EBAUB Journal Volume 2 January 2020

EBAUB Journal

ISSN: 2617 - 8338

An Academic Journal of
EXIM Bank Agricultural University Bangladesh

Mitigation of Salinity Effect in Dry Matter Distribution of Two Soybean Genotype (*Glycine max* L.) by Applying Different Level of Potassium

Uswatun Hasana Hashi*

Department of Agronomy, EXIM Bank Agricultural University Bangladesh

ARTICLE INFO

Received date: August 01, 2019
Accepted date: Nov. 12, 2019

ABSTRACT

An experiment in field was conducted to determine the dry matter distribution of two soybean genotype (one is suitable for genetic improvement and another one is resistant to salinity) in root, stem, leaves, shoot, total day matter partitioning were done by applying different doses of potassium and soybean may be mitigate the salinity stress. The percent reduction in stem dry weight (DW) due to salinity was more in Galarsum than Bangladesh soybean 4 when salinity increased from S_2(7.5 dS/m) to S_1 (5.0 dS/m) under K_2 (double to the RD i.e.119.52 kg/ha) and K_3 (triple to the RD i.e.179.28 kg/ha) potassium treatments. Moreover, the positive effect of K on the production of relative stem DW under different level of salinity was more clear in Bangladesh soybean 4 than that of Galarsum. The relative leaf DW production of Galarsum at S_1 (5.0 dS/m) level ranged from 50-73% and that at S_2 (7.5 dS/m) level from 35-43%. In Bangladesh soybean 4 the relative leaf dry weight production increased with the increasing doses of K at both S_1 (5.0 dS/m) and S_2 (7.5 dS/m) levels of salinity. Compared to the K_0 (Control or native potassium) treatment, the application of K enhanced the relative root dry weights, to some extent, under saline conditions in both the genotypes. The relative root DW ranged from 41-55% at S_1 level of salinity, and that from 28-42% at S_2 salinity in Galarsum. On the contrary, the relative root DW ranged from 86-130% in S_1 (5.0 dS/m) and that from 76-103% in S_2 (7.5 dS/m) salinity in Bangladesh soybean 4 genotype. The total dry weight (roots + shoot) was decreased severely by the salinity in both the genotypes, and the reduction in the TDW increased with the increase in salinity levels.

Key words: Dry Matter, Field experiment, Mitigating salinity, Potassium, Soybean

CORRESPONDENCE
* hashi2302@gmail.com
Department of Agronomy, EXIM Bank Agricultural University Bangladesh, Chapainawabganj 6300

1. INTRODUCTION

Soybean (*Glycine max* L.) is considered as a source of complete protein. A complete protein is one that contains significant amounts of all the essential amino acids that must be provided to the human body, because of the body's inability to synthesize them. Soya protein products can replace animal-based foods, which also have complete proteins but tend to contain more fat, especially saturated fat without requiring major adjustments elsewhere in the diet. The high-quality protein and oil of soybean seed is a major source for human consumption (Katerji et al., 2001). The

To Cite: Hashi, U.H. (2019). Mitigation of salinity effect in dry matter distribution of two soybean genotype (*Glycine max L.*) by applying different level of potassium. *EBAUB J.*, 2, 58-64.

unique chemical composition of soybean made it one of the most valuable agronomic crops worldwide (Thomas et al., 2003). Oil and protein contents of soybean account for about 60% of dry soybeans by weight of which 40% is protein and 20% oil. Despite its high nutritive values, soybean is grown in a limited scale in Bangladesh. For a long time, its cultivation has been concentrated mostly in the southern Bangladesh, most specifically in the district of Noakhali, where salinity is a potential threat for crop production. However, the cultivation of soybean is also expanding in the northern part of Bangladesh along with the increase in the southern part with the increase in its demand as an animal feed and consciousness about the nutritive values of the food made from this crop (Karim et al., 2012).

