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DRY MATTER PRODUCTION AND SEED YIELD OF SOYBEAN AS AFFECTED BY POST-FLOWERING SALINITY AND WATER STRESS

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Abstract

The experiment was conducted in a vinyl house of the Agronomy Division, Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur, during *rabi* season of 2015-2016 to evaluate the sensitivity of different post-flowering growth stages of soybean to salinity (100 mM NaCl) and water stress (70% depletion of available water) imposed at 4^{th} to 6^{th}, 6^{th} to 8^{th}, 8^{th} to 10^{th} and 10^{th} to 12^{th} weeks after emergence. Shoot dry weight was found more sensitive to salt and water stress than root dry weight at all the post flowering growth stages. The highest relative shoot dry weight (91.47%) and relative root dry weight (95.58%) were recorded from salt and water stressed plants, respectively when both the treatments imposed at 4^{th} to 6^{th} weeks after emergence. The highest seed yield (10.47 g plant^{-1}) was obtained from the control treatment followed by that (8.68 g plant^{-1}) under salt stress treatment imposed at 10^{th} to 12^{th} weeks after emergence. Contrary, the lowest seed yield of 0.69 g plant^{-1} was obtained from the salt stress treatment imposed at 4^{th} to 6^{th} weeks after emergence. Among the stages, 4^{th} to 6^{th} weeks after emergence of soybean was found the most sensitive to salt stress in relation to seed yield reduction. The salt stress imposed at 6^{th} to 8^{th} weeks after emergence was also found damaging for seed yield production.

Introduction

Soil salinity and water stresses are the dominant abiotic stresses that limiting crop production after T. aman rice in the southern region. Soybean (*Glycine max* L.) is one of the most economic and nutritious crop in the world with high protein content (Mondal *et al.*, 2002). In Bangladesh it is mostly used as poultry and fish feed. With the expanding of poultry and fish industries the demand of soybean has been increased manifold. To meet the demand a huge quantity of soybean is importing every year at the cost of substantial amount of hard currency. The cultivation area of soybean has also been increased simultaneously. However, the soybean cultivation is mostly concentrated in the coastal southern area, specifically in the greater Noakhali district. The coverage area is increasing day by day and in the year of 2013 it reached above to an area of 61,000 ha (Chowdhury *et al.*, 2014).This crop is often grown after T. aman and the sowing of seeds is made by mid- January. Since, the soybean seed sowing is done in late *rabi* season near the coastal belt, the crop often exposed to soil salinity and water stress at the terminal stages of crop, and these stresses become severe at particular post flowering growth stages.

Under both saline and water shortage conditions, the plants face difficulty in smooth uptake of water for the decreasing soil osmotic potential. Plants are unable to maintain metabolic activities, especially the turgidity of cell for normal growth under salt or water stress conditions, and that finally resulted yield reduction (Khan *et al.*, 2016). Salinity or water shortage decreased pod number in pea (Duzdemir *et al.*,

2009) and soybean (Chowdhury *et al.*, 2015). Soybean is classified as a moderately salt sensitive crop (Katerji *et al.*, 2003) and denoted as sensitive to drought stress, especially at the early reproductive stage (Westgate and Peterson, 1993). Despite a large number of studies conducted on the soybean response to salinity and water stress (Khan *et al.*, 2016; Katerji *et al.*, 2003; Westgate and Peterson, 1993), the dry matter production and yield response of the crop to salt or water stress imposed at different post-flowering growth stages are scarcely studied. Therefore, this study was initiated to find out the sensitivity of different post-flowering growth stages of soybean to salinity and water stresses.

