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EVALUATION OF SALT TOLERANCE MUNGBEAN GENOTYPES AND MITIGATION OF SALT STRESS THROUGH POTASSIUM NITRATE FERTILIZATION

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ABSTRACT

Salinity is one of the most destructive factors among the abiotic stresses, which limit the crop production considerably and ability of salt tolerance among the genotypes of a species may be varied. Appropriate nutrients application on salinity condition may alleviate its harmful effects. To achieve the aforementioned objectives, two pot experiments were performed to find out salt tolerant mungbean genotype (s) and to alleviate salinity stress through nutrient management. Eleven mungbean genotypes viz. BARI mung 2, BARI mung 3, BARI mung 4, BARI mung 5, BARI mung 6, BINA moog 1, BINA moog 2, BINA moog 5, BINA moog 6, BINA moog 7 and BINA moog 8 were screened out in three salinity levels (0, 75 and 125 mM) of NaCl. The germination of all mungbean genotypes was delayed and germination percentage was reduced with increasing level of salinity. Among the varieties, BINA moog 8 showed the best performances in terms germination and seedling growth (length, fresh and dry weights of shoot and root) and BARI mung 2 showed the least performances under saline environment. The results revealed that BINA moog 8 was the most tolerant and BARI mung 2 was the most sensitive genotype. BINA moog 8 was also used for alleviation of salinity through potassium nitrate (KNO3) application under five salinity levels (Control, 50mM salt, 50 mM salt + 10 mM KNO3, 50 mM salt + 20 mM KNO3 and 50 mM salt + 30 mM KNO3). Plants treated with 30 mM KNO3 under 50 mM salt stress produced the best growth and yield contributing characters viz. length of stem and root, no of branches plant-1, fresh and dry weight of leaf, stem and root, pods plant-1, seeds pod-1, 1000 seed weight performed better level while the least performance in respect of above traits were observed without KNO3 without stressful conditions (50 mM NaCl). Therefore, BINA moog 8 can be grown successfully at mild stress (50 mM NaCl) with application of 30 mM KNO3.

KEYWORDS:

Alleviation, potassium nitrate, screening, salt tolerance, *Vigna radiate*

INTRODUCTION

Salinity is a major abiotic constraint on crop production and adversely affects the social-economic fabric of many developing countries. In Bangladesh, over 30% of the net cultivable areas lie in the coastal area, which approximately 53% are affected by varying degrees of salinity [1]. The arable land is continuously transforming into saline (1-3% per year) either due to primary/natural salinity or secondary/irrigation-associated salinity, and is expected to increase up to 50% land loss by 2050 [2]. Salt accumulation in root zone decreases grain yield but K enhances the yield and quality of grain as well [3]. Salt stress (NaCl) caused decrease in water potential, osmotic potential, transpiration, stomatal conductance and hydraulic conductance, germination, shoot and root lengths and fresh mass [4], dry matter and biomass and root, stem and leaf weights, plant height [5], seed germination and seedling vigor [6], total soluble sugars, proteins, free amino acids [7], soluble protein [8] and caused large accumulation of sodium and magnesium ions and reduced calcium and potassium concentration in the shoots and roots. Proline content increased with increasing salinity and accumulated in different organs of mungbean plants under salt induced stress [9, 10]. The productivity of mungbean crop is drastically reduced (>70% yield loss) due to salinity stress [11].

Mungbean (*Vigna radiata* L.) is an important eco-friendly short term leguminous crop of dry land agriculture [12]. As a pulse crop of Bangladesh it ranks fifth place by both in acreage and total production. It contributed 6.5% of the total pulse production in our country and average yield was about 0.28 m ton per acre [13]. Being protein, mineral and vitamin rich source, it is a crucial ingredient in Bangladesh diets. The extreme increase in population in Bangladesh needs to increase the total yield of legume crops in order to overcome the protein deficiency through summer mungbean cultivation in the newly reclaimed lands especially under saline conditions of such soil. Several attempts have been made for improving the salt tolerant capacity of mungbean plants. It is reported that nutrients management successfully increased the salt tolerance of many crop plants [14, 15]. [16] reported that KNO3 alleviated soil salinity of mungbean. The study was, therefore, carried out to find out the suitable salt tolerant mungbean variety/s and degree of tolerance under different salinity levels, and to alleviate the salt stress effect mungbean plant through nutrient management.

