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Application of Gypsum for Amelioration of Salinity Stress in Sugar Beet

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Abstract

A pot experiment was conducted in the net house of the Department of Agronomy, Bangladesh Agricultural University, Mymensingh to find out the ameliorative effect of gypsum on yield of sugar beet (Beta vulgaris) grown under various levels of salinity stress. The experiment was conducted with two factors: five levels of salinity (0, 25, 50, 75 and 100 mM NaCl) and three levels of gypsum (0, 1 and 2 g gypsum kg^{-1} soil) in Randomized Complete Block Design with three replications. Observations were made on beet yield and different plant characters e.g. plant weight (t ha^{-1}), plant height (cm), leaf weight (t ha^{-1}), leaf length (cm), beet length (cm), beet girth (cm) and beet yield (t ha^{-1}). Salinity level had significant effect on all the parameters. All the parameters decreased with increasing salinity levels. Different rates of gypsum had significant effect on most of the parameters except leaf

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weight. The highest plant weight (28.69 t ha^{-1}), plant height (58.42 cm), beet length (22.18 cm), beet girth (12.33 cm) and beet yield (12.20 t ha^{-1}) were obtained from 1g gypsum kg^{-1} soil. The highest leaf length (36.39 cm) was found at 2 g gypsum kg^{-1} soil. The lowest plant weight (24.88 t ha^{-1}), plant height (55.05 cm), leaf length (34.43 cm), beet length (20.62 cm), beet girth (10.59 cm) and beet yield (9.24 t ha^{-1}) were obtained from control condition. Interaction between levels of salinity and gypsum had significant effect in respect of plant height, leaf weight, leaf length and beet yield. The highest plant height (68.30 cm) and beet yield (20.50 t ha^{-1}) were obtained in no salinity condition with 1g gypsum kg^{-1} soil. The highest leaf weight (22.14 t ha^{-1}) was found in control i.e. without salinity and gypsum application. The longest leaf (41.30 cm) was obtained in no salinity condition with 2 g gypsum kg^{-1} soil. The lowest plant height (42.57 cm), leaf weight (9.48 t ha^{-1}), leaf length (27.90 cm) and beet yield (4.56 t ha^{-1}) were obtained from NaCl 100 mM and no application of gypsum. The results of the study indicate that salinity stress in sugar beet could successfully be ameliorated through application of gypsum @ 1 g kg^{-1} soil.

Keywords: Gypsum, Salinity Stress, Sugar Beet, Bangladesh

INTRODUCTION

In South and South-Western part of Bangladesh, salinity coupled with climatic conditions plays a significant deleterious effect in crop agriculture. Crop yields, cropping intensity, production levels, and people's quality of livelihood are much lower in this region than in other parts of the country. The coastal region covers almost 29,000 sq. km or about 20% of the country which occupies more than 30% of total cultivable lands of our country. About 53% of the coastal areas are affected by salinity (Rasel *et al.*, 2013). Even though gross and net-cropped area in the coastal zone of Bangladesh is 144,085 and 83,416 hectors respectively (Islam, 2004). However, net-cropped area of coastal zone has been showing a decreasing trend over the years due to climate change effect. Coastal agri-lands often suffered from saline intrusion that prevented crop production in dry season (Gowing *et al.*, 2006). Salinity intrusion as the most pressing problem for yield reduction in coastal agri-culture (CCC, 2007). The study found that 830,000 million hectares of land at coastal Bangladesh were affected by soil salinity at different degrees.

Farmers of this region mostly grow low-yielding, traditional rice varieties during the wet season. Most of the lands remain fallow in the dry season (January–May) because of soil salinity and the lack of good-quality irrigation water (Karim *et al.*, 1990; Mondal, 1997). Irrigated water demand is highly affected by salinity intrusion in surface water (Shahid, 2010) and salt accumulation in the root zone of soil affects plant growth in coastal soil (Yadav et al., 2009).