Materials and Methods

The experiment was conducted in a polythene house of the Agronomy Division at Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur during *rabi* season of 2015. Soybean var. BARI Soybean-6 was used for testing salt and water stress tolerance at different post flowering growth stages. Seeds were washed several times with tap water for surface cleaning and then sown in soil medium on 26 January 2015 in plastic pots having 30 cm in height and 24 cm inner diameter. Each pot contained 12 kg air dried sandy loam soil. Chemical fertilizers of 0.30 g urea, 0.90 g TSP, 0.60 g MOP and 0.60 g Gypsum per pot were also incorporated into the soil before sowing. The pots were watered daily for easy germination. Soybean plants were emerged on 01 February, 2015. After the emergence and establishment, two uniform healthy seedlings per pot were allowed to grow for four weeks (28 DAE) in equal environment. After four weeks of emergence, all the growing plants in pots were imposed to the treatments. The treatments were; (T_1) Control, (T_2) Salt stress as irrigated the plants with 100 mM NaCl solution at 4^{th} to 6^{th} weeks after emergence, (T_3) Water shortage (irrigated with 70% depletion of available soil water when wilting sign developed) at 4^{th} to 6^{th} weeks after emergence, (T_4) Salt stress as irrigated with 100 mM NaCl at 6^{th} to 8^{th} weeks after emergence, (T_5) Water shortage at 6^{th} to 8^{th} weeks after emergence, (T_6) Salt stress as irrigated with 100 m M NaCl at 8^{th} to 10^{th} weeks after emergence, (T_7) Water shortage at 8^{th} to 10^{th} weeks after emergence, (T_8) Salt stress as irrigated with 100 mM NaCl at 10^{th} to 12^{th} weeks after emergence and (T_9) Water shortage at 10^{th} to 12^{th} weeks after emergence. The control group of plants was irrigated with tap water only. To induce salt stress, the pots were irrigated five times with 500 ml salt solution for 14 days by maintained an interval of two days. The experiment was arranged in Completely Randomized Design (CRD) with 8 replications. Admire 200SL @ 1 ml/liter of water was sprayed at 10 and 25 DAE to control Jassids and white flies. Ripcord 10 EC @ 1 ml/liter of water was sprayed at 45 and 60 DAE to control leaf roller and pod borer. After the completion of the treatments imposition plant samples were collected from 4 replications and remaining 4 were allowed to grow up to maturity with irrigated fresh water. Shoot and root parts of the collected plant samples were separated and then oven dried at 70□C for 4 days to measure the dry weight. Yield and yield contributing characters of the soybean plants under different treatments were recorded from the remaining pots after maturity. Data were analyzed by MSTAT-C program and the treatment means were compared by using Least Significant Difference (LSD).

Results and Discussion

Shoot and root dry weight

Shoot dry weight of soybean plants was remarkably reduced by salinity and water stress at different post flowering growth stages (Fig. 1). When the salt and water stress applied during at the 4^{th} to 6^{th} weeks after emergence, the shoot dry weight under salt stress (3.97 g plant^{-1}) and water stress (3.76 g plant^{-1}) differed noticeably from the control treatment (4.34 g plant^{-1}). Shoot dry weight under salt (7.36 g plant^{-1}) and water stress (7.24 g plant^{-1}) was identical but significantly differed from the control (11.98 g plant^{-1}) at 6^{th} to 8^{th} weeks after emergence. Similar result was also observed at 8^{th} to 10^{th} weeks after emergence. Significantly the lowest shoot dry weight (12.06 g plant-^{1}) was recorded from water stress when salt and water stress imposed during 10^{th} to 12^{th} weeks after emergence. Shoot dry weight under salt stress (17.90 g plant^{-1}) was identical with control (20.10 g plant^{-1}) during 10^{th} to 12^{th} weeks after emergence. Shoot dry weight of soybean was affected more in water stress than salt water stress at all post flowering stages. Application of salt water increased soil salinity; at a given level reduced the soil water potential but probably did not reduce water flow to the roots. Root cortical cells can osmotically adjust to some extent allowing water to move into the root. Therefore, shoot dry weight of soybean was presumably affected more in water stress than salt water stress condition.

