Research Article

Integrated Use of Humic Acid and Gypsum under Saline-Sodic Conditions

Amar Iqbal Saqib[1], Khalil Ahmed[1*], Abdul Rasul Naseem[1], Ghulam Qadir[1], Muhammad Qaisar Nawaz[1], Muhammad Khalid[2], Imtiaz Ahmad Warraich[3] and Muhammad Arif[4]

[1]Soil Salinity Research Institute (SSRI), Pindi Bhattian, Pakistan; [2]Soil and Water Testing Laboratory Bhakkar, Pakistan; [3]Citrus Research Institute Sargodha, Pakistan; [4]Soil and Water Testing Laboratory Layyah, Pakistan.

Abstract | Use of inorganic and organic amendments is a very effective approach to enhance crop productivity and restoring the deteriorated properties of salt-affected soils. For addressing this objective, a study was undertaken to investigate the ameliorative effect of humic acid (HA) with gypsum on rice-wheat crops under saline-sodic condition (EC_e = 4.71 dS m^{-1}, SAR = 31.82, pH_s = 9.10). Different combinations of gypsum and humic acid tested were: T_1 - control, T_2 - gypsum @ 100 % GR, T_3 - gypsum @ 75 % GR+ HA @ 15 kg ha^{-1}, T_4 - gypsum @ 75 % GR+ HA @ 30 kg ha^{-1}, T_5 - gypsum @ 50 % GR+ HA @ 15 kg ha^{-1}, T_6 - gypsum @ 50 % GR+ HA @ 30 kg ha^{-1}. Yield data of each crop was documented at maturity. Results showed that growth and yield attributes increased significantly, and properties of saline-sodic field were ameliorated remarkably by the integrated use of HA and gypsum. The maximum plant height, 1000-grain weight, paddy and grain yield of rice and wheat crops were obtained where the gypsum+ humic acid were used @75 % GR+ HA @ 30 kg ha^{-1} followed by gypsum @ 100% GR while the chemicals properties of soil (pH_s, EC_e, SAR) were under the safe limits in both treatments. Gypsum @ 75 % GR+ humic acid @ 30 kg ha^{-1} reduced the pH_s (6.70%), EC_e (27.60%) and SAR (54.96%), hydraulic conductivity (9.75%), and bulk density (3.94%) over their initial values. Therefore, it was concluded that integrated use of gypsum @ 75% GR + humic acid @ 30 Kg ha^{-1} is equally effective as gypsum @ 100 % GR in improving the yield of wheat and rice crops and restoring the deteriorated properties of salt-affected soils.

Received | March 05, 2020; **Accepted** | August 18, 2020; **Published** | September 11, 2020
***Correspondence** | Khalil Ahmed, Soil Salinity Research Institute (SSRI), Pindi Bhattian, Pakistan; **Email:** khalilahmeduaf@gmail.com
Citation | Saqib, A.I., K. Ahmed, A.R. Naseem, G. Qadir, M.Q. Nawaz, M. Khalid, I.A. Warraich and M. Arif. 2020. Integrated use of humic acid and gypsum under saline-sodic conditions. *Pakistan Journal of Agricultural Research,* 33(3): 684-691.
DOI | http://dx.doi.org/10.17582/journal.pjar/2020/33.3.684.691
Keywords | Gypsum, Humic acid, Wheat, Rice, Amendments

Introduction

Among abiotic factors, salt stress is a universal constraint for sustainable agriculture production. To increase agriculture production, it is imperative to explore the potential of unproductive salt-affected soils by employing suitable remedial strategies. Removal of toxic Na^+ out of root zone through some suitable amendments like gypsum, sulfur, H_2SO_4 is a usual way to reclaim the sodic or saline-sodic soils. Gypsum being a direct source of Ca^{2+}, low price, and ease in handling, is the most used inorganic amendment. According to Hamza and Anderson (2003), gypsum effectively removes the exchangeable Na^+ and decreases the soil pH_s, EC_e and SAR. Integrated use of gypsum with some organic amendments like compost, farmyard manure, and poultry manure not only increased the solubility and the reclamation efficiency of gypsum but also improved the health of salt prone soils (Tajada et al., 2006; Singh et al., 2015). Gypsum application with humic substance and biochar enhanced the quality and yield of two quinoa genotypes and restored the health of salt prone soils (Alcivar et al., 2018).