The reclamation of saline soil can be an effective method to minimize the adverse effect of salinity. This process involves replacing the sodium ions with more favorable calcium ions. The permanent reclamation of the saline soils in Bangladesh is difficult and complex due to frequent inundation and tidal flooding. Many attempts have been undertaken to counteract the adverse effects of salinity stress by using chemical amendments. However, gypsum is the most used agricultural amendment for the alleviation of salinity stress. It's a very cheap, available, and good source of Ca^{2+}. It replaces the Na^{+} ion of soil. Ameliorative effect of gypsum application is reported in saline soil as well as in sodic soil (Khattak *et. al.,* 2007; Singh et al., 2008; Singh et al., 2009). Siam *et al.,* 2014 found that combined application of green manure @10t/ha and gypsum @1g per kg soil ameliorated salinity stress in transplant Aman rice. Keeping this in view the present study was undertaken to investigate whether the addition of gypsum could ameliorate the adverse effects of NaCl stress on sugar beet.

Sugar beet (*Beta vulgaris* L.) is a temperate climate biennial root crop, which ranks second (45%) next to sugarcane in terms of world's sugar production. It is a crop cultivated to produce sugar and potentially, for the production of energy, bioethanol (Rinaldi and Vonella, 2006). Tropical sugar beet has now emerged as commercial field crop because of the favorable characters like (i) shorter duration of 5 to 6 months (ii) moderate water requirement of 80–100cm. (iii) higher sugar content of 12 to15% (iv) improvement of soil conditions because of tuber crop and (v) suitability for saline and alkali soil. In addition to these benefits, its industrial residues have multiple uses (Camas and Esendal, 1999). The biproducts of sugar beet *viz.,* beet top can be used as green fodder, while beet pulp and filter cake from industry can be used as cattle feed.

Tropical sugar beet is introduced in Bangladesh by Syngenta Seeds, one of the world's leading seed companies. Newly introduced tropical Sugar beet can offer a valuable alternative to sugarcane in Bangladesh. Sugarcane production area has declined every year due to its longer life cycle, higher production cost and less profit. Compared to sugarcane, this tropical sugar beet can be grown in relatively dry areas with substantially less water. It is faster growing and can be harvested after five months allowing farmers to grow a second crop on the same land. Further, as the harvesting period of sugar beet coincides with the period from March to June, the human resource of sugar factory in the off season could be efficiently utilized in the processing of sugar beet in the sugar mills, which facilitates in continuous functioning of the sugar mills.

Most importantly tropical sugar beet is a highly saline and drought tolerant crop. Therefore, cultivation of tropical sugar beet might be a very good alternative crop for drought prone *Barind* area and salinity prone coastal area of Bangladesh. Considering the above facts, the present research work was undertaken to observe the effect of different salinity levels on yield performance of sugar beet and investigate the effect of gypsum to ameliorate salinity stress effect in sugar beet.

MATERIALS AND METHODS

To monitor the ameliorative effects of gypsum on sugar beet under salinity stress, the experiment was conducted in the net house of the Department of Agronomy, Bangladesh Agricultural University, Mymensingh, during the period from November, 2012 to April, 2013 using gypsum 0, 1 and 2 g gypsum kg-1 soil to ameliorate salinity stress level 0, 25, 50, 75, 100 nM NaCl in tropical sugar beet variety 'Cauvery' developed by the international seed company "Syngenta". The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. The total number of pots was 45 (5 x 3 x 3). Considerable spacing was maintained among pots for convenience of cultural operations. The soils of pot experiment were collected from the field of Agronomy Field Laboratory at 0-15 cm depth. After collecting the soil, it was sun dried and ground well. Plant propagules, inert matter, visible insects, and pests were removed from the soil. The dry soil was thoroughly mixed with well rotten cow dung in a proportion of 2:1 by weight. This prepared soil was used in filling the pots. Each of the pots of the experiment was filled with 7 kg of soil. In each pot full doses of chemical fertilizers viz. urea (@ 1.2 g/pot), triple super phosphate (@ 0.49 g/pot) and muriate of potash (@ 1.1 g/pot) were applied to each individual pot Commercial salt (NaCl) was used for developing salinity. For treatments S1, S2, S3 and S4; 15g, 30g, 45g and 60g of salts, respectively were added in the respective pots. These amounts of salts were dissolved in water and the solutions were then poured uniformly into the pots after establishing the plants. For treatments G 1 and G 2; 7g and 14g gypsum were applied after giving NaCl solutions. One seed was placed in each hill at about 2 cm depth on 12 November 2012. Some seeds were also sown in other pots for necessary gap filling. The plant of each experimental pot was harvested separately at full maturity on 17 April 2013. After harvesting, plants were washed and cleaned properly, and data was carefully collected on yield and yield contributing characters. The data was statistically analyzed according to Gomez and Gomez (1984). Least significant difference (LSD) was used for mean companions.