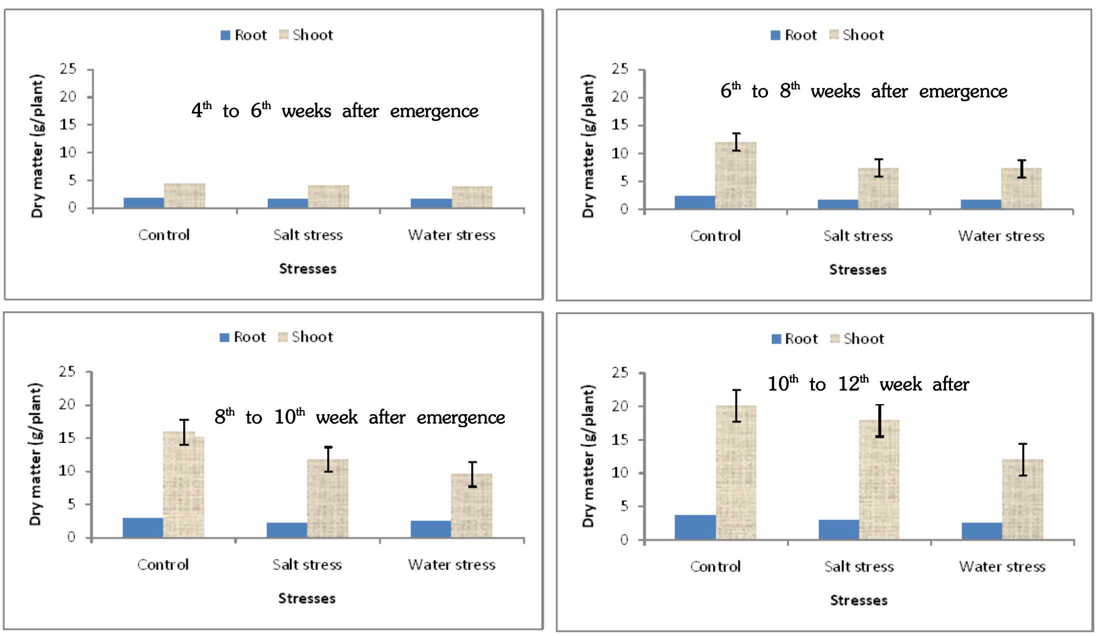
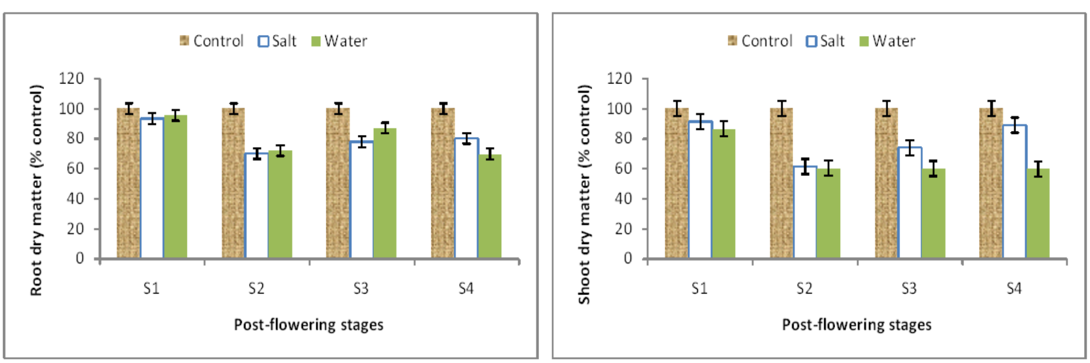


Fig.1. Dry matter production in root and shoot at different post flowering stages of soybean under salt and water stress condition.

The finding is in agreement with that of Meiri (1984) that the metric potential preferentially affected the shoot growth of bean more than did the osmotic potential. Similar result was also reported by Khan *et al.* (2016) in soybean. Shoot dry weight was found more sensitive to salt and water stress than root dry weight at all post flowering growth stages (Fig. 1). Root dry weight slightly decreased under salt and water stress at all the growth stages. The reduction in root dry weight of soybean due to salt and water stress was also reported by Khan *et al.* (2014). Under salt and water stress conditions, cell expansion is reduced due to low turgor, resulting in growth reduction. Among the stresses, root dry weight decreased more in salt stress than water stress at 4^{th} to 6^{th} weeks, 6^{th} to 8^{th} weeks and 8^{th} to 10^{th} weeks after emergence. It might be due to sodium ionic damage on cell membrane and organelles. However, at 10^{th} to 12^{th} weeks after emergence, root dry weight decreased more in water stress treatment (2.62 g plant^{-1}) than salt stress treatment (3.01g plant^{-1}). The response was probably due to translocation of food reserve to the sink at seed production stage. Chowdhury *et al.* (2015) also reported more reduction in root dry weight in soybean genotypes at pod filling stage as compared to vegetative stage under water stress condition.

Relative shoot and root dry weight

The relative shoot and root dry weight drastically reduced under salt and water stresses imposed at all the post flowering growth stages (Fig. 2). Relative shoot dry weight significantly differed from control when salt and water stress were imposed. The highest relative shoot dry weight (91.47%) recorded from the salt stress imposed during 4th to 6th weeks after emergence which was identical with water stress at the same growth period (86.64%) and salt stress during 10th to 12th weeks after emergence (89.05%). The lowest relative shoot dry weight recorded from the water stress treatment (59.90%) during 10th to 12th weeks after emergence. Relative root dry weight significantly differed from control when salt and water stress imposed at the post flowering growth stages. The highest relative root dry weight (95.58%) was recorded from water stress during 4th to 6th (S1) weeks after emergence, which was identical with salt stress at the same period (93.37%). The lowest relative root dry weight was recorded from water stress (69.87%) at 10th to 12th weeks after emergence. The reduction in relative shoot and root dry weight might be due to water shortage and sodium ionic damage. Khan *et al.* (2014) also reported that relative shoot and root dry weight decreased significantly in soybean genotype under salt and water stress condition due to water shortage and sodium ionic damage.