MATERIALS AND METHODS

Plant material and growth conditions. Seeds of different mungbean genotypes were collected from Bangladesh Agricultural Research Institute (BARI) such as BARI mung 2, BARI mung 3, BARI mung 4, BARI mung 5, BARI mung 6, and Bangladesh Institute of Nuclear Agriculture (BINA) such as BINA moog 1, BINA moog 2, BINA moog 5, BINA moog 6, BINA moog 7 and BINA moog 8. Seeds were sown in plastic pots in sand growth medium by twelve seeds from each and placed in Agronomy laboratory, Hajee Mohammad Danesh Science and Technology University, Bangladesh.

Salinity applications. Sodium chloride (NaCl) at different concentrations (0, 75 and 150 mM) was applied after sowing. To avoid osmotic shock, the seedlings were adjusted to their final NaCl level by imposing the salinity treatment in two days intervals while the control was without salt stress i.e. irrigated with only normal water.

Measurement of germination, emergence and growth attributes. For the determination of seed germination in response to salt stress seeds of the eleven mungbean genotypes were sown in plastic pots (7.5 cm × 11.3 cm). The pots were placed at Agronomy Laboratory, HSTU, Dinajpur under room temperature. Germination was calculated after seven days. The germination percentage [17], germination index [18] and vigour index [19] were calculated by their prescribed methods. The lengths of shoot and root, fresh & dry weights of shoot and root were recorded up to 168 hr of germination [20]. The seedlings were uprooted and washed with distilled water to remove sand particles. Shoot and root lengths of five randomly selected seedlings from each replicate were measured. After the measurement of root and shoot lengths, the shoots were separated from the roots and wrapped with filter paper to remove any drop of water present on their leaves and shoots. Then these were placed on the digital balance for the calculation of fresh weights. The same procedure was used for the calculation of root fresh weights. After measuring the fresh weights shoots and roots were placed in paper bags and dried in an oven at 70°C until reach constant weights. The seedling height reduction and relative dry weight (RDW) was calculated according to [21].

Salinity and potassium application. Another set of pot experiment was performed at Agronomy Laboratory, HSTU, Dinajpur to study the effect of potassium on the performance of BINA moog 8. The treatments are 0 (control) + 50 mM salt solution, 50 mM salt + 10 mM KNO_3, 50 mM salt + 20 mM KNO_3 and 50 mM salt + 30 mM KNO_3. Each plastic pot (18 cm deep × 19 cm dimeter) was filled-up with air-dried sandy loam soil. Pots were moistened with tap water up to the emergence of seedling. After seedling establishment, tap water in control pots and 12.5 mM NaCl solution were applied in salt-treated pots up to four days and 25 mM for next four days for hardening of seedlings before applying actual treatments. Control plants were irrigated with tap water up to maturity. The salt solutions and nutrient with salt solutions were applied till maturity. Plant growth and yield contributing parameters were measured at the harvesting stage. Root exudation rate (mg plant-1) was measured as previously described [16].

Statistical analysis. All obtained data were statistically analyzed according to the technique of analysis of variance (ANOVA) for factorial experiment in completely randomized design (CRD) with three replications as followed by [22] using means of MSTAT-C package. Least Significant Difference (LSD) method was used to test the differences between treatment means at 5 and 1% level of probability as described by [23].

RESULTS AND DISCUSSION

Screening of mungbean genotypes for salt tolerance. (1) Effect of salt stress on seed germination and vigor. Mungbean genotypes responded significantly when increasing salinity levels. The best performances on highest germination percentage, germination and vigor index under saline conditions were reported BINA moog 8 while BARI mung 2 gave the poorest result in this regard (Table 2). [24] observed genetically diverse arrangements resistant to salt stresses within the mungbean varieties. [25] were also reported that seed germination, length of plumule and radicle were decreased with increasing level of salinity, reduction being maximum BARI mung 2 and least in BINA moog 8. It was reported that, salinity stress conditions caused negative effects during germination stages in soybean [26].

