Alleviating the Detrimental Effects of Salinity Stress by Application of Potassium: Growth, Yield and Photosynthetic Parameters of Mung bean (*Vigna radiata*) (L.) Wilczek

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Abstract
Among all the abiotic factors, salinity stress is one of the most harmful and it severely limits crop productivity. Potassium is considered as one of the exogenous protectants which may alleviate the harmful effects of salinity stress. To attain the stated goals, pot experiments were conducted with primary aims to estimate the negative impact of salinity stress in mung bean and to mitigate the effects of salinity stress using potassium. The response to the combination of salinity stress in mung bean (Vigna radiata L.) grown under net house conditions with three levels of application of potassium (0.24g, 0.40g and 0.48g) was studied.

Salinity stress decreased various growth parameters (plant height, shoot and root length, fresh and dry weight of root and shoot and leaf area), yield parameters (no. of pods/plant, no. of seeds/pod, weight of seeds and pods) and photosynthetic parameters (Chlorophyll content and carotenoid content). Potassium application alleviates the detrimental effects of salinity even in highest level of NaCl (100mM). Therefore, mung bean (Vigna radiata MH-1142) can be grown successfully at salt stress with application of 0.48 g of KNO_3.

Keywords: Mung bean, Alleviation, Salinity stress, Yield, Potassium.

Introduction

Plant growth, productivity, yield and food quality are severely influenced by several biotic and abiotic stresses[36,39]. Salinity is one of the considerable abiotic stresses that limited the growth and yield of plants in many regions of the world especially in arid and semi-arid regions. Salinity also affects the plant morphology, anatomy, ultrastructure and metabolism[35] and causes imbalance of mineral nutrients and their distribution inside plant[11].

It is projected that this phenomenon will have substantial global ramifications, possibly resulting in 50 % reduction in land availability by 2050[13,31]. It limits the production of food cropsbecause plants are not able to take up appropriate water for metabolic processes or maintain turgidity due to their low osmotic potential. The plant's response to salinity differs greatly[6] and nearly all legume crops are sensitive to salinity[26].

Mung bean, *Vigna radiata* (L.) R. Wilczek (Fabaceae), is one of the most significant edible pulse crops cultivated on more than a million hectare in warmer parts of the world. The grain legume has a short duration (65–90 days) along with wide adaptability and low input demands[25] and has a crucial role in ensuring the nutrition safety of developing countries such as India[9].

Mung bean has been used in the treatment of several disorders including hyperglycaemia, hypertension, cancer, melanogenesis etc.[14]

In the last decades, the stable yields of mung bean have been considered for the susceptibility of crops to different biotic and abiotic stresses at various growth stagesof the crop[32]. Salt stress negatively impacts key physiological attributes of plants such as photosynthesis, stomatal activity, leaf chlorophyll content and seed germination rate[5,27,29].

Potassium (K) is one of the most essential macronutrients, playing a vital role in plant growth and development throughout their whole life cycle[28] and is a key factor for controlling the productivity of crops[22]. Potassium is a great component in the synthesis of proteins, enzyme activation, phloem uploading, the pH gradient, regulation of turgor pressure, stomatal functioning and the photosynthetic system[24], besides directing osmotic pressure and ionic balance during the disclosure of plants in salinity conditions[38]. As potassium has a competing nature with sodiumfor binding and maintaining plant water status, it supplies tolerance against salt stress[7].

Exogenous applications of potassium likepotassium chloride (KCl), monopotassium phosphate (KH_2PO_4), potassium nitrate (KNO_3) and potassium sulfate (K_2SO_4), which act as fertilizers, are widely known for assisting nutrient uptake, water use efficiency, photosynthesis and growth performance so that they reduce salt stress[8,20]. Potassium also prolongs the turgidity and reduces the adverse effect of reactive oxygen species (ROS)[15]. The present study describes the potential of potassium (in form of potassium nitrate KNO_3) to improve the productivity of mung bean under salt-affected conditions in pot trials under ambient conditions.