Salinity is a great problem in agriculture, especially in the coastal areas of the world. In many arid and semi-arid regions the soil salinity is caused by natural processes or by crop irrigation with saline water (Meloni et al., 2004). The United Nations Environment Program (UNEP) estimated that, 20% of the agricultural land is salt affected in the world (Yan, 2008).Munns,2005 also reported the matter where he claimed that over 8×10^8 ha, which is about 6% of the world's land area is affected by salinity. The salinization in Bangladesh is mainly caused by seepage of seawater, inundation of coastal land with seawater due to cyclone and intrusion of brackish water into sweet water river during dry season (Karim et al.,1982; Mannan, 2012; Khan, 2013).

Most of the salt stresses in nature are due to Na^+ salts, particularly NaCl. Sodium is a non essential plant nutrient for most of the crops. High salt content, especially high Na^+ accumulation, reduces the growth and development of a plant by affecting physiological processes, including modification of ion balance, water status, mineral nutrition, stomatal behavior, and photosynthetic efficiency (Munns, 1993). Plant physiological processes at both whole plant and cellular levels are affected by osmotic and ionic stresses caused by salinity (Murphy & Durako, 2003). The higher ratio of toxic salts in leaf leads to dehydration and turgor loss, and finally death of leaf cells and tissues. Furthermore, salt stress has various effects on plant physiological processes such as increased respiration rate and ion toxicity, changes in plant growth, mineral distribution, membrane instability resulting from the displacement of calcium and potassium ions by sodium ion (Grattan & Grieve, 1992), membrane permeability (Gupta et al.,2002) and decreased efficiency of photosynthesis (Ashraf & Shahbaz, 2003; Kao et al., 2003; Sayed, 2003). The most important process is affected by salinity is the photosynthesis (Hayat et al.,2010), which may be due to increase in stomatal resistance rather than nonstomatal factor (Karim et al.,2012). Usually, salt-tolerant plant accumulates lower amount of Na^+ and higher amount of K^+ in plant cells than salt-susceptible plant (Mannan et. al., 2013b).

So far, a large number of experiments employing more than hundreds of soybean genotypes have been conducted at the Department of Agronomy of Bangabandhu Sheikh Mujibur Rahman Agricultural University for evaluating the genotypic variations in yield performance and their salt tolerance (Mannan, 2009; Khan, 2013). Generally, salinity impaired the normal uptake of K^+ as well as other essential plant nutrients in soybean (Mannan, et al.,2013b.;Hussainet al.,2013) found that, the grain and dry matter yield of wheat at both saline and sodic soil increased significantly by addition of K. Earlier Cakmak (2005) also showed that, improving K nutrition of plants under salt stress could be essential in minimizing oxidative cell damage, at least in part by reducing reactive oxygen species (ROS) formation during photosynthesis. Therefore, it is important to examine that whether application of higher levels of potassium could ameliorate the toxic effect of salinity on nutrients uptake and subsequent growth in soybean. Such possibility was founded by Kabir et. al., (2004) where they found that application of higher potassium doses enhanced the salinity tolerance of mungbean (*Vigna radiata*). This study was initiated with the following objectives: i)To analyze the response of potassium on dry matter distribution pattern in salt affected soybean plants, ii)To draw the relationship between the dry matter production and effect of potassium in mitigating salinity stress.

2. MATERIALS AND METHODS

The Department of Agronomy of Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU) has a large number of soybeans in collection. The yield performances as well as salinity tolerance of those collections have already been evaluated (Mannan, 2009; Khan, 2013). Khan (2013) grouped the genotypes Galarsum and Bangladesh Soybean-4 as relatively salt tolerant ones. Therefore, both the genotypes were included in this study as plant materials. The plants were grown in plastic pots of 24 cm (diameter) × 30 cm (height) under natural sunlight inside vinyl house. The pots were filled with 14 kg of air-dried soils.Four levels of potassium and three levels of salinity were the treatment variables. The source of potassium was muriate of potash (MoP).