The results showed that increasing salinity levels to 75, 125 mM NaCl significantly reduced the germination percentage, germination and vigor indices compared to the control (Table 1). Saline condition reduces the ability of seed to absorb water, causing rapid reduction in germination rate and inducing many metabolic changes. Germination reduction under salinity stress might be due to this fact that dormancy increases in crop seeds as well under salinity stress [27]. Seed germination may be affected by salinity through either creating external osmotic potential or toxic effect of Na+ and Cl- ions as reported by [28, 29].

(2) Effect of salt stress on seedling growth. Shoot and root length decreased significantly with increasing salinity levels from 0 to 75 and 125 mM NaCl. (Table 1). These results are in agreement with the findings of [30] who reported that salinity reduces plant growth and development through nutritional imbalance. The plant dry matter yield declined with salinity stress [31]. However, increasing salinity levels to 75, 125 mM NaCl significantly reduced seedling height. Salt decreased the water potential due to creating the osmotic stress in the root zone of seedlings. Reduction in seedling height of mungbean under salt stress resulted from combination of ion toxicity and altered water relation that caused large accumulation of sodium and reduced potassium concentration, decreased transpiration, stomatal conductance and hydraulic conductance with increasing salinity as reported by [4]. BINA moog 8 showed the longest shoot and root length while the shortest shoot and root was recorded in BARI mung 2 (Table 2). BINA moog 8 showed the highest seedling height (61.62%) while the shortest seedlings (125.4%) were recorded in BARI mung 6, which was statistically similar to that of BARI mung 5. The differences in seedling height reduction might be due to the varietal response of mungbean varieties to salinity [32].

TABLE 1
Effect of salinity on germination, emergence and growth attributes of mungbean

Treatment	Germination percentage (%)	Germination index (%)	Vigor index	Shoot length (cm)	Root length (cm)	Seedling height reduction (%)	Shoot fresh weight (g)	Root fresh weight (g)	Shoot dry weight (g)	Root dry weight (g)	Total dry weight (g)	Relative dry weight (%)
T1	92.86a	100.0a	2270a	20.32a	8.04a	0.00c	4.03a	0.88a	0.50a	0.12a	0.62a	100.0a
T2	66.43b	71.73b	1403b	12.72b	4.81b	62.36b	2.77b	0.68b	0.37b	0.07b	0.44b	69.62b
T3	49.07c	52.40c	782.3c	6.86c	2.85c	203.6a	2.19c	0.48c	0.30c	0.05c	0.36c	52.68c
LSD	0.73	0.70	19.55	0.21	0.12	1.44	0.09	0.01	0.01	0.01	0.01	2.98
CV %	2.49	2.22	3.11	3.79	5.57	3.84	7.39	3.20	5.74	11.87	7.22	9.51

The figures in a column having common letter(s) do not differ significantly at 5% level of significance as per DMRT

Where, **T_1**= Control, **T_2**= 75 mM salt, **T_3**= 125 mM salt

TABLE 2
Response of different mungbean genotypes to salt stress

Treatment	Germination Percentage (%)	Germination index (%)	Vigor index	Shoot length (cm)	Root length (cm)	Seedling height reduction (%)	Shoot fresh weight (g)	Root fresh weight (g)	Shoot dry weight (g)	Root dry weight (g)	Total dry weight (g)	Relative dry weight (%)
BARI mung 2	57.50i	71.53h	1176h	10.21g	4.48h	92.61d	2.02h	0.48g	0.25f	0.04e	0.27g	66.5d
BARI mung 3	60.83h	74.64ef	1299g	11.64f	4.60gh	98.66c	2.17gh	0.49g	0.27f	0.04e	0.31f	70.24cd
BARI mung 4	65.00f	73.06g	1379f	12.20 e	4.78fg	107.7b	2.26fg	0.52f	0.32e	0.04e	0.36e	51.99e
BARI mung 5	68.17e	76.98cd	1437e	13.09d	4.87ef	122.7a	3.10e	0.62e	0.36d	0.06de	0.42d	69.9cd
BARI mung 6	78.25b	78.65b	1529d	13.87c	5.24cd	125.4a	3.91b	0.79cd	0.53b	0.10c	0.63b	74.79bc
BINA moog 1	62.42g	69.94i	1284g	11.44f	4.61gh	79.69f	2.12gh	0.49g	0.27f	0.04e	0.31f	73.72bc
BINA moog 2	67.58e	68.96i	1364f	12.35e	4.69f-h	82.74e	2.38f	0.54f	0.30e	0.07cd	0.38e	78.83ab
BINA moog 5	72.50d	73.44fg	1527d	13.99c	5.09de	79.98f	3.50d	0.78d	0.43c	0.08cd	0.52c	84.26a
BINA moog 6	73.92c	75.81de	1628c	14.93b	5.42c	62.02g	3.59cd	0.81c	0.44c	0.10c	0.54c	79.45ab
BINA moog 7	77.17b	78.15bc	1703b	15.33b	5.95b	62.10g	3.70c	0.84b	0.53b	0.12b	0.66b	81.21a
BINA moog 8	80.67a	80.67a	2008a	17.27a	7.82a	61.62g	4.23a	1.18a	0.61 a	0.19a	0.80a	84.99a
LSD	1.40	1.34	37.43	0.40	0.23	2.75	0.17	0.02	0.02	0.02	0.02	5.70
CV %	2.49	2.22	3.11	3.79	5.57	3.84	7.39	3.20	5.74	11.87	7.22	9.51