Here, S1= 4th to 6th weeks after emergence, S2= 6th to 8th weeks after emergence, S3= 8th to 10th weeks after emergence and S4= 10th to 12th weeks after emergence.

Fig. 2. Changes of root and shoot dry matter production at different post flowering stages of soybean under salt and water stress condition.

Yield attributes and yield

Yield contributing characters and seed yield of soybean plant under salt and water stress are presented in Table 1. Salt stress and water stress imposed at the post flowering growth stages significantly reduced number of filled pods, 100-seed weight, seed yield and days to maturity. The highest number of filled pods was obtained from control (53 plant^{-1}) which was identical with water stress imposed during 6th to 8th (49 plant^{-1}) and 8th to 10th (48 plant^{-1}) weeks after emergence, and salt stress during 10th to 12th weeks after emergence (49 plant^{-1}). The least number of pods was recorded from salt stress imposed at the post flowering growth stage of 4th to 6th weeks after emergence (4 plant^{-1}). Number of unfilled pod was significantly differed between the salt stress and water stress treatments. The highest number of unfilled pod (16 plant^{-1}) was recorded from water stress treatment of 10th to 12th weeks after emergence and the lowest recorded from salt stress during 8th to 10th (4 plant^{-1}) weeks after emergence.

Table 1. Yield contributing characters and seed yield of soybean under salt and water stress at different post-flowering growth stages

Treatment	Filled pods plant^{-1} (no.)	Unfilled pods plant^{-1} (no.)	100-seed weight (g)	Seed yield (g plant^{-1})	Days to maturity	Yield reduction (%)
Control	53.0	10.0	10.62	10.47	111	-
Salt stress at S1	3.7	6.3	5.77	0.69	92	93.41
Water stress S1	42.0	8.0	10.52	7.81	109	25.41
Salt stress at S2	39.7	13.7	7.95	5.35	94	48.90
Water stress at S2	49.3	8.0	9.74	7.48	108	28.56
Salt stress at S3	43.0	4.3	7.79	7.75	95	25.98
Water stress at S3	47.7	7.0	8.97	7.55	106	27.89
Salt stress at S4	48.7	11.3	8.49	8.68	100	17.10
Water stress at S4	45.0	16.0	7.29	8.09	103	22.73
LSD $_{(0.01)}$	7.12	4.52	0.88	1.26	2.44	
CV (%)	9.95	17.78	5.92	10.29	1.38	

Here, S1= 4th to 6th weeks after emergence, S2= 6th to 8th weeks after emergence, S3= 8th to 10th weeks after emergence and S4= 10th to 12th weeks after emergence. Yield reduction of the respective treatments was measured as compared to the yield of the control treatment.

It is well known that plants are unable to uptake water freely either in saline or water stress conditions due to decreasing osmotic potential of soil. Water stress possibly reduced pollen fertility, increased pod abortion and reduced pod filling in soybean that resulted in decreased number of filled pods (Khan *et al.*, 2016; Duzdemir *et al.*, 2009). The maximum 100-seed weight of 10.62 g was obtained from control which was identical to water stress during 4th to 6th weeks after emergence (10.52 g) and 6th to 8th weeks after emergence (9.74 g). The lowest seed weight of 5.77 g was obtained from salt stress imposed during 4th to 6th weeks after emergence. Salinity and water stress enhanced pod maturity that shortened the pod development period resulted in shriveled grain (Ghassemi- Golezani *et al.*, 2009; Mannan *et al.*, 2013; Khan *et al.*, 2016).The maximum seed yield of 10.47 g plant^{-1} was obtained from control followed by seed yield under salt stress imposed during 10th to 12th weeks after emergence (8.68 g plant^{-1}). The lowest seed yield of 0.69 g plant^{-1} was obtained from salt stress imposed at 4th to 6th weeks after emergence. The findings may be ascribed due to the fact that salt residual effect was prevailing in the soil from flowering to maturity and the plants had to uptake toxic sodium for longer period. The reduction in seed yield may be due to an increased uptake of toxic sodium that accumulated in cells and become toxic to the plant. NaCl readily dissolved in water solvent yielded toxic Na^{+} that may absorbed into root tissues and transport throughout plant organs, leading to toxic ion damage, osmotic stress and nutritional imbalance (Cha-um *et al.*, 2007; Siringam *et al.*, 2009) resulting low seed yield. The control plant took maximum days to maturity (111 days) which was followed by the plant under water stress imposed during 4th to 6th (109 days). The plant under salt stress imposed during 4th to 6^{th} weeks after emergence took minimum days to maturity (92 days). The minimum yield reduction was observed when salt stress was imposed during 10^{th} to 12^{th} weeks after emergence (17.10%) which was followed by water stress treatment (22.73%) at the same stage of growth. The highest seed yield reduction was recorded in salt stress treatment imposed during 4^{th} to 6^{th} after emergence (93.41%) followed by salt stress imposed during 6^{th} to 8^{th} weeks after emergence (48.90%). The minimum reduction in seed yield at the later stage of growth might be due to pod setting and filling before water shortage happened due to salt and water stresses.