Material and Methods

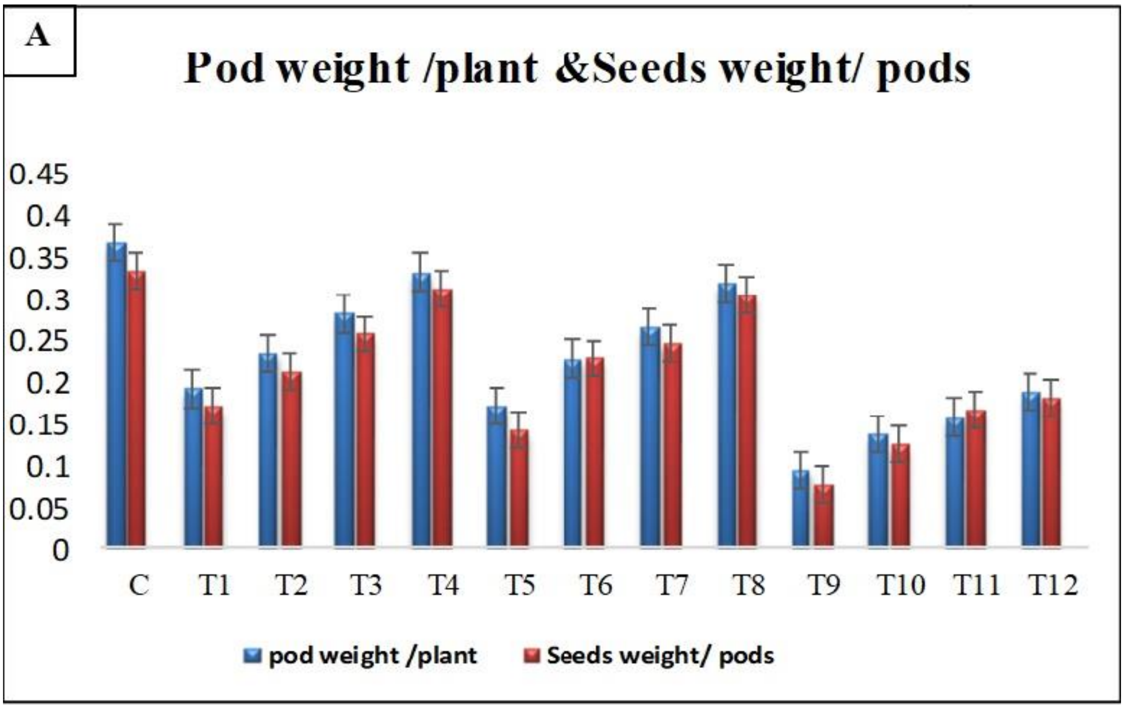
Experimental site and collection of plant material: The study was carried out during Kharif season i.e. (April 22-2023) under net house conditions in Department of Botany, Kurukshetra University, Kurukshetra, Haryana. Earthen pots were filled with mixture of soil with farmyard manure in ratio of 6:1 and the pots were arranged in a simple randomized block design (RBD). A pot experiment was conducted to know the effect of potassium application on the growth, yield and photosynthetic parameters of Mung bean [*V. radiata* (L.) R. Wilczek] variety (MH-1142) under salinity stress.

The seeds were procured from CCSHAU, Hisar. Healthy and uniform size seeds were selected for sowing; these seeds were surface sterilized with 0.01% mercuric chloride solution for 2-5 minutes followed by multiple washings with double distilled water (DDW). Pots were divided in 13 groups, each with five replicates and seven seeds were sown per pot.