Humic substances, may perform multiple roles in improving the soil health and nutritional status of salt-affected soils. Turhan (2019) evaluated the effect of humic acid @ 0, 1 and 2 g kg^{-1} of soil on physiological and yield components of cauliflower under the saline conditions (0.3, 4, 6, and 8 dS m^{-1}). They stated that the HA showed a positive effect on low to moderate salinity levels and 2 g of HA per kg of soil remarkably improved the yield and curd weight of cauliflower. Jamal et al. (2018) examined the performance of wheat crop to humic acid application (0 and 500 g ha^{-1}) in combination with phosphorus (control, 60, 90 and 150 kg ha^{-1}). They found that HA @ 500 g ha^{-1} with 60 and 90 kg P_2O_5 ha^{-1} positively influenced the yield of wheat crop while humic acid @ 500 g ha^{-1} with 90 kg P_2O_5 was an optimal dose for the maximum wheat yield and improving the soil properties. According to Manzoor et al. (2014), humic acid @ 2 kg ha^{-1} along with micronutrients like Cu and Zn significantly improved the yield components of wheat under saline conditions. Asik et al. (2009), applied the 0, 1 and 2 g of HA per kg of soil on the wheat crop grown at 15 as well as 60 mM salinity stresses. Twenty and thirty-five days after the seedling emergence, HA was also sprayed @ 0, 0.1 and 0.2 %. Results revealed that HA application in soil counteracted the negative effect of salinity, and improved the nitrogen uptake whereas foliar spray improved the uptake of Zn, K, and P. Similarly, in a field trial, Shaaban et al. (2013) applied the gypsum with FYM and HA in saline-sodic paddy field. They described that the gypsum alone or combined with FYM and HA remarkably improved the paddy yield and properties of salt-affected soils.

Humic acid not only showed the positive effects on yield of crops but also improved soil physical (moisture contents, aeration, aggregation) and chemical properties (pH_s, ion uptake etc.) (Khan et al., 2012). Hoda and Fatma (2016) evaluated the effect of HA (control, 800, 1600, and 2400 ml) on health of salt prone soils and fodder beet productivity. After two years of experimentation, they stated that O.M. content, cation exchange capacity, aggregates stability, hydraulic conductivity and available water content increased while bulk density decreased with applying the HA. They concluded that HA @ 2400 ml /400 L of water was the optimum dose for increasing the fodder beet productivity and improving the soil health under saline conditions. Khattak et al. (2013) added the HA @ 1.5 and 3.0 mg kg^{-1} in salt-affected soils and studied the chemical, physical and microbial activities. They reported that HA improved the moisture contents, microbial activity, enzymatic activities and cation exchange capacity.

Therefore, this study was planned to determine the best combination of HA and gypsum for the amelioration of saline-sodic soil and its impact on rice and wheat crops yield.

Materials and Methods

The present research work was investigated from 2015 to 2018 at Soil Salinity Research Institute, Pindi Bhattian, Pakistan. A field having EC_e (electrical conductivity of soil extract) = 4.71 dS m^{-1}, pH_s (pH of soil saturated past) = 9.10, SAR (sodium adsorption ratio)= 31.82, BD (bulk density) = 1.52 Mg m^{-3}, GR (gypsum requirement) = 7.31 t ha^{-1}, HC (hydraulic conductivity) = 0.41 cm hr^{-1} was selected. The treatments tested were: T_1 - control, T_2 - gypsum @ 100 % GR, T_3 - gypsum @ 75 % GR+ HA @ 15 kg ha^{-1}, T_4 - gypsum @ 75 % GR+ HA @ 30 kg ha^{-1}, T_5 - gypsum @ 50 % GR+ HA @ 15 kg ha^{-1}, T_6 - gypsum @ 50 % GR+ HA @ 30 kg ha^{-1}. The experimental design was RCBD with 3 repeats. Gypsum was applied thirty days before rice transplantation followed by irrigation to facilitate the leaching. While humic acid was applied 15 days before rice transplantation. Rice nursery (Shaheen Basmati) was transplanted in mid of July and the fertilizers dose of (150-90-60 NPK kg ha^{-1}) was applied. Agronomic and plant protection measures were employed uniformly. Yield and yield characteristics of rice were documented at the physical maturity of the crop. After the harvest of rice, in the same layout, wheat (Faisalabad 2008) was sown in November following the same methodology and treatments. The fertilizer dose @ 160-114-60 NPK kg ha^{-1} was applied. Yield and yield characteristics were documented at the harvest of crop. At the end of study, compositive soil samples were collected and analyzed for pH_s, EC_e, SAR, bulk density and hydraulic conductivity according to U.S. Salinity Laboratory Staff (1954). The collected crop data (rice and wheat) was statistically analyzed. The treatment mean comparison was made using the Least Significant Difference (LSD) Test @ 5% probability (Steel et al., 1997) using STATISTIX 8.1 package software.