Conclusion

From the above findings, it may be concluded that 4^{th} to 6^{th} weeks after emergence of soybean was the most sensitive post- flowering growth stage to salt for seed yield. The salt stress imposed during 6th to 8^{th} weeks after emergence was also much damaging for seed yield of soybean. Seed yield reduction was minimum both in salt and water stress treatments imposed during 10^{th} to 12^{th} weeks after emergence.

References

Cha-um, S., P. Vejchasarn and C. Kirdmanee. 2007. An effective defensive response in Thai aromatic rice varieties (*Oryza sativa* L. spp. *indica*) to salinity. J. Crop Sci. Biotechnol. 10: 257-264.

Chowdhury, J. A., M. A. Karim, Q. A. Khaliq, A. R. M. Solaiman and J. U. Ahmed. 2015. Genotypic variations in growth, yield and yield components of soybean genotypes under drought stress conditions. Bangladesh J. Agril. Res. 40(4): 537-550.

Chowdhury, M. M. U., I. S. Farhad, S. K. Bhowal, S. K. Bhowmik, and A. K. Choudhury. 2014. Fertilizer management for maximizing soybean (*Glycine max* L.) production in charlands of Bangladesh. The Agriculturists 12(2): 98-102.

Duzdemir, O., A. Kurunc and A. Unlukara. 2009. Response of pea (*Pisum sativum*) to salinity and irrigation water regime. Bulgarian J. Agril. Sci. 15(5): 400-409.

Ghassemi-Golezani, K. M. Taifeh-Noori, S. Oustan and M. Moghaddam. 2009. Response of soybean cultivars to salinity stress. J. Food Agric. Environ. 7(2): 401-404.

Katerji, N., J. W. van Hoorn, A. Hamdy and M. Mastrorilli. 2003. Salinity effect on crop development and yield, analysis of salt tolerance according to several classification methods. Agric. Water Manage.. 62: 37-66.

Khan, M. S. A., M. A. Karim and M. M. Haque. 2014. Genotypic differences in growth and ions accumulation in soybean under NaCl salinity and water stress conditions. Bangladesh Agron J. 17(1): 47-57

Khan, M. S. A., M. A. Karim, M. M. Haque, M. M. Islam, A. J. M. S. Karim and M. A. K. Mian. 2016. Influence of salt and water stress on growth and yield of soybean genotypes. Pertanika J. Trop. Agric. Sci. 39(2): 167-180.

Mannan, M. A., M. A. Karim, M. M. Haque, Q. A. Khaliq, H. Higuchi and E. Nawata. 2013. Response of soybean to salinity: II. Growth and yield of some selected genotypes. Trop. Agr. Develop. Vol. 57(1): 31-40.

Meiri, A. 1984. Plant response to salinity: Experimental methodology and application to the field. In: I. Shainberg and J. Shalhevet (eds.) Soil Salinity Under irrigation. Springer Verlag, New York. Pp. 284-297.

Mondal, M. R. I., M. A. Wahab, M. S. Alam, M. M. U. Ahmed and F. Begum. 2002. Leaflet of BARI soybean 5. ORC, BARI, Joyderbpur, Gazipur.

Siringam, K., N. Juntawong, S. Cha-um and C. Kirdmanee. 2009. Relationships between sodium ion accumulation and physiological characteristics in rice (*Oryza sativa* L. spp. *indica*) seedlings grown under iso-osmotic salinity stress. Pak. J. Bot. 41: 1837-1850.

Westgate, M. E., and C. M. Peterson. 1993. Flower and pod development in water–deficient soybean (*Glycine max* L. Merr.). J. Exp. Bot. 44: 109-117.