Treatments: Treatments were done with two factors i.e. NaCl and KNO_3 application and different operations for treatments are given in table 1 with their codes. Sodium chloride (NaCl) at different concentrations: S_1= (50 mM), S_2= (75 mM) and S_3= (100mM) were applied after sowing. Control was without salt stress and only irrigated with equal volume of tap water. Three different doses of potassium were used in this experiment. The doses were: optimum/recommended Dose (OD) (K_1) = (0.24 g/pot), high dose (HD) (K_2) = (0.40 g/pot), very high dose (VAD) (K_3) = 0.48 g/pot) in the form of potassium nitrate (KNO_3).

Table 1
T1…T13 are treatments, C (control), S_0 (no salt stress), K_0 (no potassiumapplication) S_1= (50 mM), S_2= (75 mM), S_3= (100 mM), (K_1) = (0.24 g/pot), (K_2) = (0.40 g/pot), (K_3) = 0.48 g/pot).

S.N.	Treatment	Code	Operations Details
1	T_1	C (S_0 + K_0)	Only irrigation with tap water
2	T_2	S_1	(50 mM) NaCl
3	T_3	K_1+S_1	50 mM NaCl+0.24 g/pot KNO_3
4	T_4	K_2+S_1	50 mM NaCl+0.40 g/pot KNO_3
5	T_5	K_3+S_1	50 mM NaCl+0.48 g/pot KNO_3
6	T6	S2	75 mM NaCl
7	T_7	K_1+S_2	75 mM NaCl+0.24 g/pot KNO_3
8	T_8	K_2+S_2	75 mM NaCl+0.40 g/pot KNO_3
9	T_9	K_3+S_2	75 mM NaCl +0.48 g/pot KNO_3
10	T10	S_3	100 mM NaCl
11	T11	K1+S3	100 mM NaCl+0.24 g/pot KNO_3
12	T12	K_2+S_3	100 mM NaCl+0.40 g/pot KNO_3
13	T13	K_3+S_3	100 mM NaCl+0.48 g/pot KNO_3