Results and Discussion

Rice crop

Pooled data of rice crop depicted that humic acid and gypsum significantly influenced the growth characteristics of rice crop. However, at the similar, combined use of humic acid and gypsum had more positive effects than sole application of gypsum. Data concerning the plant height (Table 1) displayed that the highest plant height of 134.33 cm was observed with addition of gypsum @ 75 % GR + HA @ 30 kg ha^{-1} which was non-significant with gypsum @ 100% GR. Whereas, the lowest plant height of 119.67 cm was documented in control (T_1). Data about tillers m^{-2} and spikelet $panicle^{-1}$ showed that maximum number of tillers (230.67) and spikelet (215.67) were recorded with gypsum @ 75 % GR + HA @ 30 kg ha^{-1} followed by gypsum @ 100 % of GR and statistically both treatments were alike. On the other hand, minimum number of tillers (214.33) and number of spikelet (196.67) were observed where no amendments were used, the control (Table 1). Similarly, the highest 1000-grain weight (30.33 g) was divulged at gypsum @ 75 % GR + HA @ 30 kg ha^{-1} and gypsum @ 100 % of GR and both the treatments were at par (Table 2). While, control recorded the lowest grain weight (24.66 g). Data about paddy and straw yield showed that humic acid and gypsum in combination performed better than gypsum alone and the highest paddy (4.30 t ha^{-1}) and straw yield (9.96 t ha^{-1}) was documented in gypsum @ 75 % GR + HA @ 30 kg ha^{-1} followed by gypsum @ 100 % of GR and both treatments were insignificant from each other (Table 2). On the contrary, minimum paddy (2.35 t ha^{-1}) and straw yield (5.42 t ha^{-1}) were documented in control (T_1).

Wheat crop

Data about wheat crop exhibited that different levels of humic acid combined with gypsum significantly improved performance of wheat crop and HA @ 30 kg ha^{-1} when used with gypsum @ 75 % GR performed equally as gypsum alone @ 100 % GR in most of the studied parameters. Data in (Table 3) showed that taller plants (71 cm) were observed in gypsum @ 75% GR + HA @ 30 kg ha^{-1} statistically similar with gypsum @ 100% of GR. Data also showed that maximum grain $spike^{-1}$ (30.33), 1000-grain weight (33.33 g) and number of tillers (163.33), were obtained when HA @ 30 kg ha^{-1} was applied with gypsum @ 75 % of GR. However, these attributes were alike ($P \leq 0.05$) with gypsum @ 100 % of GR. Minimum number of tillers (132), 1000-grain weight (25.33 g), and grain per spike (24.66) were divulged in control. Maximum grain (3.96 t ha^{-1}) and straw (4.98 t ha^{-1}) yield were achieved with application of gypsum @ 75 % GR + HA @ 30 kg ha^{-1} statistically alike with gypsum @ 100 % of GR (Table 4). Whereas minimum grain (2.50 t ha^{-1}) and straw (3.23 t ha^{-1}) yield were recorded by control.

