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RESPONSE OF SALINE WATER IRRIGATION AND SOIL APPLICATION OF HA AND GLM ON GROWTH AND YIELD OF HYBRID MAIZE

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Abstract

Humic Acid (HA) is naturally occurring polyphenolic and polyhydroxy compounds formed during the decomposition of organic matter. Application of these humic acids to the crops influences the growth and yield as well as quality of crops. To meet out the various objectives of the study, a pot experiment was carried out. The experiment was conducted with eight treatments viz., T_1 : bore well water irrigation, T_2 : saline water irrigation, T_3 : HA @ 50 kg ha^{-1} + bore well water irrigation, T_4 : HA @ 50 kg ha^{-1} + saline water irrigation, T_5 : GLM @ 6.25ha^{-1} + bore well water irrigation, T_6 : GLM @ 6.25 t ha^{-1} + saline water irrigation, T_7 : HA @ 50 kg ha^{-1} + GLM @ 6.25 t ha^{-1} + bore well water irrigation T_8 : HA @ 50 kg ha^{-1} + GLM @ 6.25 t ha^{-1} + saline water irrigation in a Randomized Block Design (RBD) with three replications using maize hybrid HP 100 as a test crop. The HA extracted from Neyveli lignite was used for this experiment. The HA was applied as K-humate by dissolving calculated quantity of HA in 0.1 N KOH to the respective pots. Four plants in each pot were maintained. Growth and yield parameters of maize were recorded at appropriate stages of crop growth. The results of pot experiment clearly showed that the impact of salinity on maize due to saline water irrigation as well reduced in the presence of HA. This was clearly indicated that application of HA @ 50 kg ha^{-1} + GLM @ 6.25 t ha^{-1} to bore well water irrigated plants recorded the higher plant height, stem girth, leaf area index, plant water status, yield parameters, grain yield and stover yield as compared to saline water irrigated plants. It was on par with the treatment applied with 50 kg of HA ha^{-1} alone. Hence, it is concluded that, addition of HA @ 50kg ha^{-1} as soil application is recommended to maize to minimize the effect of salinity grown in saline water irrigation.

Key words: Humic acid (HA), green leaf manure (GL), Saline water

Introduction

Maize hybrid proline HP-100 is a high yielding hybrid with an average yield of 4 t ha^{-1}. The chromosome number of maize plant is n=10. It is an excellent Double Cross hybrid. The maturity period is 95-105 days. It is excellent seed setting crop with complete tip filling. It is suitable for both irrigated and rainfed cultivation and also suitable for both kharif and rabi season. Therefore, it is cultivated throughout the year (www.prolineseeds.com).

Abiotic stresses, such as drought, salinity, extreme temperatures, chemical toxicity and oxidative stress are serious threats to agriculture and the natural status of the environment. Salinity is one of the major environmental threats for agriculture and affects approximately 7% of the world's total land area (Imene Ben-Salah *et al*., 2011) nearly 40% of the world land surface can be categorized as suffering from potential salinity problem (Abd El-Kader, 2006). Salinity is one of the world's oldest and most widely distributed environmental challenges. Salinity is defined as the presence of excessive concentration of soluble salts in the soil which suppressed plant growth. In more specific definition soil with Electrical Conductivity (EC) of more than 4 dSm^{-1}, low Exchangeable Sodium Percentage (ESP) (<15%) and low pH (< 8.5). The main salt present in saline soil is NaCl. However, some other salts like Na_2SO_4, $MgSO_4$, $CaSO_4$, $MgCl_2$ and KCl are also present.

The deleterious effects of salinity on plant growth are associated with:

(1)Low osmotic potential of soil solution (water stress),

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(2) Nutritional imbalance,

(3) Specific ion effect (salt stress), or

(4) A combination of these above factors (Murat Turan, 2010).

Ionic effects of salinity include two primary effects on plants: direct toxicity due to excessive accumulation of toxic ions (Na^+, Cl^-) in the tissues and a nutritional imbalance caused by a reduction in some particularly essential ions (K^+, Ca^{2+}).