Treatment compositions

i. Genotypes: V_1= Galarsum and V_2= Bangladesh Soybean-4
ii. Potassium: Four levels, namely
   K_0= Control or native potassium,
   K_1 = recommended dose (RD) i.e.59.76 kg/ha,(Fertilizer Recommendation Guide, BARC)K_2 =double to the RD i.e.119.52 kg/ha and K_3 = tripletothe RD i.e.179.28 kg/ha
iii. Salinity: Three levels of salinity created by dilution of sea water such as S_0= Control (tap water), S_1= 5.0 dS/m and S_2= 7.5 dS/m

Fertilization

Nitrogen, phosphorus, sulphur and boron were applied as urea, TSP, gypsum and borax at the rate of 60, 175, 120, 115 and 10 Kilogram per hectare respectively for all treatments. The amount of different fertilizers for each pot containing 8 kilogram dry soil was calculated and mixed with soil during pot filling.

Seed sowing
Eight healthy seeds were sown in each pot on 17April 2012. Immediately after sowing seed, a light irrigation was given for the ease of seed germination.

Intercultural operation
Thinning: Thinning was done during the appearance of second trifoliate and kept two uniform and healthy plants in each pot.

Weeding: Weeding was done intensively to keep the pots weed free.

Pesticide application: To protect the plant from cutworm, insecticide Carate was sprayed when it was needed.

Irrigation: Irrigation was applied with tap water in all the pots up to imposition of salinity treatment.

Salinity imposition
Tap water of 0.1 dS/cm electrical conductivity (EC) was applied to the pots up to the emergence of 1^{st} trifoliate leaf. Afterwards the tap water was applied only to the control plot. Seawater was collected from the Bay of Bengal at the Cox's Bazar point. The initial EC value of the seawater was 49 dS/m. The seawater was diluted with tap water and a sufficient amount of diluted seawater of 2.5 dS/m was applied to the pots in excessively so that the excess seawater dripped out from the bottom of the pots. Two days later, the diluted seawater of 5.0 dS/m (S_1) was applied similarly. As the salinity concentration of the applied solution increased by 2.5 dS/cm every alternate day, it increased to 7.5 dS/m (S_2) after 4 days of salinity imposition. Thus, the salinity treatments were S_0= Control, S_1= 5.0 dS/m and S_2= 7.5 dS/m. The saltwater was applied till harvest, on 27August, 2013. The salinity was applied for 3 months and 14 days.

Dry matter accumulation
After harvest, the plants were partitioned into root, stem, leaf and pod (in Bangladesh soybean-4 only). Though Bangladesh soybean-4 produced some pods but there were no any developed seeds in those pods. The plant parts were oven dried at 70^0C for 72 hours. Total dry weight (DW) was calculated by summing up the dry weight of roots, stem, leaf and petiole of the plant. Shoot DW was calculated by excluding dry weight of root from total dry weight. Root: shoot ratio was calculated for all the treatments.

3. RESULTS

Salinity effects on dry matter production
3.1 Stem dry weight
Application of different levels of K increased the production of relative stem dry weight (DW) at both 5 dS/cm (S_1) and 7.5 dS/cm (S_2) levels of the salinity compared to the control (S_0). At S_1 salinity the relative stem DW in Galarsum ranged from 46 to 66% and that at S_2 salinity from 35 to 40%. Whereas, in Bangladesh Soybean-4 the stem DW ranged from 58 to 75% at S_1 and that from 34 to 52% at S_2 level of salinity. Therefore, the percent reduction in stem DW due to salinity was more in V_2thanV$_1$ when salinity increased from S_1 to S_2 under K_0 and K_1 potassium treatments. The percent reduction in stem DW due to salinity was more in V_1 than V_2 when salinity increased from S_1 to S_2under K_2 and K_3 potassium treatments. Moreover,the positive effect of K on the production of relative stem DW under different level of salinity was more clear in V_2(34%-48% in S2) in than that of V_1(35%-40% in S2).