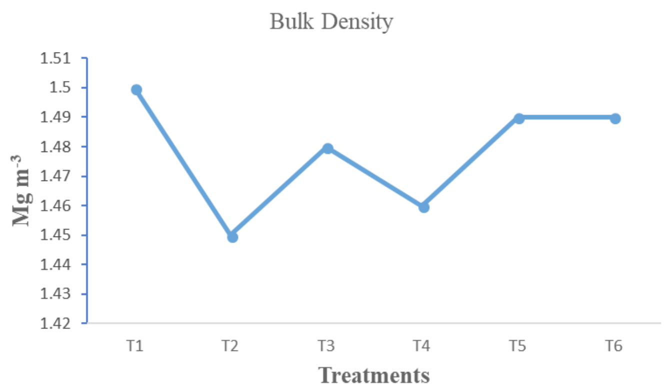

Figure 1: *Effect of humic acid and gypsum on bulk density (Mg m^{-3}) of soil at the end of study.*

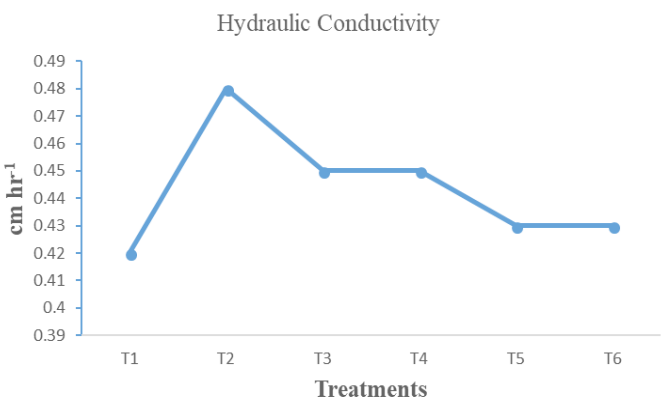

Figure 2: *Effect of humic acid and gypsum on hydraulic conductivity (cm hr^{-1}) of soil at the end of study.*

Soil properties

Soil analysis data indicated that HA and gypsum substantially improved the soil chemical and physical properties. At the end of study data regarding the EC_e revealed that maximum reduction of 30.78% over its initial value was noted with gypsum @ 100% of GR followed by gypsum @ 75 % of GR + HA @ 30 kg ha^{-1} with a reduction of 27.60% over its initial value (Table 5). With respect to soil pH_s maximum reduction (6.92%) was observed with gypsum @ 100% of GR followed

Table 1: *Effect of humic acid and gypsum on rice growth characters (average of three seasons).*

Treatments	Plant height (cm)	No. of spikelet panicle^{-1}	No. of tillers m^{-2}
T_1 Control	119.67 d	196.67 c	214.33 d
T_2 Gypsum @ 100% GR	132.00 a	213.33 a	229.67 a
T_3 Gypsum @ 75 % GR + HA @ 15 kg ha^{-1}	127.00 b	213.33 a	224.00 b
T_4 Gypsum @ 75 % GR + HA @ 30 kg h^{a}-1	134.33 a	215.67 a	230.67 a
T_5 Gypsum @ 50 % GR + HA @ 15kg ha^{-1}	125.33 bc	204.33 b	221.67 bc
T_6 Gypsum @ 50% GR + HA @ 30 kg ha^{-1}	123.67 c	200.00 bc	217.67 cd
LSD	2.8379	6.3948	4.5663

Table 2: *Effect of humic acid and gypsum on rice yield and yield components (average of three seasons).*

Treatments	Paddy yield (t ha^{-1})	Straw yield (t ha^{-1})	1000 grain weight (g)
T_1 Control	2.35 d	5.42 d	24.66 c
T_2 Gypsum @ 100% GR	4.25 a	9.84 a	30.33 a
T_3 Gypsum @ 75 % GR + HA @ 15 kg ha^{-1}	3.74 b	8.65 b	29.00 ab
T_4 Gypsum @ 75 % GR + HA @ 30 kg ha^{-1}	4.30 a	9.96 a	30.33 a
T_5 Gypsum @ 50 % GR + HA @ 15kg ha^{-1}	3.32 c	7.71 c	26.33 bc
T_6 Gypsum @ 50% GR + HA @ 30 kg ha^{-1}	3.79 b	8.77 b	25.00 c
LSD	0.3851	0.8868	2.8119

Table 3: *Effect of humic acid and gypsum on wheat growth characters (average of three seasons).*