FINDINGS AND DISCUSSIONS

Plant characters and yield of sugar beet var. Cauvery as affected by salinity stress

The effect of salinity stress on yield and yield components viz. plant height (cm), plant weight (t ha-1), leaf weight (t ha-1), leaf length (cm), beet length(cm), beet girth (cm) and beet yield (t ha-1) of Tropical sugar beet var. Cauvery was statistically significant (Table 1). The highest plant height(67.18 cm), plant weight (37.99 t/ha), Leaf length (41.00 cm), leaf weight (20.03t/ha), beet length (26.14 cm) and beet yield (17.96 t/ha) were observed at non saline condition. All parameters plant height (48.24 cm), plant weight (17.49 t/ha), Leaf length (31.77 cm), leaf weight (11.40t/ha), beet length (16.48 cm), beet girth (8.86cm) and beet yield (6.09 t/ha) showed lowest result at S4 treatment (salinity @NaCl 100mM). So, the salinity stress @ 25mM, 50mM, 75mM and 100mM had significant negative impact on sugar beet. The above stated results revealed that plant characters and yield of sugar beet decreased with increasing salinity level, which might be due to higher uptake of sodium. Salinity level had significant effect on all of the parameters. This result is in conformal with the previous results of Jamil et al. (2007), Dadkhah (2011), Bybordi (2010) and Mostafavi (2012).

Table Error! No text of specified style in document. Effect of salinity on the yield and yield components of sugar beet var. Cauvery

Levels of salinity stress	Plant Height (cm)	Plant Weight (t ha^{-1})	Leaf Weight (t ha^{-1})	Leaf Length (cm)	Beet Length (cm)	Beet Girth (cm)	Beet Yield (t ha^{-1})
S_0	67.18a	37.99a	20.03a	41.00a	26.14a	14.73a	17.96a
S_1	59.19b	30.27b	18.24b	36.10b	23.09b	12.41b	12.03b
S_2	56.30c	25.65c	16.10c	34.61c	21.69c	11.39c	9.55c
S_3	53.99d	21.76d	14.12d	34.92c	19.07d	9.99d	7.64d
S_4	48.24e	17.49e	11.40e	31.77d	16.48e	8.856e	6.09e
Level of significance	**	**	**	**	**	**	**
LSD (0.05)	1.498	2.097	1.260	1.124	1.238	0.795	0.604
CV (%)	5.82	3.81	8.17	3.26	6.02	7.17	5.87

Note. In a column, figures with same letter(s) or without letter do not differ significantly whereas figures with dissimilar letters differ significantly as per DMRT level.
S_0 = No salinity; S_1 = Salinity @ NaCl 25 mM; S_2 = Salinity @ NaCl 50 mM
S_3 = Salinity @ NaCl 75 mM; S_4 = Salinity @ NaCl 100 mM.
** = Significant at 1% level of probability

Effect of gypsum on the yield and yield contributing characters of sugar beet var. Cauvery

The results revealed that different rate of gypsum application exerted significant influence on the yield and yield contributing characters except leaf weight of sugar beet var. Cauvery. Highest plant height (58.42 cm), Plant Weight (28.69 t/ha), Leaf length (36.22cm), Beet length (22.18 cm), Beet girth (12.33cm) and Beet yield (12.20 t/ha) were performed at 1g gypsum application at per kg soil. But lowest data for the parameters plant height (55.05 cm), Plant Weight (24.88 t/ha), Leaf length (34.43cm), Beet girth (10.59cm) and Beet yield (9.24 t/ha) were recorded at G_0 treatment (no gypsum application).On contrary, plant weight (26.33 t/ha), beet length (21.08cm), beet girth (11.51cm) and beet yield (10.54t/ha) were reduced when 2g gypsum per kg soil was applied. Only plant height (57.47cm) and leaf length

(36.39cm) at application of 2 g gypsum per kg soil were statistically similar to the treatment of 2g gypsum per kg soil. This statement also supports the previous results of Mathad and Hiremath (2010), Jaleel *et al.* (2008) and Samaraweera *et al.* (1994).