3.2 Leaf dry weight
Irrespective of K levels salinity decreased the leaf dry weight in both the genotypes and the reduction in leaf DW increased with the increasing of salinity levels (Table 2). The leaf DW of Galarsum (V_1) was much higher than that of Bangladesh Soybean-4 at all level of salinity and potassium. At the control (S_0) the increasing levels of K application decreased the leaf DW production in V_1, though in V_2 the weight increased substantially. Contrary, at both 5 dS/cm

Table 1.Effect of salinity and potassium level on stem dry weight of two soybean genotypes

		Stem dry weight							
		K_0		K_1		K_2		K_3	
		(g/plant)	Relative value	(g/plant)	Relative value	(g/plant)	Relative value	(g/plant)	Relative value
V_1	S_0	12.93a		13.21a	102	12.13a	94	13.18a	102
	S_1	5.96efg	46	8.40bc	65	7.25cde	56	8.53bc	66
	S_2	4.82ghil	37	5.15fghi	40	4.56ghij	35	5.23fghi	40
	S_0	8.56bc	-	7.57cd	88	7.62cd	89	9.62b	112
V_2	S_1	4.94fghij	58	5.20fghi	61	5.62fgh	66	6.38def	75
	S_2	2.90k	34	3.54jk	41	4.11ijk	48	4.43hij	52
CV(%)					12.65				

Means followed by common letter(s) within a parameter do not differ significantly (P>0.05) by DMRT.Values presented in relative value indicate percent value to the control. V_1=Galarsum, V_2= Bangladesh Soybean-4;S_0=Control, S_1=5.0 dS/cm and S_2=7.5 dS/cm; K_0=Control, K_1=recommended dose (RD) i.e. 48 g MP per pot(59.76 kg/ha), K_2=double to the RD i.e. 96 g MP per pot(119.52 kg/ha) and K_3=triple to the RD i.e. 144 g MP per pot(179.28 kg/ha).

Table 2.Effect of salinity and potassium level on leaf dry weight of two soybean genotypes

		Leaf dry weight							
		K_0		K_1		K_2		K_3	
		(g/plant)	Relative Value	(g/plant)	Relative Value	(g/plant)	Relative Value	(g/plant)	Relative Value
V_1	S_0	11.52a	-	10.92ab	95	10b	87	7cd	61
	S_1	5.75f	50	7.3de	63	7de	61	8.4c	73
	S_2	4hi	35	4.59ghi	40	5fgh	43	4.5ghi	39
	S_0	5.17fg	-	6.8e	131	7.3de	141	7.12de	137
V_2	S_1	3.86ij	75	4hi	77	4.60ghi	89	5.82f	113
	S_2	1.83l	35	2.61kl	50	3jk	58	3.75ij	72
CV(%)				10.55					

Means Followed by common letter(s) within a parameter do not differ significantly (P>0.05) by DMRT. Values presented in relative value indicate percent value to the control. Abbreviation of (V_1-V_2),(K_0-K_3) and (S_0-S_2) are same as Table 1.

(S_1) and 7.5 dS/cm (S_2) K increased the leaf DW in both V_1 and V_2. The relative leaf DW production of V_1 at S_1 level ranged from 50-73% and that at S_2 level from 35-43%. In V_2 the relative leaf dry weight production increased with the increasing doses of K at S_1 and S_2 levels of salinity. At the S_1 salinity level the relative leaf dry weight ranged from 75-113% in V_2 and that at S_2 salinity level from 35 to 72%. The relative leaf DW of two soybean genotypes increased with increasing K application in each salinity level except S_1K_2, S_2K_3 treatments of V_1. Therefore, the relative leaf DW was increased due to increasing levels of K more in V_2 than V_1 under saline conditions.

3.3 Root dry weight

Like other parameters salinity affected root dry weight in both Galarsum (V_1) and Bangladesh Soybean-4 (V_2) at all levels of K (Table 3). However, in general, the absolute root dry weight in V_1 was higher than V_2 irrespective of salinity and potassium levels. Compared to the K_0 treatment, the application of K enhanced the relative root dry weights, to some extent, under saline conditions in both the genotypes. The relative root DW ranged from 41-55% at S_1 level of salinity, and that from 28-42% at S_2 salinity in V_1. On the contrary, the relative root DW ranged from 86-130% in S_1 and that from 76-103% in S_2salinity in V_2 genotype.Therefore, the relative root dry weight production in V_2 was higher than that of V_1 due to potassium application.