Treatments	Plant height (cm)	No. of grain spike^{-1}	No. of tillers m^{-2}
T_1 Control	59.33 d	24.66 b	132.00 c
T_2 Gypsum @ 100% GR	69.33 ab	29.33 a	161.33 a
T_3 Gypsum @ 75 % GR + HA @ 15 kg ha^{-1}	67.33 b	29.00 a	161.00 a
T_4 Gypsum @ 75 % GR + HA @ 30 kg ha^{-1}	71.00 a	30.33 a	163.33 a
T_5 Gypsum @ 50 % GR + HA @ 15kg ha^{-1}	63.33 c	26.33 b	151.00 b
T_6 Gypsum @ 50% GR + HA @ 30 kg ha^{-1}	60.33 d	25.00 b	150.33 b
LSD	2.9460	2.6503	6.8313

Table 4: *Effect of humic acid and gypsum on wheat yield and yield components (average of three seasons).*

Treatments	Grain Yield (t ha^{-1})	Straw Yield (t ha^{-1})	1000 grain weight (g)
T_1 Control	2.50 e	3.23 e	25.33 c
T_2 Gypsum @ 100% GR	3.68 b	4.66 b	32.66 a
T_3 Gypsum @ 75 % GR + HA @ 15 kg ha^{-1}	3.34 c	4.26 c	28.66 b
T_4 Gypsum @ 75 % GR + HA @ 30 kg ha^{-1}	3.96 a	4.98 a	33.33 a
T_5 Gypsum @ 50 % GR + HA @ 15kg ha^{-1}	3.04 d	3.85 d	27.66 bc
T_6 Gypsum @ 50% GR + HA @ 30 kg ha^{-1}	3.31 c	4.18 c	26.66 bc
LSD	0.1458	0.3128	2.5657

Table 5: *Effect of humic acid and gypsum on soil chemical properties at the end of study.*

Treatments	EC_e	% decrease over initial value	pH_s	% decrease over initial value
T_1 Control	4.38	7.00	8.95	1.64
T_2 Gypsum @ 100% GR	3.26	30.78	8.47	6.92
T_3 Gypsum @ 75 % GR + HA @ 15 kg ha^{-1}	3.95	16.13	8.87	2.52
T_4 Gypsum @ 75 % GR + HA @ 30 kg ha^{-1}	3.41	27.60	8.49	6.70
T_5 Gypsum @ 50 % GR + HA @ 15kg ha^{-1}	4.03	14.43	8.86	2.63
T_6 Gypsum @ 50% GR + HA @ 30 kg ha^{-1}	3.96	15.92	8.83	2.96

Table 6: *Effect of humic acid and gypsum on soil chemical properties at the end of study.*

Treatments	SAR	% decrease over initial value
T_1 Control	26.73	15.99
T_2 Gypsum @ 100% GR	13.16	58.64
T_3 Gypsum @ 75 % GR + HA @ 15 kg ha^{-1}	22.3	29.91
T_4 Gypsum @ 75 % GR + HA @ 30 kg ha^{-1}	14.33	54.96
T_5 Gypsum @ 50 % GR + HA @ 15kg ha^{-1}	25.46	19.98
T_6 Gypsum @ 50% GR + HA @ 30 kg ha^{-1}	24.1	24.26

by gypsum @ 75 % of GR + HA @ 30 kg ha^{-1} with a reduction of 6.70% while minimum reduction (1.64%) was noted in control (Table 5). Similarly, soil sodicity indicator, the SAR was also significantly improved by the gypsum alone or combined with humic acid. Maximum reduction (58.64%) in soil SAR was recorded with gypsum @ 100% of GR followed by gypsum @ 75 % of GR + HA @ 30 kg ha^{-1} which reduces the SAR by 54.96% over its initial value. While minimum reduction (15.99%) was observed in control (Table 6). Gypsum @ 100% of GR and gypsum @ 75 % of GR + HA @ 30 kg ha^{-1} performed almost equally in improving the soil bulk density with a maximum reduction of 4.60% and 3.94% respectively over its initial value and on the other hand minimum reduction of 1.31% was documented in control (Figure 1). Soil hydraulic conductivity was also remarkably improved by gypsum alone or combined with humic acid. A maximum increase (17.07%) in hydraulic conductivity was documented where gypsum was incorporated @ 100% of soil GR, while gypsum @ 75 % of GR + HA @ 30 kg ha^{-1} increased the hydraulic conductivity by 9.75% over its initial value. On the contrary, a minimum increase of 2.43% was observed in control (Figure 2).