(3) Effect of salt stress on plant biomass. Salt stress significantly reduced the plant fresh and dry biomass in all tested genotypes (Table 3). Genotype BINA moog 8 showed the maximum salt tolerance potential in terms of having the least percent reduction in plant fresh weight at all imposed salinity levels. However, the genotype BARI mung 2 proved to be highly salt sensitive showing the lowest plant fresh weight at 75 and 125 mM NaCl with respect to control. Similarly, the plants subjected to salinity stress exhibited the significant decrease in plant dry weights but maximum reduction was caused by 125 mM NaCl stress (Table 2 and 3). The genotypes, BINA moog 8 had the highest relative plant dry weight (%) over the control, whereas BARI mung 2 found to be the most severely affected genotypes in this regard. The gradual reduction in germination percentage, plant height, shoot and root length, shoot and root weights, total dry matter, total biomass with progressive increase in salinity stress as reported earlier by [32, 33] in mungbean, and [26, 34] in soybean plants.

Varying degree of genetic diversity among the mungbean varieties resistant to salt stress might be due to substantial practical value for studying the mechanism of salt tolerance and for the delivery of genetic resources for salinity in breeding programs [24]. Thus, the differences observed among mungbean cultivars in final germination index might be a result of the genetic basis and heredity variation among the eleven cultivars under present study.

TABLE 3
Effect of salinity on germination, emergence and growth attributes of mungbean genotypes