3.4 Shoot dry weight

Irrespective of K levels, salinity decreased the shoot dry weight (DW) in both Galarsum (V_1) and Bangladesh Soybean-4 (V_2) & the reduction was increased with the increase of salinity levels (Table 4).At S_0 condition the application of increasing rates of K did not reflect any beneficial effect on the shoot DW in V_1, though in V_2 the higher level of K application increased the shoot DW substantially indicating a differential response of the genotypes to K application. At S_1 level of salinity the relative shoot DW in V_1 ranged from 49-68% due to variation in K levels, and that ranged from 36-40% at S_2 salinity. On the contrary, the relative shoot DW increased steadily with the increase in K levels in V_2 at both S_1 and S_2 levels of salinity. The relative shoot DW in V_2 ranged from 64-88% at S_1 and that ranged from 34-59% at S_2 level of salinity. Therefore, the role of K in ameliorating salinity effect on relative shoot dry weight was more conspicuous in V_2 than in V_1.

Table 3.Effect of salinity and potassium level on root dry weight of two soybean genotypes

		Root dry weight							
		K_0		K_1		K_2		K_3	
		(g/plant)	Relative value	(g/plant)	Relative value	(g/plant)	Relative value	(g/plant)	Relative value
	S_0	3.16a	-	2.55b	81	2.37b	75	2.30 bc	72
V_1	S_1	1.31fghi	41	1.52efg	48	1.73de	55	1.63ef	52
	S_2	1.05ij	33	1.05ij	33	1.33fghi	42	0.90j	28
	S_0	1.16hij	-	2.02cd	174	1.56ef	134	2.14b	184
	S_1	1.15hij	99	1.41efgh	121	1.00 j	86	1.51efg	130
V_2	S_2	0.88 j	76	1.20ghij	103	1.00 j	86	1.00 j	86
CV(%)					14				

Means Followed by common letter(s) within a parameter do not differ significantly (P>0.05) by DMRT. Values presented in parenthesis indicate percent value to the control. Abbreviation of (V_1-V_2),(K_0-K_3) and (S_0-S_2) are same as Table 1.

Table 4.Effect of salinity and potassium level onshoot dry weightof two soybean genotypes

		Shoot dry weight							
		K_0		K_1		K_2		K_3	
		(g/plant)	Relative value	(g/plant)	Relative value	(g/plant)	Relative value	(g/plant)	Relative value
V_1	S_0	24.46a	-	24.13a	98	22.22b	91	21b	86
	S_1	11.71fg	49	15.73cd	64	14.3de	58	16.7c	68
	S_2	8.82hi	36	9.7hi	39	9.51hi	39	9.73hi	40
	S_0	13.82e	-	14.37de	104	14.92de	107	16.75c	121
	S_1	8.8hi	64	9.12hi	70	10.22gh	74	12.20f	88
V_2	S_2	4.74l	34	6.15kl	45	7.11jk	51	8.18ij	59
CV(%)					8.44				

Means Followed by common letter(s) within a parameter do not differ significantly (P>0.05) by DMRT. Values presented in relative value indicate percent value to the control. Abbreviation of (V_1-V_2),(K_0-K_3) and (S_0-S_2) are same as Table 1.

3.5 Total dry weight (TDW)

The total dry weight (roots + shoot) was decreased severely by the salinity in both the genotypes, and the reduction in the TDW increased with the increase in salinity levels (Table 5). At the S_0 level of salinity the application of higher levels of K did not improve TDW in Galarsum (V_1), though the higher doses of K increased the TDW substantially in V_2 indicating a genotypic variations in response to higher level of K. At the S_1 salinity level the TDW ranged from 47-67% due to K levels and that at S_2 from 36-39% in V_1. Conversely, in V_2 the relative TDW varied from 66 to 91% due to K application at S_1, and that from 37 to 61% at S_2 salinity level. The result indicated the more response of TDWV_2 to K under saline conditions than V_1.