Use of inorganic (gypsum, calcium chloride, acids) and organic (humic substances, compost, press mud, organic manures) amendment is a very well established and effective technology for improving health of salt prone soils and crop productivity. Hence, the current study was planned to explore the effectiveness of integrative use of HA and gypsum for the reclamation of saline-sodic soil and crop production. Growth and yield attributes of both crops i.e. wheat and rice were influenced remarkably with the combination of humic acid and gypsum, however, gypsum @ 75% GR incorporated with HA @ 30 Kg ha^{-1} proved more superior over other treatments and performed equally as gypsum @ 100% GR. A plausible reason for improved growth and yield components may be that the soil properties are amended by addition of gypsum as it removed excessive Na^+ out of the root zone (Muhammad and Khattak, 2011) and accelerated the reclamation process (Abdel-Fattah, 2012) by leaching the soluble salts and decreasing the salinity as well as sodicity. It has also been stated by Ghafoor et al. (2008) that gypsum application in a paddy field under the submerged condition results in the removal of Na^+ which causes the lowering of SAR, EC_e and pH_s. In the present study, gypsum alone or with HA @ 30 Kg ha^{-1} also significantly reduced the SAR, pH_s, and EC_e, and all these values were under the safe limits as classified by US Salinity Laboratory Staff Parameters (1954). These results are strengthened by earlier findings of Ahmed et al. (2015) and Murtaza et al. (2017) that gypsum application-alone or with some organic amendments lowered the salinity and sodicity indices of soil. Therefore, lowered pH_s, EC_e, and SAR provided the favorable growth conditions and more yield was obtained in this treatment (gypsum @ 75% GR + humic acid @ 30 Kg ha^{-1}).

Deteriorated physical and chemicals properties of salt prone soils limit the water availability and nutrients uptake and a negative correlation occurs between plant growth and soil salinity indices (Rasouli et al., 2013). Present results clearly demonstrated that gypsum and HA application also significantly improved the physical properties e.g. the hydraulic conductivity and bulk density which may be primarily cause of increased yield of wheat and rice crops (Hanay et al., 2004).

Improved crop growth and soil properties by HA may be explained that HA retained more moisture, improved soil structure, microbial activities and increased the available plant nutrient contents (Ounia et al., 2104; Hua et al., 2008). Therefore, application of humic acid directly or indirectly exert the several encouraging effects on plant functions, and increased the photosynthesis, oxygen and phosphorus intake and respiration (Nardi et al., 2002; Pizzeghello et al., 2013). Under the condition of moderate salinity, HA application increased the fresh and dry weight of shoots/roots and lengths of the pepper plant (Çimrin et al., 2010) which is in agreement with our results. Humic substances increased the stress tolerance while acting as a growth regulator of plants (Çimrin et al., 2010). Application of organic matters and humic substances inactivate the soil Na, decreased soil pH and EC mainly due to supply of potassium, magnesium and calcium. High supplies of these minerals reduced the Na adsorption on exchange sites and increased its leaching (Lakhdar et al., 2009). Furthermore, humic acid immobilizes the organic matter (Oste et al., 2002), improved the nutrients uptake (Tahir et al., 2012), and increased the microbial activity (Wong et al., 2009). Hence all these factors might contribute to increased yield of rice and wheat crops.

Conclusions and Recommendations

Under salt stressed (saline-sodic) field conditions, addition of gypsum and HA remarkably improved the soil physical and chemicals properties. These amended soil properties produced the favorable growth conditions for stressed plants which was reflected by improved plant height, tillers m^{-2}. 1000-grain weight, paddy/grain and straw yield of rice and wheat crops. Consequently, the integrated use of gypsum @ 75% GR + humic acid @ 30 Kg ha^{-1}, is equally effective as gypsum @ 100 % GR in improving the yield of rice and wheat crops and to reclaim/restore the health of saline-sodic soils.

Author's Contribution

Amar Iqbal Saqib, conceived the idea, conducted the study for three years and wrote the article, Khalil Ahmed, and Ghulam Qadir, wrote abstract and materials and methods, Muhammad Qaisar Nawaz, Muhammad Khalid, and Muhammad Arif did data collection and statistical analysis, Abdul Rasul Naseem and Imtiaz Ahmad Warraich, provided technical Input at every step.