There are 397 Million ha. area of saline soil in the World as against 6.73 Million ha. in India. 25% of underground water resources in India are saline. Continuous use of such water for irrigation is bound to increase the problem of saline soil in years to come. India is estimated to have 11.7 Million ha. of soil will be affected by salinity in 2025.

Salinity is a major abiotic stress which affects the growth and productivity of a variety of crops all over the world (Abbasi *et al*., 2012). About 100 M ha of arable land worldwide is adversely affected by high salinity which ultimately decreases crop production (Ghassemi *et al*., 1995). High concentration of salts in the root zone reduces soil water potential resulted in reduction of the relative water content, dehydration at cellular level and osmotic stress. The stability of the membrane decreased under salinity because of membrane disorganization responsible for higher leakage of salts per ion from the leaves. It also caused swelling of membranes in chloroplasts of sensitive plants which affects their chlorophyll content.

There are huge potentials in this versatile crop, export potentials and variety of uses and application being some of them. It is right time to reclaim the salinity affected areas and produce higher yield by using hybrid seeds.

Humic acid is water soluble organic acid, naturally, presented in soil organic matter; it could be recognized that humic acid substances have many beneficial effects on soil structure and soil microbial populations as well as increase modify mechanisms involved in plant growth stimulation, cell permeability and nutrients uptake and increasing yield. Humic substances may possibly enhance the uptake of minerals through the stimulation of microbiological activity.

Humic substances have a very profound influence on the growth of plant roots. HA and FA are applied to the soil for enhancement of root initiation and increased root growth. Significant increase in maize vegetative growth characters and grain quality parameters due to HA application was reported. Application of HA @ 25 kg ha^{-1} is ideal to improve growth and quality of maize in similar environmental conditions (Ihsanullah Daur and Ahmed Bakhashwain, 2013). Increasing rate of HA increased the growth characters, yield characters and increased the percentage of protein.

Application of Humic substances showed beneficial effects on plant growth, mineral nutrient content, seed germination, seedling growth, root initiation, root growth, shoot development and the uptake of macro and microelements. It is widely believed that 1 kg of HA can substitute for 1 ton of manure (Tahir *et al*., 2011). Humic substances are shown to have abilities to counteract abiotic stress conditions e.g., un-favourable temperature, pH and salinity enhancing the uptake of nutrients and reducing the uptake of some toxic elements.

Materials and methods

A pot experiment was carried out to study the effect of HA on the performance of hybrid maize grown under saline water irrigation on the growth, yield and nutrient uptake by maize as well as nutrient status in post harvest soil. The experiment was conducted in RBD with the following eight treatments. T_1 – Bore well water irrigation, T_2 – Saline water irrigation, T_3 – HA @50 kg ha^{-1} + Bore well water irrigation, T_4 – HA @50 kg ha^{-1} + Saline water irrigation, T_5 – GLM @6.25 t ha^{-1} + Bore well water irrigation, T_6 – GLM @6.25 t ha^{-1} + Saline water irrigation, T_7 – HA @50 kg ha^{-1} + GLM @6.25 t ha^{-1} + Bore well water irrigation, T_8 – HA @50 kg ha^{-1} + GLM @6.25 t ha^{-1} + Saline water irrigation. Each treatment was replicated 3 times. 25 kg air dried, processed soil was filled in 1 × $1m^2$ cement pots. Calculated quantity of HA was dissolved in small quantity of KOH and the solution (pH ≈ 7) was diluted with deionised water and applied to the respective pots as K-humate.

A uniform NPK dose of 157:75:75 kg ha^{-1} was applied to all the pots through urea, super phosphate and muriate of potash. Full dose of P and K and half dose of N were applied as basal dose while the remaining half dose of N was applied fifty days after sowing. Maize hybrid HP 100 was grown as test crop. Four plants were maintained in each pot. Plants in two replications were allowed to grow up to maturity and one replication was harvested on 110 DAS and utilize for recording DMP. Utmost care was taken to maintain the crop free from pest and diseases. Pots were irrigated with saline water as per the treatments.