4. DISCUSSION

The present study was initiated with the objectives to clarify the role of K on the pattern of dry matter distribution in different plant parts and the accumulation of different mineral ions in leaves as well as to estimate the relatioships between the accumulated mineral ions and dry matter production. Two soybean genotypes, Galarsum (V_1) and Bangladesh Soybean-4 (V_2) were used. None of the two genotypes were able to produce seeds, mostly because of serious flowers and pod dropping. The temperature inside the vinyl house rose to >40^{o}C, which was probably the cause for the flower dropping. According to Blum (1985) and Karim et al. (2003) several reproductive processes are sensitive to heat stress, such as floral bud development,

Table 5.Effect of salinity and potassium level on total dry weight of two soybean genotypes

		Total dry weight							
		K_0		K_1		K_2		K_3	
		(g/plant)	Relative value	(g/plant)	Relative value	(g/plant)	Relative value	(g/plant)	Relative value
V_1	S_0	27.62a	-	26.68a	96	24.60b	89	23.13b	83
	S_1	13.02h	47	17.26de	64	15.97de	58	18.53ef	67
	S_2	9.87cd	36	10.7ij	39	10.6ij	38	10.7ij	39
	S_0	14.98ij	-	16.4fg	109	16.48ef	110	19.16ef	127
	S_1	9.95c	66	10.62ij	71	11.14ij	76	13.71i	97
V_2	S_2	5.61m	37	7.35l	49	8kl	53	9.1jk	61
CV(%)					7.71				

Means Followed by common letter(s) within a parameter do not differ significantly (P>0.05) by DMRT. Values presented in relative value indicate percent value to the control. Abbreviation of (V_1-V_2),(K_0-K_3) and (S_0-S_2) are same as Table 1.

Results of the study clearly indicated that salinity decreased plant height, the production of dry matter in leaves, stem, roots and finally total dry weight (DW). Salinity affects plant growth by (i) creating physiological drought in plant cells by reducing smooth uptake of water due to lowering of the soil water potential, Under saline stress, leaf area *vis a vis* leaf DW is mostly reduced because of lower cell expansion due to maintaining low turgor. According to Gunes et al. (1996) under salt stress plant suffered from physiological drought state and consequently the reduction in plant height occurred due to either osmotic effect or excess accumulation of Na^+ and Cl^- in plant tissue. It is reported that salinity stress reduced net photosynthesis rate, increased energy loss for salt exclusion mechanism, largely hindered nutrient uptake mechanism and finally reduced plant growth (Long & Baker, 1986; Seeman & Sharkey,1986; Orcutt & Nilsen, 2000). Reduction in dry weight also indicated the increased metabolic energy cost in saline condition and reduced carbon gain. It was reported further that the salt affected largely on the tissuefunctions (Karimi et al.,2005), photosynthetic rates

(Ziska et al.,1990; Ashraf, 2004) and the attainment of maximum salt concentrations tolerated by the fully expanded leaves (Hu et al.,2000).anther development and embryo development. In legumes, the individual anther is sensitive to heat 9 to 7 days before anthesis which is just after meiosis. The damage is associated with premature degeneration of the tapetal layer, lack of endothecial development, low pollen viability and low anther dehiscence. Pollen viability and pollen shedding are highly sensitive to high temperature though the ability of the pistil to be fertilized remains unaffected (Hall, 1992; Suzuki, et al.,1999; Taiz & Zeiger, 2006).