Interaction (Varieties × Treatments)	**Germination Percentage (%)**	**Germination Index (%)**	**Vigor index**	**Shoot length (cm)**	**Root length (cm)**	**Seedling height reduction (%)**
BARI mung 2 × T_1	80.25c	100.0a	1846g	16.02j	7.05d	0.00o
BARI mung 3 × T_1	81.50c	100.0a	2035 e	18.33gh	7.11d	0.00o
BARI mung 4 × T_1	89.25b	100.0a	2180d	19.81f	7.44d	0.00o
BARI mung 5 × T_1	88.75b	100.0a	2369c	22.14c	7.47d	0.00o
BARI mung 6 × T_1	99.50a	100.0a	2513b	23.44b	7.97c	0.00o
BINA moog 1 × T_1	89.25b	100.0a	1962f	17.25i	7.27d	0.00o
BINA moog 2 × T_1	98.00a	100.0a	2084e	18.72g	7.32d	0.00o
BINA moog 5 × T_1	98.75a	100.0a	2318c	20.92e	8.05c	0.00o
BINA moog 6 × T_1	97.50a	100.0a	2340c	21.01de	8.24c	0.00o
BINA moog 7 × T_1	98.75a	100.0a	2466b	21.70cd	9.12b	0.00o
BINA moog 8 × T_1	100.0a	100.0a	2855a	24.21a	11.47a	0.00o
BARI mung 2 × T_2	57.50l	71.43ef	1084m	9.46no	4.09g	65.60 k
BARI mung 3× T_2	64.25hi	78.84b	1211l	10.99m	4.15g	66.71k
BARI mung 4× T_2	67.50f	76.06c	1227kl	11.01m	4.32g	79.97j
BARI mung 5× T_2	68.00f	76.96bc	1238kl	11.12m	4.35g	99.26i
BARI mung 6× T_2	73.00de	73.38de	1344j	12.00l	4.802f	95.23i
BINA moog 1 × T_2	59.25kl	66.39h	1210l	10.95m	4.177g	57.18l
BINA moog 2 × T_2	62.00ij	63.27i	1291jk	11.88l	4.26g	58.40l
BINA moog 5 × T_2	64.75gh	65.60h	1452i	13.81k	4.34g	50.73m
BINA moog 6 × T_2	67.50f	69.23fg	1624h	15.31j	4.98f	37.72n
BINA moog 7 × T_2	72.00e	72.92de	1683h	15.46j	5.57e	40.06n
BINA moog 8 × T_2	75.00d	75.00cd	2063e	17.89hi	7.89c	35.08n
BARI mung 2 × T_3	34.75q	43.17l	596.4r	5.13t	2.31m	212.2e
BARI mung 3 × T_3	36.75pq	45.09l	651.4qr	5.60st	2.54j-m	229.3d
BARI mung 4 × T_3	38.25p	43.11l	728.8p	5.77r-t	2.60i-m	243.2c
BARI mung 5 × T_3	47.75n	53.99k	705.2pq	6.00rs	2.81h-l	268.9b
BARI mung 6 × T_3	62.25h-j	62.57i	730.4p	6.15rs	2.97h-j	281.0a
BINA moog 1 × T_3	38.75p	43.43l	680.6 pq	6.11rs	2.39lm	181.9g
BINA moog 2 × T_3	42.75o	43.63l	715.8pq	6.46r	2.48k-m	189.8f
BINA moog 5 × T_3	54.00m	54.71k	810.8o	7.23q	2.89h-k	189.2f
BINA moog 6 × T_3	56.75l	58.21j	921.0n	8.46p	3.04hi	148.3h
BINA moog 7 × T_3	60.75jk	61.53i	959.2n	8.81op	3.17h	146.3h
BINA moog 8 × T_3	67.00fg	67.00gh	1105m	9.69n	4.12g	149.8h
LSD	2.42	2.32	64.83	0.70	0.40	4.77
CV %	2.49	2.22	3.11	3.79	5.57	3.84