Life irrigation was given immediately after sowing of seeds as per the treatment schedule. Subsequent irrigation was given every evening till maturity. Gap filling

was done after emergence of seedlings on seven DAS. The seedlings were thinned on 10 DAS to maintain one healthy seedling per hole. Hand weeding and earthing up were done on 30 DAS. According to the treatments, plants of each pot in each replication were harvested on 110 DAS. The number of cobs were counted and then dried. The leaves as well as stalks were removed from the pot and dried for further analysis.

Results and Discussion

Effect of saline water irrigation and soil application of humic acid and green leaf manure on plant growth (Table 1)

The crop responded well for the soil application of humic acid (HA). Application of HA @ 50 kg ha^{-1} along with green leaf manure (GLM) @ 6.25 t ha^{-1} positively increased the plant height from 44.84 cm to 77.00 cm at 30 DAS, 148.90 cm to 212.44 cm at 60 DAS and 195.87 cm to 258.33 cm at harvest stage.

Among the two sources of irrigation, irrigation of bore well water was found to be better than saline water irrigation in all the stages. The combined application of HA @50 kg ha^{-1} and GLM @6.25 t ha^{-1} irrigated with bore well water (T_7) recorded the highest plant height of 77.00, 212.44 and 258.33 cm at 30 DAS, 60 DAS and harvest stage respectively as compared to the treatment which received HA @50 kg ha^{-1} + GLM @6.25 t ha^{-1} with saline water irrigation (T_8). The treatment which irrigated with saline water and normal RDF (T_2) was recorded lowest plant height on 44.84 cm, 148.90 cm and 195.87 cm at 30 DAS, 60 DAS and harvest stage respectively.

Effect of saline water irrigation and soil application of humic acid and green leaf manure on stem girth of maize (Table 2)

Soil application of HA @50 kg ha^{-1} and GLM @6.25 t ha^{-1} gradually increased the stem girth of maize in both bore well water and saline water irrigated plants. Bore well water irrigated plants (T_1) recorded largest stem girth as compared to saline water irrigated plants (T_2) at 3.11 cm (30 DAS) and 4.59 cm (60 DAS) respectively and 2.87 cm (30 DAS) and 4.3 cm (60 DAS).

Application of HA @50 kg ha^{-1} and GLM @6.25 t ha^{-1} to bore well water irrigated plants (T_7) recorded the largest stem girth of 5.23 cm at 30 DAS and 6.13 cm at 60 DAS respectively. This was followed by the treatment (T_3) which received 50 kg HA ha^{-1} to bore well water irrigation on 4.85 cm at 30 DAS and 5.54 cm at 60 DAS respectively. The plants which received the recommended dose of NPK to saline water irrigation (T_2) recorded the least stem girth at 30 DAS (2.87 cm) and 60 DAS (4.30 cm) respectively.

Effect of saline water irrigation and soil application of humic acid and green leaf manure on Leaf Area Index (LAI) of maize (Table 3)

A significant increase in LAI was observed due to the application of HA @50 kg ha^{-1}and GLM @6.25 t ha^{-1} either through bore well water irrigation or saline water irrigation. Among the various treatments, combined application of HA @50 kg ha^{-1} and GLM @6.25 t ha^{-1} with bore well water irrigation (T_7) recorded the highest LAI at 30 DAS (3.24) and 60 DAS (7.78) respectively.

Irrigation of maize with bore well water (T_1) registered higher LAI of 2.33 and 5.53 at 30 and 60 DAS as compared to saline water irrigated plants (T_2) which recorded the LAI of 2.16 and 5.11 at 30 and 60 DAS respectively. This was followed by treatment T_3, the plants received HA @50 kg ha^{-1} to bore well water irrigated plants recorded LAI of 3.09 and 7.26 at 30 and 60 DAS respectively, which was on par with treatment (T_8).