The two genotypes showed variability in their salt tolerance considerably. Between the two genotypes, Galarsum (V_1) showed higher biomass production in different plant parts at all levels of salinity. However, when relative values (% value to the control) are concerned Bangladesh Soybean-4 (V_2) had the higher values. According to Maas & Hoffman (1977) and Mannan, *et al.* (2013a) both absolute and relative productivity are important consideration for improving crop production in the marginal environment. The absoulte productivity is an important consideration for increasing farm productivity in the saline area, whereas the relative tolerance is important in improving salinity tolerance of a crop through genetic engeneeriring. Therefore both V_1 and V_2 are important genotypes for improving soybean productivity in Bangladesh.

5. CONCLUSIONS

The following conclusions may be drawn based on the findings of this study -

Salinity decreased biomass production in leaves, stem and roots of the soybean genotypes. Of the two genotypes, Galarsum (V_1) showed higher biomass production in different plant parts at all levels of salinity. However, when relative values were concerned, Bangladesh Soybean-4 (V_2) had the higher values. Since, the absoulte productivity is an important consideration for increasing farm productivity in the saline area and the relative tolerance is important in improving salinity tolerance of a crop through genetic engeneeriring, both V_1 and V_2genotypes are important for improving soybean productivity in Bangladesh. While Galaursum showed high absolute growth under saline conditions, Bangladesh Soybean-4 had the high relative value of plant growth. So on the basis of result, Bangladesh Soybean-4 has high genetic potential for inproving any variety. Therefore, both of the genotypes are important in improving soybean productivity in the saline areas of Bangladesh.

6. REFERENCES

Ashraf, M., 2004. Some important physiological selection criteria for salt tolerance in plants. Flora, 199: 361-376.

Ashraf, M. & Shahbaz, M. (2003). Assessment of genotypic variation in salt tolerance of early CIMMYT hexaploidwheat germplasm using photosynthetic capacity and water relations as selection criteria.*Photosynthetica*, 41: 273-280.

Blum, A. (1985).Breeding crop varieties for stress environments.*CRC. Critical Rev. Plant Sci.* 2: 199- 238.

Cakmak, I. (2005). The role of potassium in alleviating detrimental effects of abiotic stresses in Plants*. J. Plant Nutr. Soil Sci.,* 168:521–530.

Grattan, S.R. & Grieve, C. M. (1992). Mineral element acquisition and growth response of plants grown in saline environment. *Agric. Eco. Env*., 38: 275-300.

Gunes, A., A. Inal and M. Alpaslan. (1996). Effect of salinity on stomatal resistance, proline and mineral composition of pepper. *J. Plant Nutr.,* 19: 389-396.

Gupta, N.K., S. K. Meena, S. Gupta and S. K. Khandelwal. (2002). Gas exchange, membrane permeability, and ionuptake in two species of Indian jajuba differing in salt tolerance .*Photosynthetica*, 40: 535-539.

Hall, A. H. (1992). Breeding for Heat Tolerance.*PlantBreed.Rev.* 10: 129-168.

Hayat, S., Hasan, S. A., Yusuf, M., Hayat, Q. & A. Ahmad. (2010).Effect of 28-homobrassinolide on photosynthesis, fluorescence and antioxidant system inthe presence or absence of salinity andtemperature in*Vignaradiata*. Env. Exp. Bot. 69: 105-112.

Hu, Y.& Schmidhalter. U. (2005). Drought and salinity: A comparison of their effects on mineral nutrition of plants.J. *Plant Nutr. Soil Sci.,* 168:541-54.

Hussain, Z.,R. A. Khattak, M. Irshad & A. E. Eneji.(2013). Ameliorative effect of potassium sulphate on the growth and chemical composition of wheat (*Triticumaestivum*L.) in salt affected soils*. J. Soil Sci. Plant Nutr*.,13: 401-415.

Kao, W.Y., Tsai, T. T. & Shih,C. N. (2003). Photosynthetic gas exchange and chlorophyll *a* fluorescence of threewild soybean species in response to NaCl treatments. *Photosynthetica* *,* 41:415-419.

Karim, M.A., Utsunomiya, N.& Shigenaga, S. (1982). Effect of sodium chloride on germination and growth of hexaploid triticale at early seedling stage. *Jpn. J. crop Sci*. 61:279-284.