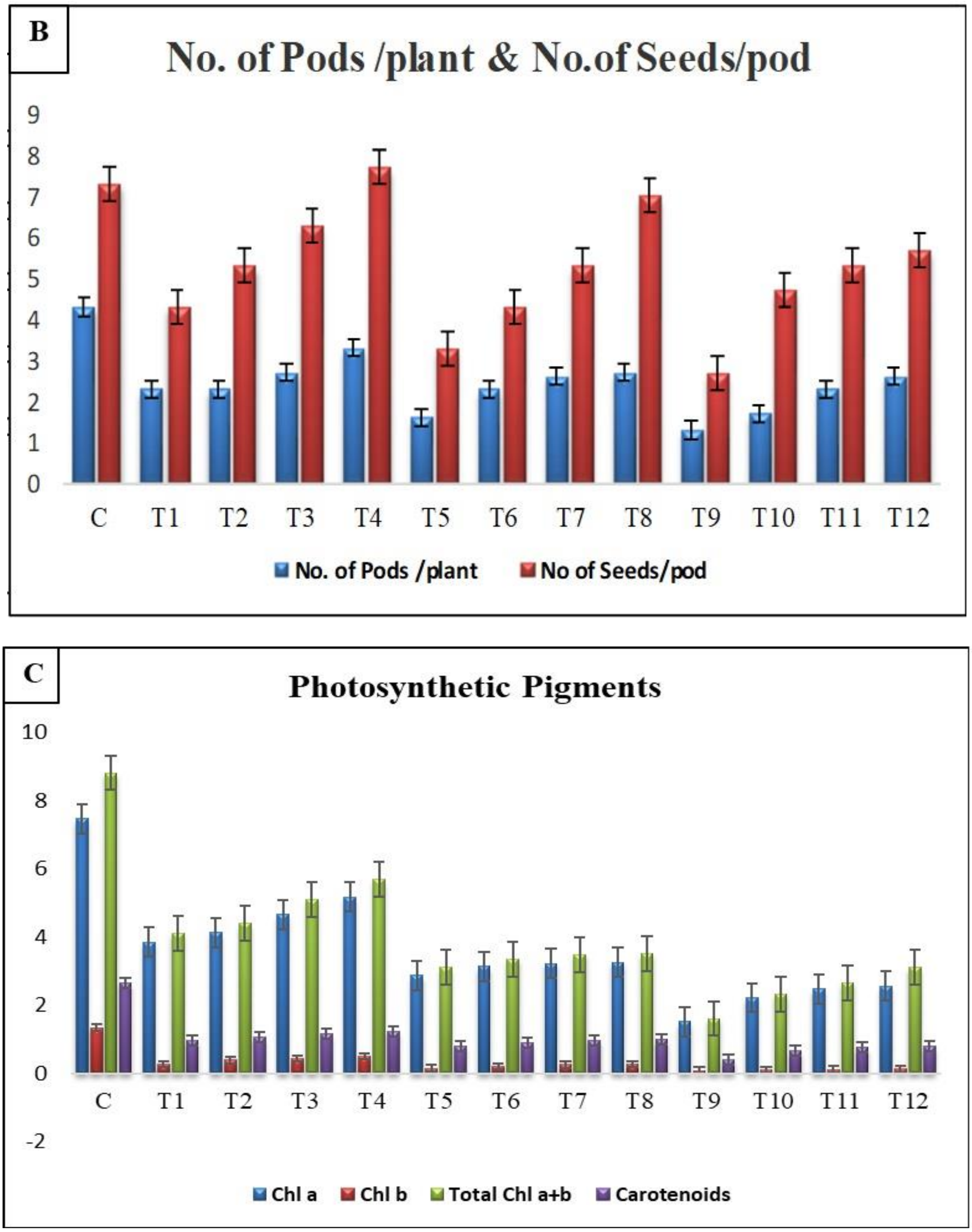


Fig. 1: Effect of salinity stress + Potassium nitrate (KNO_3) in mung bean on different yield and photosynthetic parameters: (A) Pod weight /plant and Seeds weight/ pods, (B) No. of Pods/Plant and No. of seeds /pod, (C) Photosynthetic pigments under various concentrations

Growth Parameters: Fresh and dry weight of leaves, shoots and roots was measured with help of weighing balance while, shoot and root length were analysed with help of measuring scale. Leaf area was estimated with help of leaf area meter.

Yields Parameters: Number of pods per plant and number of seeds per pod were recorded manually and their weight was recorded by electronic weighing balance.

Photosynthetic pigments estimation: Chlorophyll-a, chlorophyll-b, total chlorophyll and carotenoids were determined by the Arnon method.

Statistical analysis: The data of different treatments was subjected to Analysis of Variance (ANOVA) using SPSS 16 statistical software. To determine the significance of results between different treatments and Tukey's, multiple comparison tests were performed at significance level in different treatments. The mean values along with standard errors and least significant differences ($P<0.05$) are presented in the table and figures. The histogram is prepared with help of R- studio and the correlation between different parameters was interpreted.

Results and Discussion

The increasing levels of salinity significantly suppress plant growth and yield as obvious from the results (Table 2). The exogenous application of potassium (0.48 gm) significantly increased shoot length, shoot dry weight, root fresh weight, root dry weight etc. under all levels of salinity stress.

Salt stress decreased the shoot length of mung bean by about 11 % in the case of S_1 (17.9±0.318 cm), 15% in case of S_2 (17.1±0.153 cm) and 19% in case of S_3 (16.1±0.589 cm) salinity level in comparison to control. Application of KNO_3 increased the shoot length considerably. In salinity group S_1, the maximum shoot length was recorded in treatment K_3+S_1 (21.8±0.472 cm), while in salinity group S_2 and S_3, the maximum shoot length was recorded for treatments K_3+S_2 (23.5±0.318 cm) and K_3+S_3 (19.7±0.612 cm) respectively.