Table 2. Effect of gypsum on the yield and yield components of sugar beet var. Cauvery

Levels of gypsum	Plant Height (cm)	Plant Weight (t ha^{-1})	Leaf Weight (t ha^{-1})	Leaf Length (cm)	Beet Length (cm)	Beet Girth (cm)	Beet Yield (t ha^{-1})
G_0	55.05b	24.88c	15.65	34.43b	20.62b	10.59c	9.24c
G_1	58.42a	28.69a	16.49	36.22a	22.18a	12.33a	12.20a
G_2	57.47a	26.33b	15.79	36.39a	21.08b	11.51b	10.54b
Level of significance	**	**	NS	**	**	**	**
LSD (0.05)	1.624	1.160	0.976	0.871	0.959	0.616	0.468
CV (%)	3.81	5.82	8.17	3.26	6.02	7.17	5.87

Note. In a column, figures with same letter(s) or without letter do not differ significantly whereas figures with dissimilar letters differ significantly as per DMRT level.
G_0 = No gypsum; G_1 = 1g gypsum kg^{-1} soil; G_2 = 2g gypsum kg^{-1} soil
** = Significant at 1% level of probability
NS = Nonsignificant

Interaction effect of salinity and gypsum application on the yield and yield components of sugar beet

As evident in table 3, the interaction between levels of salinity and gypsum had significant effect in respect of plant height, leaf weight, leaf length and Beet yield. Interaction effect between salinity level and gypsum application on plant weight, beet length and beet girth were found not significant. The highest plant height (68.30 cm) and the highest beet yield (20.50 t ha-1) were obtained in control salinity condition with 1g gypsum kg-1 soil. The highest leaf weight (22.14 t ha-1) was found in control and the longest leaf (41.30 cm) was measured in control salinity condition with 2g gypsum kg-1 soil. The lowest plant height (42.57 cm), the lowest leaf weight (9.48 t ha-1), the shortest leaf (27.90 cm) and the lowest beet yield (4.56 t ha-1) were obtained from the interaction of NaCl 100 mM salinity level with control gypsum treatment. The study revealed that the application of gypsum could alleviate the adverse effects of salinity and increase the tolerance of sugar beet to salinity.

Table 3. Interaction effect of salinity and gypsum application on the yield and yield components of sugar beet var. Cauvery

Interaction (S x G)	Plant Height (cm)	Plant Weight (t ha^{-1})	Leaf Weight (t ha^{-1})	Leaf Length (cm)	Beet Length (cm)	Beet Girth (cm)	Beet Yield (t ha^{-1})
S_0G_0	67.23a	38.13	22.14a	40.70a	26.53	13.17	15.99c
S_0G_1	68.30a	40.22	19.72b	41.00a	27.20	16.20	20.50a
S_0G_2	66.00a	35.63	18.23bc	41.30a	24.70	14.83	17.40b
S_1G_0	57.40cd	28.94	18.47bc	35.00c	22.40	11.80	10.47f
S_1G_1	61.23b	31.70	17.68bc	37.43b	23.80	13.47	14.01d
S_1G_2	58.93bc	30.17	18.56bc	35.87bc	23.07	11.97	11.61e
S_2G_0	55.47cde	23.54	14.82de	34.40cd	21.07	10.77	8.73gh
S_2G_1	56.83cd	27.41	16.99cd	34.60cd	22.23	11.80	10.42f
S_2G_2	56.60cd	26.00	16.49cd	34.83cd	21.77	11.60	9.51fg
S_3G_0	52.57ef	19.82	13.39ef	34.13cd	18.43	9.13	6.43j
S_3G_1	54.63def	23.78	15.01de	35.07c	19.57	10.53	8.77g
S_3G_2	54.77de	21.69	13.97e	35.57bc	19.20	10.30	7.72hi
S_4G_0	42.57g	13.99	9.43g	27.90e	14.67	8.07	4.56k
S_4G_1	51.10f	20.33	13.06ef	33.00d	18.10	9.67	7.27ij
S_4G_2	51.07f	18.16	11.73f	34.40cd	16.67	8.83	6.43j
Level of significance	*	NS	**	**	NS	NS	*
LSD (0.05)	3.632	2.595	2.183	1.947	2.144	1.377	1.046
CV (%)	3.81	5.82	8.17	3.26	6.02	7.17	5.87