Karim, M.A., Kondo, T., Ueda, K., Higuchi, H., & Nawata, E., (2012). Effect of NaCl treatment growth and some physiological characteristics of salt-tolerant soybean genotype AGS 313bred in Bangladesh. *Trop. Agr. Develop*.56:130-142.

Karim, M.A., Fukamachi ,H., Komori, S., Ogawa, K., & Hidaka. T. (2003). Growth, yield and photosynthetic responses of *Vignaradiata* L. grown at different temperature and light levels *Plant Prod. Sci.* 6: 43-49.

Kabir, M.A., Karim, M. A. & Azad. M. A. K. (2004). Effect of potassium on salinity tolerance of mungbean (*Viganaradiata*L. Wilezek). *J. Biol. Sci*. 4:103-110.

Katerji, N., Hoorn, J. W., Mastrorilli, M. & Hamdy, A. (2001).Crop sensitivity to salinity.*Non*-conventional water use:WASAMED project,BARI: CIHEAM, 53:43-51.

Khan, M.S.A. (2013).Evaluation of soybean genotypes in relation to yield performance, salinity and drought tolerance. A PhD Dissertation. Department of Agronomy, Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Gazipur-1706, Bangladesh.

Long, S. P. andN. R. Baker. (1986).Saline terrestrial environments. *In:* Baker NR, Long SP (eds) Photosynthesis in contrasting environments. Topics in photosynthesis, vol 7. Elsevier, Amsterdam. pp. 63-102.

Maas, E. V. & C. M. Grieve. (1987). Sodium-induced calcium deficiency in salt-stressed corn.PlantCell Env.10: 559-564.

Mannan, M. A. (2009).Response of Soybean Genotypes to Salinity Stress.A PhD Dissertation. Department of Agronomy, Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU),Gazipur-1706, Bangladesh.

Mannan, M. A., Karim, M. A ., Haque, M. M.. Khaliq, Q. A., Higuchi, H. & Nawata. E. (2013)a.Response of soybean to salinity: II. Growth and yield of some selected genotypes. Trop. Agr. Develop., 57:31-41.

Mannan, M. A., Karim, M. A., Haque, M. M., Khaliq, Q. A., Higuchi, H. & Nawata. E. (2013)b. Response of soybean to salinity: III.Water status and accumulation of mineral ions. Trop. Agr. Develop., 57:41-47.

Meloni, D. A., Gulotta, M. R., Martinez, C. A. & Oliva,M. A.(2004). The effects of salts on growth, nitrate reduction and proline and glycine-betaine accumulation in*Prosopisalba*. Braz. J. Plant Physiol., 16: 39-46.

Munns R.(2005). Genes and salt tolerance: bringing them together. New Phytol., 167: 645-663.

Munns, R. (1993). Physiological processes limiting plant growth in saline soils: some dogmas and hypotheses. Plant Cell Env.,16:15-24.

Orcutt, M. D. & E. T.Nilsen. (2000).Salinity Stress. *In:* The Physiology of Plants under Stress. John Wiley and Sons, Inc. New York. pp. 177-234.

Suzuki, K., H. Takeda, S. Masuda,S. You and Y. Egawa. (1999). Morphological Study on injury of pollen of snap bean by heat stress. Proc. Int. Symp. World Food Security. Kyoto, Japan. 2003-2006.

Seeman, J.R. & Sharkey, T. D. (1986). Salinity and nitrogen effects on photosynthesis, ribulose 1,5-bisphosphate carboxylase and metabolite pool size in *Phaseolusvulgaris.*Plant Physiol., 82: 555- 560.

Taiz, L. & Zeiger. E. (20060. Plant Physiology. 4thEdition.Sinuer Associates, Inc. Sunderlands, MA, USA. p. 700.

Ziska, L. H., Seemann, J. R. & Dejong, T. M. (1990). Salinity induced limitation on photosynthesis in *Prunussalicina*, a deciduous tree species. PlantPhysiol., 93: 864- 870.