Thus, shoot length and root length were found to decrease with increasing salinity level from S1 to S3 and significantly alleviated by potassium application. Our results are in accordance with Sharma et al[34] who observed that at 2mM phosphorus level, the shoot and root length recorded maximum despite of salinity stress. Dolatabadian et al[10] indicated that plant height, shoot and root weight and plant biomass were significantly decreased by salt stress.

Root length also decreased significantly with increasing salinity levels from 0 to 100 mM NaCl. Application of potassium from 0 to 0.48 g levels increased root length significantly under saline conditions. The reduced water potential in the cells and the ensuing water scarcity in the root zone due to salt stress prevented the roots from taking up enough water and nutrients that are necessary for optimal plant development[21]. Salt stress caused a significant reduction in the shoot fresh weight of the mung bean by about 36.63% in S_1, 55% in S_2 and 67% in S_3 compared to their respective controls. Plant treated with KNO_3 increased the fresh weight of shoot progressively with maximum shoot fresh weight recorded in treatment K_3+S_1 (0.502±0.012 gm).

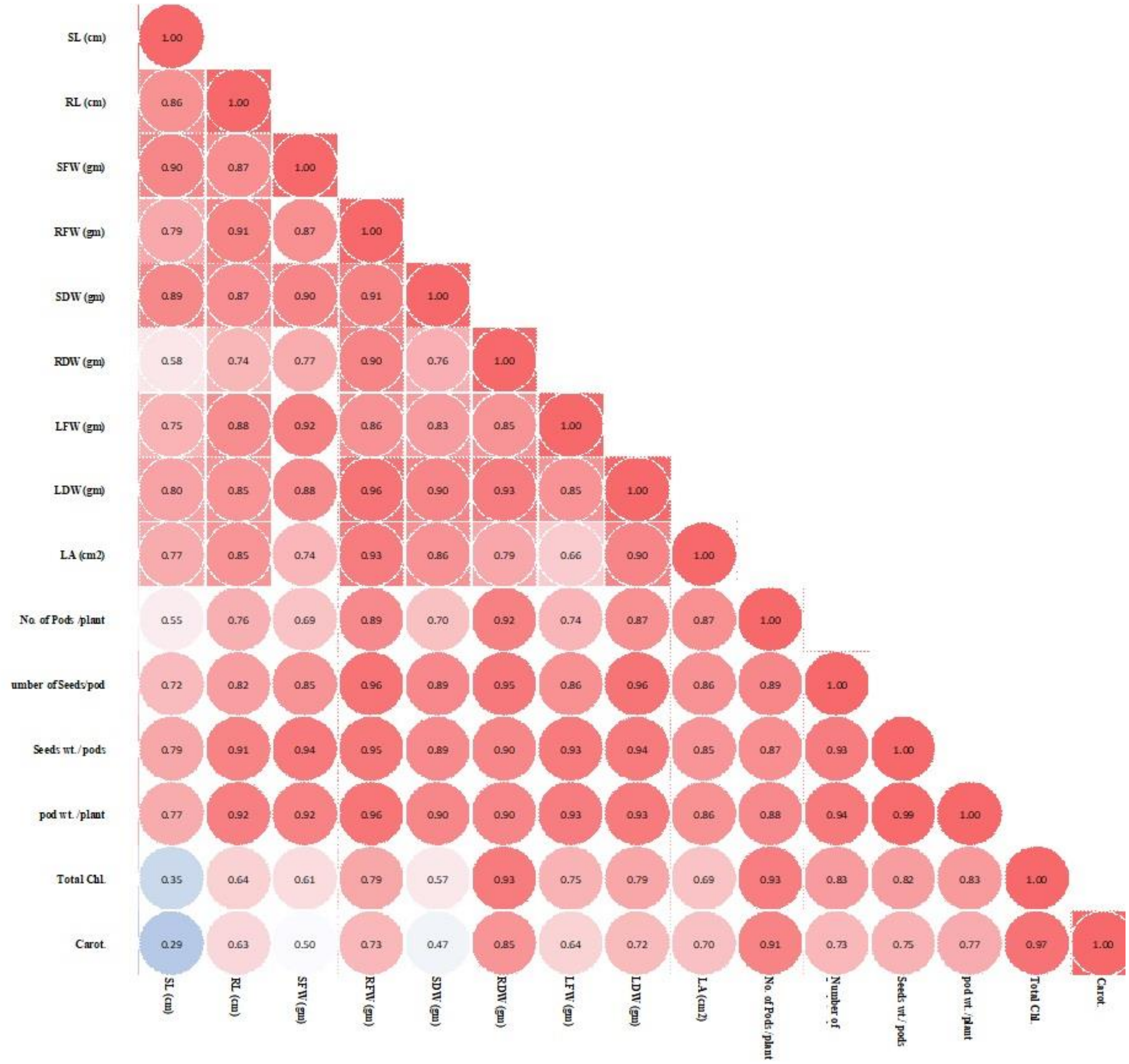


Fig. 2: Histogram showing correlation between different growth, yield and photosynthetic parameters

Table 2
Effect of different salinity stress levels (S) and foliar application of potassium (K) on different growth parameters of mung bean.

Treatments	SL (cm)	RL (cm)	SFW (gm)	RFW (gm)	SDW (gm)	RDW (gm)	LFW (gm)	LDW (gm)	LA (cm^2)
