatments on number of pods and grain yield per pot**

| Treatment | No. of pods per pot | Grain yield per pot (g) |
|---|---|---|
| T1=Canal water | 64.0b | 22cd |
| $T_2$=Brackish water | 39.2c | 13e |
| $T_3$=BW+ GYP | 66.0b | 21d |
| $T_4$=BW+ BioGYP | 68.0b | 22cd |
| $T_5$=BW+ bioS | 80.6a | 27a |
| $T_6$=BW+BioGYP+BioS | 84.0a | 24ab |
| $T_7$=BW+GYP+BioS | 74.0ab | 25ab |

**Table 6: Physico-chemical characteristics of soil before and after experiment**

| Characteristic | unit | Before sowing | After chickpea harvesting | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | $T_1$ | $T_2$ | $T_3$ | $T_4$ | $T_5$ | $T_6$ | $T_7$ |
| pHs | -- | 8.20 | 8.35a | 8.75a | 8.45a | 8.40a | 8.09b | 7.85bc | 8.0b |
| ECe | dS $m^{-1}$ | 1.46 | 1.97e | 6.90a | 4.72b | 3.84d | 3.91c | 3.01e | 3.75cd |
| Bulk density | Mg $m^{-3}$ | 1.47 | 1.43c | 1.77a | 1.59b | 1.40c | 1.39c | 1.22d | 1.29d |

by $T_7$ and $T_5$. Sole application of brackish water caused significant increase in ECe that was 6.90 dS $m^{-1}$ compared to 1.46 dS $m^{-1}$. However, gypsum and sulfur application with or without bacterial inoculation mitigate this negative effect of brackish water. Minimum increase in pH compared to normal soil was observed in case of canal water treatment (1.97 dS $m^{-1}$) followed by $T_6$ (3.01 dS $m^{-1}$) and $T_7$ (3.75 dS $m^{-1}$) where brackish water was used. Similar results were observed in case of bulk density. Maximu buld density value was observed in $T_2$ i.e 1.77 $Mgm^{-3}$ and minimum by $T_6$ i.e 1.22 $Mgm^{-3}$. Treatments T1, $T_4$ and $T_5$ showed statistically similar results.

## Discussion

Canal water is a good source of irrigation for better crop production. However, due to shortage of good quality canal water people have to use poor quality underground water to fulfil crop irrigation requirement. Due to presence of hazardous and excessive ion concentration in brackish water it causes harmful effect on plant growth. The amelioration of such water will be useful for mitigating the negative effect of water. This investigation demonstrates the efficacy of gypsum and sulfur enriched with effective strains of bacteria for amending the negative impact of brackish water. The results showed that brackish water application results in significant adverse effect on growth of chickpea. However, the application of biogypsum and bioassimilable sulfur mitigated this adverse effect of brackish water on growth and yield of chickpea.

Significant improvement in chickpea nodulation has been observed owing to biogypsum and biosulfur application in the presence of brackish water. Salinity caused negative impact on nodulation. Salinity diminished root hair curling, infection thread formation and reduction in number of nodules (Zahran and Sprent, 1986). PGPR can improve nodulation by increasing the availability of sulfur in the soil, which is an essential nutrient for both plants and the rhizobia that form nodules. The improvement in growth and nodulation of cowpea was observed by the addition of sulfur and/or gypsum in sodic soil reported by Stamford *et al.* (2015). Similar increase in nodulation was also observed by other workers with the addition of sulfur oxidizing bacteria (Scherer, 2001; Joshi *et al.*, 2021). Sulphur requirement of

legumes is high and the application of sulfur oxidizing bacteria promotes nodules and satisfies the sulphur plant need (Patel *et al.* 2024). They demonstrated that application of elemental sulfur with sulfur oxidizing bacteria significantly enhanced the growth and yield parameters of chickpea (*Cicer arietinum*).

In this study, the high concentration of Cl and Na ion present in brackish water caused negative impact on chickpea. Borucki and Sujkowska (2008) also reported the reduction in nodulation due to high concentration of sodium chloride. In our research, application of biogypsum and biosulfur protected the plant from negative impact of high concentration of ions present in brackish water.

An increase in chlorophyll content has been observed by the application of biogypsum and bioassimilable sulfur alone or in combination. An increase in chlorophyll content was also observed by Kacar and Katkat, (2007). It is reported that sulfur should be added into the soil in addition to other nutrients for maintaining appropriate nutrient balance for improving yield and quality of produce (Scherer, 2001; Jez, 2008). Sulfur is a constituent of chlorophyll, and its deficiency decrease chlorophyll content and photosynthesis (Namvar and Khandan 2015). Recently, Kong et al (2024) demonstrated an increase in chlorophyll content of lettuce in the presence of sulfur.

Sulfur is a crucial element for growth of plant as it supports the peptide synthesis, which consist of cysteine alike glutathione, vitamins (B, thiamine and biotine) and different secondary metabolites (Abdallah *et al.*, 2010). Beyond ideal sulfur level in soil, crops are unable to attain their maximum potential with reference to protein content or yield (McGrath, 2003; Tarafdar*et al.*, 2005). It was described by Wilson *et al.* (2000) that calcium and sulfur can correct the selectivity of K/Na and enhances the activity of $Ca^{2+}$ in decreasing the deleterious impacts of $Na^{+}$ upon plants. It has been reported that sulfur is not only important for crop production and better-quality produce but also ameliorate the soil conditions for healthy crop growth (El-Tarabily*et al.*, 2006; Abdou, 2006).

The results of water analysis shows that the underground water quality is not good for crop production. The water has high electrical conductivity value i.e. 7.02 dS $m^{-1}$. The brackish water application induces significant negative impact on soil physical and chemical properties. The soil pH before initiation of experiment was 8.36 that increased to 8.75 because of brackish water application. However, notable reduction in soil pH was noticed because of the application of biogypsum and bioassimilable sulfur. The brackish water caused increase in soil EC both in treated and untreated pots however, the increase in EC was more significant in $T_2$ where brackish water was applied without treatment. The maximum soil EC was ascertained that was 3.6 fold more than original EC of soil i.e. 1.91 dS $m^{-1}$ which shows that application of brackish water without any treatment cause negative impact on soil ECe. While in case of bulk density alike outcomes were observed and the application of biogypsum and bioassimilable sulfur reduces the bulk density.

This enhancement is because of the sodium displacement by calcium, which leads to the reduction in soil pH and to the enhancement in the use efficiency of nutrients of the crops.

Sulfur might be added on calcareous soils having pH greater than 6.6, which upon microbial oxidation changes into $H_2SO_4$, that forms gypsum upon reaction with the indigene $CaCO_3$ (Rana *et al.* 2020). Winter wheat showed noteworthy increment in yield with S and Ca addition (Mahmood *et al.*, 2010). Alike, it has been revealed that the gypsum and sulfur as coherent amendment, modulate the pH and total soluble salts of soil of salt-affected soils (Muhammad *et al.*, 2007; Kubenkulov *et al.*, 2013). Meantime, leaching of $Na^{+}$ out of root zone is speed up because of applied amendments like gypsum and sulfur, which is most likely the reason for decreasing the values of ECe, pH sand SAR to secure values (Abdel-Fattah, 2012; Abdelhamid *et al.*, 2013).

It might be ended from the outcomes of experiment that sulfur and gypsum decreased the hazardous effect of saline irrigation water, as well have a favourable impact on the chickpea growth and yield upon irrigation with brackish water.

## Conclusion

It can be concluded from present study that application of biogypsum and bioassimilable sulfur could be an effective and novel strategy for ameliorating adverse effect of brackish water.

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