Note. In a column figures with same letter(s) or without letter do not differ significantly whereas figures with dissimilar letters differ significantly as per DMRT level.
S_0 = No salinity, S_1 = Salinity @ NaCl 25 mM, S_2 = Salinity @ NaCl 50 mM, S_3 = Salinity @ NaCl 75 mM, S_4 = Salinity @ NaCl 100 mM
G_0 = No gypsum, G_1 = 1g gypsum kg^{-1} soil, G_2 = 2g gypsum kg^{-1} soil
* = Significant at 5% level of probability
** = Significant at 1% level of probability
NS = Nonsignificant

Ameliorative effect of gypsum under salinity stress on the yield of sugar beet var. Cauvery

Percentage of beet yield reduction or increase as compared to control has been presented in Table 4. In control (S_0G_0) condition where no salinity was imposed and no gypsum was given, beet yield of sugar beet was obtained 15.99 t ha^{-1}. But beet yield (20.50 t ha^{-1}) increased by 28.21% when 1g gypsum kg^{-1} soil was applied. However, application of 2g gypsum kg^{-1} soil increased beet yield (17.40 t ha^{-1}) only by 8.82% as compared to control but lower than that of 1g gypsum kg^{-1} soil.

As compared to control (no salinity stress) beet yield decreased by 34.52%, 45.40%, 59.79% and 71.48% at salinity levels of 25, 50, 75 and 100 mM NaCl, respectively when gypsum was not given. The application of gypsum @ 1g kg^{-1} soil could minimize the reduction of beet yield to 12.38%, 34.83%, 45.15% and 54.53% against 34.52%, 45.40%, 59.79% and 71.48%, respectively. However, application of gypsum at higher dose such as 2g gypsum kg^{-1} soil was not as effective as 1g gypsum kg^{-1} soil in ameliorating salinity stress.

The results of the present study indicate that beet yield reduction was observed due to salinity increases, but application of gypsum ameliorated salinity stress of sugar beet var. Cauvery in terms of beet yield as well as different yield parameters.

Table 4. Ameliorative effect of gypsum under salinity stress on the yield of sugar beet var. Cauvery

Treatment	Beet Yield (t ha^{-1})	% beet yield reduction/increase as compared to control
S_0G_0	15.99	-
S_0G_1	20.5	28.21
S_0G_2	17.4	8.82
S_1G_0	10.47	-34.52
S_1G_1	14.01	-12.38
S_1G_2	11.61	-27.39
S_2G_0	8.73	-45.40
S_2G_1	10.42	-34.83
S_2G_2	9.51	-40.53
S_3G_0	6.43	-59.79
S_3G_1	8.77	-45.15
S_3G_2	7.72	-51.72
S_4G_0	4.56	-71.48
S_4G_1	7.27	-54.53
S_4G_2	6.43	-59.79

Note. S_0 = No salinity, S_1 = Salinity @ NaCl 25 mM, S_2 = Salinity @ NaCl 50 mM, S_3 = Salinity @ NaCl 75 mM, S_4 = Salinity @ NaCl 100 mM
G_0 = No gypsum, G_1 = 1g gypsum kg^{-1} soil, G_2 = 2g gypsum kg^{-1} soil

CONCLUSION & RECOMMENDATIONS

This study implies that the yield and yield contributing characters of sugar beet were affected by salinity and application of gypsum was effective in ameliorating salinity stress. The tolerance level of sugar beet increased due to gypsum application under salinity stress. The result of the study concludes that salinity stress in sugar beet could successfully be ameliorated through application of gypsum @ 1 g kg^{-1} soil which increased the beet yield by 28.21%. To validate the result, however, similar experiment needs to be conducted under natural occurrence of salinity stress.