Control	20± 1.041	11.3± 0.376	0.404± 0.062	0.179± 0.005	0.153± 0.010	0.056± 0.004	0.244± 0.004	0.054± 0.004	9.5± 0.764
S1	17.9± 0.318	7.9± 0.285	0.256± 0.025	0.084± 0.005	0.111± 0.011	0.031± 0.001	0.205± 0.004	0.028± 0.002	4.8± 0.153
K1+S1	20.6± 0.185	8.8± 0.666	0.366± 0.003	0.104± 0.002	0.135± 0.005	0.036± 0.003	0.215± 0.002	0.043± 0.005	06± 0.289
K2+S1	20.9± 1.539	9.3± 0.318	0.419± 0.067	0.145± 0.001	0.163± 0.001	0.044± 0.004	0.231± 0.005	0.046± 0.005	7.3± 0.167
K3+S1	21.8± 0.472	9.6± 0.481	0.502± 0.012	0.169± 0.021	0.186± 0.011	0.048± 0.006	0.242± 0.003	0.053± 0.006	8.1± 0.185
S2	17.1± 0.153	6.6± 0.120	0.232± 0.019	0.056± 0.002	0.099± 0.001	0.017± 0.001	0.137± 0.002	0.021± 0.001	4.7± 0.441
K1+S2	21.4± 0.777	8.3± 0.448	0.415± 0.034	0.091± 0.007	0.129± 0.003	0.029± 0.004	0.192± 0.011	0.036± 0.002	6.2± 1.202
K2+S2	22.5± 0.252	11.1± 1.317	0.428± 0.032	0.141± 0.008	0.144± 0.007	0.031± 0.004	0.217± 0.003	0.041± 0.001	7.5± 0.288
K3+S2	23.5± 0.318	12.1± 1.826	0.452± 0.025	0.153± 0.015	0.193± 0.004	0.033± 0.005	0.233± 0.002	0.045± 0.002	8.7± 0.441
S3	16.1± 0.589	4.9± 0.317	0.134± 0.022	0.044± 0.004	0.075± 0.008	0.015± 0.002	0.095± 0.009	0.017± 0.001	04± 0.288
K1+S3	18.3± 0.120	6.6± 0.436	0.199± 0.038	0.073± 0.006	0.113± 0.011	0.021± 0.002	0.111± 0.001	0.029± 0.003	06± 0.288
K2+S3	18.7± 0.802	7.03± 1.067	0.213± 0.019	0.089± 0.003	0.115± 0.001	0.023± 0.002	0.112± 0.003	0.031± 0.006	6.5± 0.288
K3+S3	19.7± 0.612	7.1± 0.260	0.229± 0.013	0.092± 0.001	0.122± 0.009	0.029± 0.004	0.129± 0.004	0.034± 0.004	07± 0.288
F-Stat value	1.53	1.44	0.116	0.565	2.31	1.5	0.062	0.5	0.37
LSD value	2.45	5.6	0	0.11	0	0.02	0	0.04	0