TABLE 3
Continued

Interaction (Varieties × Treatments)	Shoot fresh weight (g)	Root fresh weight (g)	Shoot dry weight (g)	Root dry weight (g)	Total dry weight (g)	Relative dry weight (%)
BARI mung 2 × T_1	2.51k-m	0.66j	0.34j-l	0.07e-i	0.41ij	100.0a
BARI mung 3 × T_1	2.87ij	0.68j	0.37ij	0.07e-i	0.44hi	100.0a
BARI mung 4 × T_1	3.00h-j	0.74hi	0.47fg	0.08d-h	0.55f	100.0a
BARI mung 5 × T_1	4.10d	0.85f	0.53e	0.08d-g	0.61e	100.0a
BARI mung 6 × T_1	5.40b	0.93de	0.66ab	0.19b	0.85b	100.0a
BINA moog 1 × T_1	2.69j-l	0.69j	0.35jk	0.07e-i	0.42ij	100.0a
BINA moog 2 × T_1	3.17g-i	0.74hi	0.40hi	0.08d-g	0.49gh	100.0a
BINA moog 5 × T_1	4.87c	0.93de	0.52e	0.09d-f	0.61e	100.0a
BINA moog 6 × T_1	4.905c	0.97d	0.55de	0.13cd	0.68d	100.0a
BINA moog 7 × T_1	4.83c	1.02c	0.61bc	0.19b	0.81bc	100.0a
BINA moog 8 × T_1	5.98a	1.50a	0.60a	0.26a	0.95a	100.0a
BARI mung 2 × T_2	1.97o-q	0.49l	0.22q-s	0.05e-j	0.20o	50.38 j
BARI mung 3× T_2	1.98o-q	0.49l	0.23p-s	0.04f-j	0.27l-n	60.47g-j
BARI mung 4× T_2	2.01op	0.50l	0.26n-q	0.04f-j	0.30l	55.52ij
BARI mung 5× T_2	2.95h-j	0.61k	0.28m-o	0.07e-h	0.35k	57.78h-j
BARI mung 6× T_2	3.53ef	0.78gh	0.51ef	0.03g-j	0.54f	63.88f-i
BINA moog 1 × T_2	2.02op	0.49l	0.25o-r	0.05e-j	0.30l	70.77d-g
BINA moog 2 × T_2	2.07n-p	0.57k	0.30l-n	0.08d-h	0.38jk	78.76cd
BINA moog 5 × T_2	3.27f-h	0.81g	0.47fg	0.08d-h	0.55f	90.07ab
BINA moog 6 × T_2	3.46e-g	0.86f	0.45g	0.09d-f	0.54f	79.78b-d
BINA moog 7 × T_2	3.51e-g	0.80g	0.51ef	0.10de	0.61e	75.88c-e
BINA moog 8 × T_2	3.75e	1.13b	0.60cd	0.18b	0.78c	82.54bc
BARI mung 2 × T_3	1.59r	0.29n	0.19s	0.01j	0.20o	49.27j
BARI mung 3 × T_3	1.65qr	0.29n	0.21rs	0.01j	0.22no	50.26j
BARI mung 4 × T_3	1.79p-r	0.30n	0.22q-s	0.01ij	0.24m-o	44.25k
BARI mung 5 × T_3	2.25m-o	0.40m	0.27m-p	0.02h-j	0.30l	49.48j
BARI mung 6 × T_3	2.79jk	0.67j	0.43gh	0.08d-g	0.51fg	60.49g-j
BINA moog 1 × T_3	1.66qr	0.29n	0.20rs	0.01j	0.21o	50.39j
BINA moog 2 × T_3	1.91o-r	0.31n	0.21rs	0.07e-i	0.28lm	57.72h-j
BINA moog 5 × T_3	2.36l-n	0.59k	0.31k-m	0.07d-h	0.39jk	62.72f-i
BINA moog 6 × T_3	2.41lm	0.60k	0.32k-m	0.08d-h	0.40i-k	58.58h-j
BINA moog 7 × T_3	2.76jk	0.70ij	0.46g	0.09d-f	0.55f	67.76e-h
BINA moog 8 × T_3	2.97h-j	0.90e	0.54e	0.14bc	0.68d	72.42c-f
LSD	0.31	0.04	0.04	0.04	0.04	9.88
CV %	7.39	3.20	5.74	11.87	7.22	9.51

The figures in a column having common letter(s) do not differ significantly at 5% level of significance as per DMRT
Where, **T1**= Control, **T_2**= 75 mM salt, **T_3**= 125 mM salt

Alleviation of salt stress through potassium nitrate fertilization. (1) Potassium increased improve morphological characters. The morphological parameters of mungbean seriously affected by salt stress (Table 4). The applications of potassium overcome the adverse effects of salt stress and improve morphological parameters of salt stress. The length of shoot and root progressively increased with increasing potassium level under saline condition. With the application of K, the number of fruit bearing branches plant^{-1} showed an increasing tendency under saline condition (Table 4). Foliar application of potassium nitrate to the salt treated plants may reduce toxic ions uptake as well as improve K and N status of salt treated plants resulting better plant growth [35].

(2) Potassium increased biomass production in different plant parts. In this study leaf, petiole, stem and root fresh and dry weight were measured at maturity. Salinity negatively influenced all the fresh and dry weights remarkably (Table 4). Reduction in growth and total dry matter production under saline condition was previously reported in [4, 36, 37]. Reduction in turgor pressure for plants exposed to salinity might be the major cause of growth reduction in excessive accumulation of an internal ion concentration [38]. The fresh and dry weights of plant parts *viz*. leaves, stems and roots increased with the application of K under saline condition (Table 4). These findings are in conformity with that of [16] who reported that application of K improves water relations and growth of plants as well. [39] reported that the supplementary potassium reduced the effects of salt stress on the growth of plants and better for high biomass production of mungbean genotype.