In the present study, application of HA and GLM improved the growth parameters such as plant height, stem girth, leaf area index and DMP of maize crop. Application of HA @ 50 kg ha^{-1} along with GLM @ 6.25 t ha^{-1} leads to 38.27 % increase in plant height, 45.77% in stem girth, 38.88% in leaf area

Table 1: Effect of saline water irrigation and soil application of HA and GLM on plant height (cm) at different stages of maize.

Treatments	30 DAS (cm)	60 DAS (cm)	AT HARVEST (cm)
T_1 – Bore well water irrigation	49.83	159.47	206.60
T_2 – Saline water irrigation	44.84	148.90	195.87
T_3 – HA 50 kg ha^{-1} + Bore well water irrigation	71.20	201.44	250.20
T_4 – HA 50 kg ha^{-1} + Saline water irrigation	60.67	183.33	229.43
T_5 – GLM 6.25 t ha^{-1} + Bore well water irrigation	69.53	192.21	237.23
T_6 – GLM 6.25 t ha^{-1} + Saline water irrigation	55.17	171.21	218.67
T_7 – HA 50 kg ha^{-1} + GLM 6.25 t ha^{-1} + Bore well water irrigation	77.00	212.44	258.33
T_8 – HA 50 kg ha^{-1} + GLM 6.25 t ha^{-1} + Saline water irrigation	70.43	198.08	244.33
SEd	1.55	1.79	3.28
CD(P=0.05)	3.33	3.84	7.04

index and 46.77 % in DMP.

The trend of increasing growth parameters with application of HA in maize was reported earlier by Gomaa *et al.,* (2014). It is due to the fact that application of HA stimulates plant growth by accelerating cell division, increasing the rate of development of root systems and increasing the yield of dry matter. Application of HA improves plant cell permeability enabling the plant cells to absorb more nutrients. These findings are in good harmony with the reports of Clapp *et al.,* (2002).

HA extracted from lignite contains many functional groups which could form complex with Na^+ and Cl^- ions and thus reducing the negative effects caused by salinity (Ouni *et al.,* 2014). Incorporation of GLM can favorably influence the biological, chemical and physical properties of soil and it also increase the soil microbial biomass and the mineralization of nitrogen (Singh, 1995; Lopez *et al.,* 2003).

Table 2: Effect of saline water irrigation and soil application of HA and GLM on stem girth (cm) at different stages of maize.

Treatments	30 DAS (cm)	60 DAS (cm)
T_1 – Bore well water irrigation	3.11	4.59
T_2 – Saline water irrigation	2.87	4.30
T_3 – HA 50 kg ha^{-1} + Bore well water irrigation	4.85	5.54
T_4 – HA 50 kg ha^{-1} + Saline water irrigation	3.98	5.07
T_5 – GLM 6.25 t ha^{-1} + Bore well water irrigation	4.17	5.27
T_6 – GLM 6.25 t ha^{-1} + Saline water irrigation	3.33	4.85
T_7 – HA 50 kg ha^{-1} + GLM 6.25 t ha^{-1} + Bore well water irrigation	5.23	6.13
T_8 – HA 50 kg ha^{-1} + GLM 6.25 t ha^{-1} + Saline water irrigation	4.73	5.45
SEd	0.07	0.04
CD(P=0.05)	0.15	0.10

Table 3: Effect of saline water irrigation and soil application of HA and GLM on LAI at different stages of maize.