Conflict of interest

The authors have declared no conflict of interest.

References

Abdel-Fattah, M.K., 2012. Role of gypsum and compost in reclaiming saline-sodic soils. J. Agric. Vet. Sci., 1(3): 30-38. https://doi.org/10.9790/2380-0133038

Ahmed, K., G. Qadir, A.R. Jami, M.Q. Nawaz, A. Rehim, K. Jabran and M. Hussain. 2015. Gypsum and farm manure application with chiseling improve soil properties and performance of fodder beet under saline-sodic conditions. Int. J. Agric. Biol.,17(6): 1225-1230. https://doi.org/10.17957/IJAB/14.0036

Alcivar, M., Z.S. Andres, S. Marco, M. Cristina and S. Mauricio. 2018. Reclamation of saline–sodic soils with combined amendments: Impact on quinoa performance and biological soil quality. Sustainability, 10: 2-17. https://doi.org/10.3390/su10093083

Asik, B.B., M.A. Turan, H.C. Ali and A.V. Katak. 2009. Effect of humic substances on plant growth and mineral nutrients uptake of wheat (*Triticum durum* cv. Salihli). Under conditions of salinity. Asian J. Crop Sci., 1(2): 87-95. https://doi.org/10.3923/ajcs.2009.87.95

Çimrin, K.M., Ö. Türkmen, M. Turan and B. Tuncer. 2010. Phosphorus and humic acid application alleviate salinity stress of pepper seedling. Afr. J. Biotech., 9: 5845-5851.

Ghafoor, A., G. Murtaza, B. Ahmad and T.M. Boers. 2008. Evaluation of amelioration treatments and economic aspects of using saline-sodic water for rice and wheat production on salt-affected soils under arid land conditions. Irrig. Drain., 57: 424-434. https://doi.org/10.1002/ird.377

Hamza, M.A. and W.K. Anderson. 2003. Responses of soil properties and grain yields to deep ripping and gypsum application in a compacted loamy sand soil contrasted with a sandy clay loam soil in Western Australia. Aust. J. Agric. Res., 54: 273-282. https://doi.org/10.1071/AR02102

Hanay, A., B. Fatih, M. Fatih. Kızıloglu and Y.C. Mustafa. 2004. Reclamation of saline-sodic soils with gypsum and MSW compost. Compost Sci. Utiliz., 2: 175-179. https://doi.org/10.1080/1065657X.2004.10702177

Hoda, M.R.M. and S.H. Ismail. 2016. Effectiveness of humic acid application in improving saline soil properties and fodder beet production. J. Soil Sci. Agric. Eng. Mansoura Univ., 7(9): 623-634. https://doi.org/10.21608/jssae.2016.40333

Hua, Q.X., J.Y. Li, J.M. Zhou, H.Y. Wang, C.W. Du and X.Q. Chen. 2008. Enhancement of phosphorus solubility by humic substances in ferrosols. Pedosphere, 18: 533-538. https://doi.org/10.1016/S1002-0160(08)60044-2

Jamal, A., H. Iqrar, S.S. Muhammad, S. Muhammad and F. Muhammad. 2018. Investigating combination and individual impact of phosphorus and humic acid on yield of wheat and some soil properties. Turk. J. Agric. Natl. Sci., 5(4): 492-500. https://doi.org/10.30910/turkjans.471297

Khan, A., A.L.I.R. Gurmani, M.Z. Khan, F. Hussain, M.E. Akhtar and S. Khan. 2012. Effect of humic acid on the growth, yield, nutrient composition, photosynthetic pigment and total sugar contents of peas (*Pisum sativum* L.). J. Chem. Soc. Pak., 1: 1-7.

Khattak, R.A., K. Haroon and M. Dost. 2013. Mechanism(s) of humic acid induced beneficial effects in salt-affected soils. Sci. Res. Essays, 8(21): 932-939.

Lakhdar, A., M. Rabhi, T. Ghnaya, F. Montemurro, N. Jedidi and C. Abdelly. 2009. Effectiveness of compost use in salt-affected soil. J. Hazard. Mater., 171: 29-37. https://doi.org/10.1016/j.jhazmat.2009.05.132

Manzoor, A., R.A. Khattak, M. Dost. 2014. Humic acid and micronutrient effects on wheat yield and nutrients uptake in salt affected soils. Int. J. Agric. Biol., 16(5): 991-995.