(3) Potassium increased exudation rate significantly under saline condition. Salinity decreased exudation rate substantially. The minimum root exudation rate (55.40 mgh^{-1}) was observed at 50 mM saline condition. Application of potassium from 0 to 30 mM levels increased root exudation rate significantly under saline condition (Table 4). Salinity induced reduction in exudation rate was also observed in mungbean [40]. Elemental K has a marked effect on exudation rate. [41] concluded that K$^+$ promotes the loading of the sieve tube companion cell complex with assimilates, thus decreasing the water potential in the phloem sap and inducing an increased water uptake to the sieve cell companion cell components. That may result in a stronger push and increase the phloem exudation. [42] reported that the beneficial effects of K to diminish salinity effects in cotton might be due to improved plant water status, as well as the status of better mineral nutrient relationship. The present study also proved that salinity decreased the exudation rate of mungbean substantially and application of K increased exudation rate significantly under saline condition.

(4) Potassium fertilization increased mungbean yield attributes significantly under salinity stress. Salt stress led to a significant reduction in yield attributes of mungbean. Reduction in yield components under saline condition reported previously in mungbean [4, 43, 44, 45, 46, 47, 48, 49, 50]. Potassium application increased the yield parameters significantly under saline condition (Table 5). The higher seed yield plant^{-1} due to application of potassium might be due to higher number of seeds pod^{-1} and greater seed size [16, 51]. [52] observed that potassium application not only enhanced the availability of other nutrient but also increased the photosynthetic activity in chickpea. Transportation of photosynthates from source to sink might be the main reason for increase in number of seed per pod [52]. This study concluded that the maximum seed yield plant^{-1} (1.82 g) was obtained when the mungbean genotype was fertilized at the rate of 30 mM potassium under 50mM NaCl salty soil.

TABLE 4
Effect of salinity and potassium levels on morphological characters of mungbean

Salinity level (mM)	Potassium level (mM)	Shoot length (cm)	Root length (cm)	Branch number	Shoot fresh wt (g)	Shoot dry Wt (g)	Root fresh wt (g)	Root dry wt (g)	Leaf fresh wt (g)	Leaf dry wt (g)	Petiole fresh wt (g)	Petiole Dry Wt (g)	Root exudation rate (mgh^{-1})
0	**0**	37.79a	10.63a	4.58a	3.05a	0.74a	0.91a	0.48 a	2.05a	0.71a	0.62a	0.08a	116.3a
50	**0**	25.65d	7.32b	1.81d	1.50d	0.41d	0.61d	0.19 c	0.74d	0.37e	0.12d	0.036a	55.40e
50	**10**	29.93c	8.85ab	2.95c	2.02c	0.51c	0.61d	0.22 c	0.98c	0.48d	0.23c	0.043a	69.78d
50	**20**	34.66b	10.20a	3.25bc	2.45b	0.61b	0.73c	0.36 b	1.23b	0.57c	0.42b	0.046a	78.55c
50	**30**	35.92ab	10.40a	3.68b	2.59b	0.70a	0.82b	0.39 b	1.24b	0.63b	0.48b	0.065a	87.70b
LSD		2.51	1.99	0.58	0.33	0.06	0.05	0.05	0.22	0.05	0.07	0.05	4.02
CV %		5.08	13.94	11.96	9.48	7.37	4.91	6.15	11.75	3.73	12.52	13.34	3.28

TABLE 5
Effect of salinity and potassium levels on yields and yield contributing character of mungbean

Salinity levels (mM)	Potassium levels (mM)	Pods /plant	Seeds /plant	Seed yield /plant (g)	1000-seed wt (g)
0	**0**	9.60a	48.25a	2.12 a	38.82a
50	**0**	4.97d	17.51e	0.66e	32.76d
50	**10**	5.03d	24.58d	0.98d	32.90d
50	**20**	6.02c	35.85c	1.21c	34.02c
50	**30**	7.52b	41.08b	1.82b	36.83b
LSD		0.44	2.85	0.14	0.793
CV %		4.38	5.65	6.46	1.50

The figures in a column having common letter(s) do not differ significantly at 5% level of significance as per DMRT

CONCLUSIONS

The present study demonstrated that impact of salinity on seed germination and initial growth stage of mungbean. Application of potassium seemed promising to overcome the adverse effects of salt stress and to improve the morphological parameters, yield and yield components of mungbean grown under salt stress.

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