Abbreviations used: SL= shoot length; RL= root length, SFW= shoot fresh weight; RFW= root fresh weight; SDW= shoot dry weight; RDW= rot dry weight; LFW= leaf fresh weight; LDW= leaf dry weight; LA= leaf area

The shoot dry weight also decreased with increasing salinity stress as compared to the respective control and the highest decrease was observed at 100 mM salinity level by about 51% followed by 35% at 75 mM and 27.45% at 50 mM. Potassium treatment increased the shoot dry weight of the crop significantly where the maximum enhancement in shoot dry weight was observed in case of K_3+S_1, K_3+S_2 and K_3+S_3 with respect to their controls S_1, S_2 and S_3 respectively. The root fresh weight significantly decreased by about 46.93 %, 68.71 % and 75.41 % under 50 mM, 75 mM and 100 mM of salinity respectively as compared to the control, yet potassium treatment increased the fresh weight of the root.

The maximum enhancement in root fresh weight was observed in treatments K_3+S_1 (0.169±0.021 gm), K_3+S_2 (0.153±0.015 gm), K_3+S_3 (0.092±0.001 gm) in their respective groups. The root dry weight showed remarkable reduction with increasing salinity while potassium treatment enhanced the dry weight of the roots. Despite of this, the control (0.056±0.004 gm) plants without any treatments were found to have maximum root dry weight. The main effect of salinity is to generally limit plant development. Previous research on mung bean plants has shown a systematic decrease in a number of growth metrics when salinity stress increases including plant height, shoot and root length, dry matter and root, stem and leaf area[19].

The similar trend was recorded for leaf area where control (9.5±0.764 cm^2) plants were having maximum leaf area without any treatment and salinity level progressively decreased the leaf area. The fresh weight of the leaf significantly decreased with increasing salt stress by about 15.98 %, 43.85 % and 61 % at 50 mM, 75 mM and 100 mM respectively of salinity levels as compared to the respective control. Potassium treatment significantly increased the leaf fresh weight while a less significant increase was observed by K_1 at all salinity levels. The similartrend was observed in case of leaf dry weight where increasing level of salinity causes a decrease in dry weight of leaf while accommodation of potassium proliferates the leaf dry weight.

In the current case, the salinity has a severe effect on leaf area where minimum leaf area was recorded in S_3 followed by S_2 and S_1 while the potassium application mitigates the effect of salinity.

Mahmood et al[23]found that the incorporation of both organic and inorganic sources such as FYM, poultry manure and chemical phosphorus and potassium fertilizer resulted in an augmentation of leaf area in mung bean. Potassium brought a significant expansion ofleaf area under control as well as stress conditions at all stages as it greatly improved the retention of water and the plant tissues under conditions of water stress as well[17].

In response to different salt stress levels, the number of pods/plant and no. of seeds/pod decreased with increasing salinity and the supply of potassium (KNO_3) enhanced salt stress by increasing the number of pod and seeds. The maximum no. of pods/plant (4.3±0.333) and no. of seeds/plant (7.3±0.333) were recorded in control without any treatment. Likewise, other parameters, the maximum number of pods andseeds were recorded in pots supplied with maximum concentration of potassium along with NaCl, with their respective controls.