Muhammad, D. and R.A. Khattak. 2011. Wheat yield and chemical composition as influenced by integrated use of gypsum, pressmud and FYM in saline-sodic soil. J. Chem. Soc. Pak., 33: 82-86.

Murtaza, B., G. Murtaza, M. Sabir, G. Owens, G. Abbas, M. Imran and G.M. Shah. 2017. Amelioration of saline–sodic soil with gypsum can increase yield and nitrogen use efficiency in rice–wheat cropping system. Arch. Agric. Soil Sci., 63(9): 1267-1280. https://doi.org/10.1080/03650340.2016.1276285

Nardi, S., D. Pizzeghello, A. Muscolo and A. Vianello. 2002. Physiological effects of humic substances on higher plants. Soil Biol. Biochem., 34: 1527-1536. https://doi.org/10.1016/S0038-0717(02)00174-8

Oste, L.A., E.J.M. Temminghoff and W.H.V. Riemsdijk. 2002. Solid-solution partitioning of organic matter in soils as influenced by an increase in pH or Ca concentration. Environ. Sci. Technol., 36: 208-214. https://doi.org/10.1021/es0100571

Ounia, Y., T. Ghnayaa, F. Montemurrob, C. Abdellya, A. Lakhdara. 2014. The role of humic substances in mitigating the harmful effects of soil salinity and improve plant productivity. Int. J. Plant Prod., 8(3): 353-374.

Pizzeghello, D., O. Francioso, A. Ertani, A. Muscolo, S. Nardi. 2013. Isopentenyladenosine and cytokinin-like activity of different humic substances. J. Geochem. Explor., 129: 70-75. https://doi.org/10.1016/j.gexplo.2012.10.007

Rasouli, F., P.A. Kiani and N. Karimian. 2013. Wheat yield and physicochemical properties of a sodic soil from semi-arid area of Iran as affected by applied gypsum. Geoderma, 193: 246-255. https://doi.org/10.1016/j.geoderma.2012.10.001

Shaaban, M., M. Abid and Abou-Shanab. 2013. Amelioration of salt affected soils in rice paddy system by application of organic and inorganic amendments. Plant Soil Environ., 59(5): 227-233. https://doi.org/10.17221/881/2012-PSE

Singh, N.J., H.S. Athokpam, K.N. Devi, N. Chongtham, N.B. Singh, P.T. Sharma. 2015. Effect of farmyard manure and press mud on fertility status of alkaline soil under maize-wheat cropping sequence. Afr. J. Agric. Res., 10(24): 2421-2431. https://doi.org/10.5897/AJAR2013.8233

Steel, R.G.D., J.H. Torrie and D.A. Dickey. 1997. Principles and procedures of statistic: A biometrical approach. 3rd edition, McGraw Hill book Co. Inc. New York. pp. 400-428.

Tahir, M.M., M. Khurshid, M.Z. Khan, M.K. Abbasi and M.H. Kazmi. 2012. Lignite-derived humic acid effect on growth of wheat plants in different soils. Pedosphere, 21: 124-131. https://doi.org/10.1016/S1002-0160(10)60087-2

Tajada, M., C. Garcia, J.L. Gonzalea, M.T. Hernadez. 2006. Use of organic amendments as a strategy for saline soil remediation: influence on the physical, chemical and biological properties of soil. Soil Bio. Biol., 6: 1413-1421. https://doi.org/10.1016/j.soilbio.2005.10.017

Turhan, A., 2019. The role of humic acid application in reducing detrimental effects of salt in cauliflower (*Brassica Oleraceae* L. Var. Botrytis). KSÜ Tarım ve Doğa Derg. 22(6): 837-842.

US Salinity Laboratory Staff. 1954. Diagnosis and improvement of saline and alkali soils. USDA Handbook 60, Washington, DC., USA.

Wong, V.N.L., R.C. Dalal and R.S.B. Greene. 2009. Carbon dynamics of sodic and saline soils following gypsum and organic material additions: a laboratory incubation. Appl. Soil. Ecol., 41: 29-40. https://doi.org/10.1016/j.apsoil.2008.08.006