Treatments	30 DAS (cm)	60 DAS (cm)
T_1 – Bore well water irrigation	2.33	5.53
T_2 – Saline water irrigation	2.16	5.11
T_3 – HA 50 kg ha^{-1} + Bore well water irrigation	3.09	7.26
T_4 – HA 50 kg ha^{-1} + Saline water irrigation	2.69	6.52
T_5 – GLM 6.25 t ha^{-1} + Bore well water irrigation	2.84	6.86
T_6 – GLM 6.25 t ha^{-1} + Saline water irrigation	2.51	6.00
T_7 – HA 50 kg ha^{-1} + GLM 6.25 t ha^{-1} + Bore well water irrigation	3.24	7.78
T_8 – HA 50 kg ha^{-1} + GLM 6.25 t ha^{-1} + Saline water irrigation	2.99	7.12
SEd	0.06	0.07
CD(P=0.05)	0.14	0.15

Effect of saline water irrigation and soil application of humic acid and green leaf manure on yield parameters of maize plant (Table 4)

Maize responded well for the addition of HA and GLM either through bore well water irrigation or saline water irrigation. The cob length, cob girth and 100 grain weight of maize was significantly increased with addition of HA and GLM in both bore well water irrigation and saline water irrigation. However, addition of HA @50 kg ha^{-1} and GLM @6.25 t ha^{-1} to bore well water irrigated plants (T_7) recorded highest cob length (18.77 cm), cob girth (21.27 cm), cob weight (57.50 g) and 100 grain weight (22.67 g) respectively which was followed by the treatment (T_3) which received HA @50 kg ha^{-1} with bore well water recorded the cob length (17.60 cm), cob girth (19.07 cm), cob weight (49.67 g) and 100 grain weight (21.30 g) respectively. This was found to be on par with T_8 (HA @50 kg $ha^{-1}$and GLM @6.25 t ha^{-1} with saline water irrigation.

The lowest cob length (13.43 cm), cob girth (10.90 cm), cob weight (33.67 g) and 100 grain weight (15.90 g) were noticed in T_2, saline water irrigated plants which had not received HA and GLM.

Effect of saline water irrigation and soil application of humic acid and green leaf manure on yield of maize (Table 5)

The grain yield (g pot^{-1}) and stover yield (g pot^{-1}) of maize was significantly influenced by the application of HA and GLM in both bore well and saline water irrigation.

Soil application of HA @50 kg ha^{-1} and GLM @ 6.25 t ha^{-1} which was irrigated with bore well and saline water significantly increased the yield of maize. Among the different treatments, application of HA @ 50 kg ha^{-1} and GLM @ 6.25 t ha^{-1} to bore well water irrigated plants (T_7) registered highest grain yield (548.07 g pot^{-1}) and stover yield (919.13 g pot^{-1}) and harvest index (37.16 %). This was closely followed by the treatment (T_3) which received 50 kg HA ha^{-1} with bore well water irrigated plants recorded the grain yield (503.85 g pot^{-1}), stover yield (863.25 g pot^{-1}) and harvest index (35.5 %).However, it was found to be on par with T_8 treatment which received soil application of HA @50 kg ha^{-1} and GLM @6.25 t ha^{-1} with saline water irrigation registered 489.31 g pot^{-1} of grain yield, 844.75 g pot^{-1} of stover yield and 35.16 %

Table 4: Effect of saline water irrigation and soil application of HA and GLM on yield parameters of maize.

Treatments	Yield parameters			
	Cob length(cm)	Cob girth(cm)	Cob weight(g)	100 grain weight(g)
T_1 – Bore well water irrigation	14.55	12.63	35.33	17.23
T_2 – Saline water irrigation	13.43	10.90	33.67	15.90
T_3 – HA 50 kg ha^{-1} + Bore well water irrigation	17.60	19.07	49.67	21.30
T_4 – HA 50 kg ha^{-1} + Saline water irrigation	16.03	15.71	42.35	19.20
T_5 – GLM 6.25 t ha^{-1} + Bore well water irrigation	16.23	16.78	46.67	19.77
T_6 – GLM 6.25 t ha^{-1} + Saline water irrigation	14.92	13.82	38.67	17.80
T_7 – HA 50 kg ha^{-1} + GLM 6.25 t ha^{-1} + Bore well water irrigation	18.77	21.27	57.50	22.67
T_8 – HA 50 kg ha^{-1} + GLM 6.25 t ha^{-1} + Saline water irrigation	17.37	18.76	48.96	21.03
SEd	0.51	0.49	0.65	0.58
CD(P=0.05)	1.10	1.05	1.39	1.25

Table 5: Effect of saline water irrigation and soil application of HA and GLM on yield of maize.