REFERENCES

1. Bybordi, A. 2010. The Influence of Salt Stress on Seed Germination, Growth and Yield of Canola Cultivars. Not. Bot. Hort. Agrobot. Cluj. 38 (1): 128-133.
2. Camas, N. and Esendal, E. 1999. Effects of planting times and seedling transplanting on sugarbeet (*Beta vulgaris* L.) cultivars. OMU J. Agric. 14: 31-42.
3. CCC (Climate Change Cell). 2007. Climate Change and Bangladesh. Department of Environment, Government of the People's Republic of Bangladesh, Dhaka.
4. Dadkhah, A. 2011. Effect of Salinity on Growth and Leaf Photosynthesis of Two Sugar Beet (*Beta vulgaris* L.) Cultivars. J. Agr. Sci. Tech. 13: 1001-1012.
5. Gomez, K. A. and Gomez, A. A. 1984. Statistical Procedure for Agricultural Research. 2^{nd} Edn. John Wiley and Sons, New York. pp. 97-411.
6. Gowing, J.W., Tuong, T.P. and Hoanh, C.T. 2006. Land and Water Management in Coastal Zones: Dealing with Agriculture-Aquaculture-Fishery Conflicts. Environmental Livelihoods in Tropical Coastal Zones: Managing Agriculture-Fishery-Aquaculture Conflicts.
7. Islam, M.R. 2004. Where Land Meets the Sea: A Profile of the Coastal Zone of Bangladesh. The University Press Limited, Dhaka.
8. Jaleel, C.A., Sanker, B., Sridharan, R. and Panneerselvum, R. 2008. Soil salinity alters growth, chlorophyll content and secondary metabolite accumulation in Cathranthus roseus. Turk. J. Biol. 32: 79-83.
9. Jamil, M., Rehman, S. and Rha, E.S. 2007. Salinity effect on plant growth, psii photochemistry and chlorophyll content in sugar beet (*Beta vulgaris* L.) and cabbage (*Brassica oleracea capitata* L.). Pak. J. Bot. 39(3): 753-760.
10. Karim, Z., Hussain, S.G. and Ahmed, M. 1990. Salinity Problems and Crop Intensification in the Coastal Regions of Bangladesh. Soils Publication No. 33, Soils and Irrigation Division, BARC, Farmgate, Dhaka, Bangladesh. pp. 1–20.
11. Khattak, S. G., A. Izhar, M. J. Khattak and Navedullah. 2007. Effect of Various levels of gypsum application on the reclamation of salt affected soil. Pakistan. J. Sharhad Agric 23(3):675-680
12. Mathad, P. and Hiremath, S. 2010. Alleviation of Saline Stress by Gypsum in *Chlorella vulgaris* BEIJERINCK. J. Algal Biomass Utln. 1 (3): 43 – 53.
13. Mondal, M.K. 1997. Management of soil and water resources for higher productivity of the coastal saline rice lands of Bangladesh. PhD thesis. University of the Philippines, Los Baños, Philippines. pp. 18-120.
14. Mostafavi, K. 2012. Effect of Salt Stress on Germination and Early Seedling Growth Stage of Sugar Beet Cultivars. American-Eurasian J. of Sust. Agric. 6(2): 120-125.
15. Rasel H. M., Hasan, M. R., Ahmed B., and Miah., M. S. U., 2013 Investigation of soil and water salinity, its effect on crop production and adaptation strategy. International Journal of Water Resources and Environmental Engineering. Vol.5(8), pp 475-476
16. Samaraweera, M.K.S.A., Bell, R.W., Beaton, S.A., Kanabo, L. and Ho, G. 1994. Role of gypsum in revegetation of saline gold ore refining residues. Proc XVth International Society of Soil Science Congress, Mexico.

17. Shahid, S. 2010. Impact of climate change on irrigation water demand of dry season Boro rice in northwest Bangladesh. Climatic Change. 105:433–453.
18. Siam, M. Z., Hossain, S. S., Hassan A.K., and Kader, M. A., 2014. Amelioration of Salinity Stress on Transplant Aman Rice Through Green Manure and Gypsum. *Bangladesh Agron. J.* 2014, 17(1): 8-10
19. Singh, Y. P., R. Singh and, D. K. Sharma. 2009. Combined effect of reduced dose of gypsum and salt tolerant varieties of rice (*oryza sativa)*. Indian J. Agron. 54(1):24-28
20. Singh, Y. P., R. Singh and, N. Kumar. 2008. Responses of rice (*oryza sativa) to* gypsum rates in sodic soils, Indian J. Agric Res. 78(4):362-365
21. Rinaldi, M. and Vonella, A.V. 2006. The response of autumn and spring sown sugar beet (*Beta vulgaris* L.) to irrigation in Southern Italy: Water and radiation use efficiency. Field Crops Res. 95: 103-114.
22. Yadav, J. S. P., Sen, H.S. and Bandyopadhyay, B.K. 2009. Coastal soils-management for higher agricultural productivity and livelihood security with special reference to India. J. of Soil Salinity & Water Quality. 1(1-2): 1-13.