The results indicated that salt stress decreased the seed weight per pod by 48.65% at 50 mM, 57.35% at 75 mM and 77% at 100 mM salinity stress and increased significantly by applying KNO_3. The maximum increase was observed in plants treated with K_3 (96.47%) at 75 mM salinity level while, K_1 shows a less significant increase at 100 mM salt stress level. The obtained result indicated that salt stress decreased pod weight per plant with increasing salinity from 0 mM to 100 mM salinity levels over control and KNO_3 significantly increased the pod weight per plant in all given treatments. The minimum no. of pods/plant were recorded in S_3 treatment (1.3±0.333) followed by S_2 (1.9±0.333) and S_1 (2.3±0.333).

Likewise, the no. of seeds/pod decreases as the salinity level increased from S_1 to S_3. But the no. of pods and no. of seeds increases in treatments where the potassium has been supplied despite in presence of high salinity.

Our results for no. of pods/plant and no. of seeds/plant are in accordance with Shakil Ahmed[33] who also reported the reduced yield in mung bean under salt stress. The possible reason for reduced pods and seed number is due to reduced efficiency to fill the developing seeds in severe salinity stress. A decrease in yield parameters under saline conditions was also observed by Karim et al[16] in black gram and mung bean, Hasan et al[12] in Mung bean, Abd EI-Wahed et al[2] in barely and Sabagh et al[30] in soybean.

Ali et al[3] have investigated the effect of various application rates of potassiumon, the yields and quality of mung bean production and they declared that the number of seeds per pod and the number of pods per plant were significantly enhanced by the application of potassium. Abbas et al[1] reported in mung bean plant that the number of pods/ plant and seed yield were significantly affected by potassium application as compared to controls. With the increase in potassium level, there was corresponding increase in no. of pods, no. of seeds, pod weight and seed weight in a study by Singh and Kuhad[37].

The total chlorophyll content dramatically declined in severe salinity stress of S_1 (1.612±0.066). But a progressive increase in photosynthetic pigments was observed after supplementation of potassium. Highest increase was observed in K_3 treatment where 0.48 gm of potassium was applied. Maximum carotenoid content was observed in case of control (2.658±0.028) without any treatments and progressively decreased with salinity treatments S_1 (50 mM), S_2 (75 mM) and S_3 (100 mM). The maximum carotenoid content was recorded in K_3+S_1 (1.233±0.001) application after which the increase in potassium did not result in increment in carotenoid content. Consistent with these results, Kaya et al[18] showed that salinity-induced decrease in chlorophyll could be significantly reduced by foliar application of K fertilizer.

The values of total chlorophyll content in current research were found to be minimum in S_3 (1.612±0.066) followed by S_2 (3.111±0.047) and S_1 (4.119±0.060) while the application of potassium improves total chlorophyll content in mung bean with highest chlorophyll content was observed in K_3+S_1, K_3+S_2 and K_3+S_3. Stress from salinity caused membranes in the chloroplasts of vulnerable plants to expand which affected the amount of chlorophyll in the plant. One explanation for these phenomena could be the presence of excess ions (Na+ and Cl-) in the leaves, which would cause the chlorophylls to be depleted[4]. The present investigation showed a clear interaction of potassium to overcome the deleterious effect of salinity stress in mung bean.

Conclusion

In the current study, the obtained results demonstrated that different levels of NaCl stress inhibited the growth, yield and photosynthetic parameters of mung bean [*V. radiata*] MH-1142. As salt stress increased, there was a gradual reduction in the measured parameters and the most significant effects were observed at S3 (100 mM) salinity levels at all measured parameters. Chlorine and sodium ions caused toxicity to the plant at high salt concentrations which unfavourably affected its photosynthetic activities.

Application of potassium seems to overcome the adverse effects of salinity stress and ameliorate the growth, yield components and photosynthetic pigments of mung bean grown under salt stress. The treatment with 0.48 g of KNO_3 showed better results at all salinity levels. Thus, to achieve improved crop yield under higher concentrations of NaCl, there is a need for a higher amount of potassium consumption.

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