Treatments	Grain yield (g pot^{-1})	Stover yield (g pot^{-1})	Harvest index (%)
T_1 – Bore well water irrigation	348.15	645.97	32.23
T_2 – Saline water irrigation	304.75	574.64	30.40
T_3 – HA 50 kg ha^{-1} + Bore well water irrigation	503.85	863.25	35.50
T_4 – HA 50 kg ha^{-1} + Saline water irrigation	413.01	733.34	33.26
T_5 – GLM 6.25 t ha^{-1} + Bore well water irrigation	462.06	808.16	34.55
T_6 – GLM 6.25 t ha^{-1} + Saline water irrigation	383.79	683.74	32.77
T_7 – HA 50 kg ha^{-1} + GLM 6.25 t ha^{-1} + Bore well water irrigation548.07	919.13	37.25	
T_8 – HA 50 kg ha^{-1} + GLM 6.25 t ha^{-1} + Saline water irrigation	489.31	844.75	35.16
SEd	4.86	9.76	0.17
CD(P=0.05)	10.42	20.92	0.37

of harvest index respectively. The lowest grain yield (304.75 g pot^{-1}), stover yield (574.64 g pot^{-1}) and harvest index (30.4%) were observed in the plants which were irrigated with saline water only (T_2).

The result of the study clearly revealed that addition of HA @ 50 kg ha^{-1} + GLM @ 6.25 t ha^{-1} to bore well water irrigated plants registered maximum yield parameters such as length and girth of cob, weight of cob, 100 grain weight, grain yield and stover yield of maize crop.

Application of HA @ 50 kg $ha^{-1}$and GLM @ 6.25 t ha^{-1} with bore well water irrigation increase cob length, cob girth, cob weight, 100 grain weight and grain yield and stover yield when compare to saline water irrigated plants. The higher response of yield parameters to application of HA can be correlated with its intrinsic ability of undistinguished direct and indirect positive effect on plant growth. HA improves aggregation, aeration and permeability of soil as well as increases its water holding capacity. Apart from that HA enhances the availability of macro and micronutrients in soil to meet the demand of rapid growth of crops (Kaya *et al.,* 2005). HA enhances vitamins, amino acids and also auxin, cytokinin and abscisic acid contents of the plants (Vanitha and Mohandass, 2014). Similar findings were reported by Muhammad Ijaz *et al.,* (2015). The increase in grain yield with application of HA might be due to the fact that HA facilitates slow release of nutrient due to decomposition of residue for a longer time (Dev and Bhardwaj, 1995).

Addition of GLM @6.25 t ha^{-1} had positive increase in grain and stover yields of maize. This could be attributed to stimulating effect of applied GLM @6.25 t ha^{-1} due to continuous supply of nutrients especially nitrogen and micronutrients which induced meristematic activity, photosynthetic efficiency, regulation of water into cells, conductive physical environment leading to better aeration, root activity and nutrient absorption resulting in higher grain and stover yield. (Itnal and Palled, 2001). The plants irrigated with saline water indicated decreasing yield parameters and yield of maize. The decreased yield and yield parameters might be due to salinity stress caused swelling of membranes in chloroplasts of sensitive plants, which affects their chloroplast content (Ashraf and Bhathi, 2000) and photosynthetic production and lower

uptake and translocation of essential plant nutrients from source to sink.

Conclusion

The impact of salinity on maize due to saline water irrigation was well reduced in the presence of HA followed by GLM. Though application of HA @50 kg ha^{-1} in combination with GLM @6.25 t ha^{-1} recorded higher growth and yield in bore well water irrigation, application of HA + GLM to saline water irrigated plants also recorded the higher growth rate and yield. Therefore, addition of HA @50 kg ha^{-1} as soil application is recommended for maize crop to minimize the effect of salinity, the crop grown under saline water irrigation due to its comparable performance.

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