Salinity Tolerance of Blackgram and Mungbean: I. Dry Matter Accumulation in Different Plant Parts

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ABSTRACT : Dry matter (DM) accumulation in different plant parts of two *Vigna spp*., blackgram (*Vigna mungo*) and mungbean (*Vigna radiata*), was compared at different levels of salinity. Two varieties of each of blackgram (Barimash-1 and Barimash-2) and mungbean (Barimung-3 and Barimung-4) were grown with 50, 75 and 100 mM NaCl solutions and tap water as a control till maturity. The DM accumulation in all plant parts of the two crops decreased with the increasing salinity levels. The reduction was severe in mungbean compared to blackgram. On an average mungbean produced only 3% grain yield compared to 37% in blackgram at 100 mM NaCl. The salinity induced growth reduction was relatively less in Barimash-2 than that in Barimash-1. In mungbean, the relative DM production of Barimung-3 was greater than Barimung-4. The extent of biomass reduction due to salinity in different plant parts was not similar. At maturity the rank of biomass accumulation (at 100 mM NaCl) in different plant parts of blackgram was in decreasing order by seeds pod^{-1} (97%), branch plant^{-1} (88%), 1000-grain weight (79%), plant height (72%), pods plant^{-1} (50%), leaf weight and root mass (both 49%) and stem weight (48%). In mungbean, the rank was in decreasing order by 1000-grain weight (57%), leaf weight (54%), plant height (52%), seeds pod^{-1} (50%), branch plant^{-1} (41%), root weight (34%), stem weight (24%) and pods plant^{-1} (6%). Therefore, salinity reduced grain yield more than straw and roots of the *Vigna* spp., and blackgram is relatively more salt-tolerant than mungbean.

Keywords : blackgram, mungbean, dry matter production, salinity tolerance.

The variation in salinity tolerance between crops and/or varieties of a crop is well known (Maas and Hoffman, 1977; Maliwal and Paliwal, 1982). A judicial selection of a crop for saline soils is, therefore, considered as an important management option to minimize yield loss due to salinity. Blum (1988) pointed out that, for sustainable crop production in the saline soils, it is more important to select a salt tolerant crop rather than a variety of a susceptible crop. Blackgram (*Vigna mungo*) and mungbean (*V. radiata*), the two important grain legumes in the tropics, belong to the same genus *Vigna* though different species. There is a high possibility that these two crops might show a great variability in their salt tolerance. Variation in tolerance level between closely related crops should be of helpful in crop improvement program.

Salinity induced changes in water relation, ionic balance and accumulation of essential elements exert deleterious effects on growth and yield of glycophytes. In general, all the plant organs are affected by salinity, though the extent of growth reduction of the organs is not similar. For example, leaf biomass was less affected by salinity than the shoot in alfalfa (Hoffman *et al.*, 1975), grain yield was decreased more than straw in triticale (Karim *et al.*, 1992), while the roots were damaged more than shoot in root crops (Hoffman and Rawlins, 1971). Salinity tolerance is a complex physiological process and the reasons for such dissimilar response of different plant parts of a single plant to salinity are not fully understood. An understanding on the pattern of salinity induced damage of individual plant part is necessary for crop improvement program for saline soils agriculture.

Although salinity tolerance of blackgram and mungbean has been studied earlier (Ashraf and Karim 1990; Balasubramanian and Sinha, 1976), insufficient attention has been paid to evaluate their comparative salt tolerance under a common condition in a comprehensive study. This study was initiated to evaluate the relative salt tolerance of *Vigna spp*., blackgram and mungbean, in relation to biomass distribution in different plant parts. In the following paper we will report the mineral ions accumulation pattern in plants of the two *Vigna* species as influenced by salinity.

MATERIALS AND METHODS

Two varieties of each of blackgram (Barimash-1 and Barishmash-2) and mungbean (Barimung-3 and Barimung-4) were used in the experiment. All the varieties were released from Bangladesh Agricultural Research Institute. They are high yielding varieties with semi-synchronous fruiting pattern and extensively grown in Bangladesh.

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Pre-soaked four bold seeds were sown in each earthen pot (24 cm × 27 cm) containing 10 kg air-dried soil, and kept inside vinylhouse under natural light. Compost (1/4th of the soil by volume) and 0.27-0.28-0.20 g of urea, triple super phosphate and muriate of potash per pot were incorporated uniformly with the soil. After seedling establishment two uniform and healthy plants were kept and allowed to grow in each pot. All cultural and plant protection measures were taken as and when needed.

Saline solutions were prepared artificially by dissolving calculated amount of NaCl with tap water to make 50, 75 and 100 mM NaCl solutions. Tap water was used as control. The electrical conductivity (EC) of the respective solutions was equivalent to 5, 7.5 and 10 dS/m, and 0.1 dS/m for tap water (control). At the appearance of 1st trifoliate leaf i.e. ten days after emergence, sufficient quantity of salt solution was applied in 8 pots per treatment. The salt solutions were applied with an increment of 12.5 mM in every alternate day till respective concentrations were attainted. Plants in control group were irrigated with tap water. The salt solutions were applied till maturity. EC values of the respective treatments were monitored throughout the experimental period. Eight plants per variety per treatment were harvested at 50% flowering and the remaining eight plants per treatment were harvested at maturity. Roots were carefully cleaned with running tap water. The plant samples were then separated into roots (roots + nodule), stem (stem + branch +petiole), upper three leaves of the main stem, rest of lower leaves and reproductive organs at harvest. After recording growth characters, the samples were oven-dried to a constant weight at 70°C and the dry weight of the organs recorded separately. Data for different treatments were compared with those in the control treatment to calculate the relative growth reduction of individual plant part. The data were analyzed following completely randomized design and the mean values were separated by LSD test.

RESULTS AND DISCUSSION

In general, salt affected leaves became yellow (chlorosis), especially the older leaves. The symptom appeared earlier in mungbean than in blackgram. We have recorded data on different plant characters at 50% flowering as well as at maturity. In general, the salt induced damage to plant characters was higher at maturity than at 50% flowering in both the *Vigna* crops. However, the trend of salt damage was similar at both the stages. For simplicity of presentation the data recorded at 50% flowering will not be presented but will be discussed when it is needed.

Growth response

Plant height

Salinity decreased plant height significantly in both black-

Table 1. Effect of NaCl on different plant characters of blackgram and mungbean varieties at maturity.

NaCl (mM)	Plant height (cm)		Branch plant^{-1} (no)		Leaf area (cm^2 plant^{-1})	
	Blackgram					
	B_1†	B_2	B_1	B_2	B_1	B_2
0	48.5	44.38	6.25	5.88	1692	1431
50	44.63(92)	44.25(100)	5.63(90)	5.75(98)	1596(94)	1257(88)
75	41.63(86)	43.13(97)	5.63(90)	5.38(92)	1456(86)	1149(80)
100	31.75(65)	35(78)	5.13(82)	5.5(94)	923(55)	972(68)
LSD(0.05)	3.37		NS		206.7	
CV %	5.45		9.92		10.63	
	Mungbean					
	M_3	M_4	M_3	M_4	M_3	M_4
0	67.75	68.75	3.5	3.63	1075	947
50	58.75(87)	47.88(70)	3.25(93)	2.63(72)	730(68)	686(72)
75	49.25(73)	42.13(61)	3(86)	2.5(69)	700(65)	377(40)
100	38.13(56)	33.13(48)	1.63(47)	1.25(34)	391(36)	172(18)
LSD(0.05)	4.42		0.26		75.28	
CV %	5.86		15.63		7.99	

†B_1: Barimash-1, B_2: Barimash-2, M_3: Barimung-3, M_4: Barimung-4
Values presented in parentheses indicate percent value to the control.

gram and mungbean, though the reduction was more in mungbean than in blackgram (Table 1). Moreover, longer the plant exposure to salinity higher was the height reduction (plant height at flowering vs. at maturity). The plant height at control was higher in Barimash-1 than in Barimash-2 but at 100 mM NaCl the result was opposite. In mungbean a greater reduction was observed in Barimung-4 than in Barimung-3 at higher level of salinity. Clearly higher reduction in plant height was recorded in the two mungbean varieties compared to blackgram varieties, and the heights with 100 mM were 78%, 65%, 56% and 48% (to the control) in Barimash-2, Barimash-1, Barimung-3 and Barimung-4, respectively. Salinity induced reduction in plant height is a common phenomenon and was reported earlier for different crops, e.g. mungbean (Shi *et al.*, 1997), mungbean, cowpea and soybean (Egeh and Zamora, 1992).

Branch number per plant

Salinity did not influence significantly the production of branch plant^{-1} in blackgram though salinity >75 mM seriously decreased the number of branch plant^{-1} in mungbean. In mungbean varieties, the number of branch of Barimung-4 was reduced more than Barimung-3. The degree of reduction in the number of branch plant^{-1} was much higher at maturity compared to that at flowering in mungbean, though blackgram did not show such different response. Therefore, *V. mungo* is much more salt tolerant in this character than *V. radiata*.

Leaf area

The leaf area per plant, measured at flowering, decreased progressively with the increasing salinity (Table 1), and the reduction was conspicuously greater in mungbean than in blackgram. At all levels of salinity the absolute leaf area plant^{-1} was higher in blackgram than in mungbean. Barimash-1 maintained higher absolute as well as relative leaf area (% to the control) up to 75 mM NaCl, though at the highest level of salinity Barimash-2 performed better than Barimash-1. In mungbean, the leaf area reduction was noticeably greater in Barimung-4 than in Barimung-3. Leaf area of Barimash-1, Barimash-2, Barimung-3, Barimung-4 was reduced to 55, 68, 36 and 18 % (of the control) with 100 mM NaCl, respectively.

Salinity, at high concentrations, caused chlorosis on the leaves, which was noticed within 10-12 days in mungbean but much later in blackgram. It indicated that leaf of mungbean was more sensitive to salinity than that of blackgram. At 75 and 100 mM NaCl necrotic spots were noticed on the older leaves and many leaves were killed. Balasubramanian and Sinha (1976) reported that salinity retarded the growth of leaves in cowpea and mungbean. The leaf nacrosis, as observed at high salt concentration, was probably due to the toxic effect of excessive accumulation of Na^+ as well as Cl^- or may be due to the hydration of protein and protoplasm to some extent (Mangal and Lal, 1988).

Table 2. Effect of NaCl on dry matter production (g plant^{-1}) in different plant parts of blackgram and mungbean varieties at maturity.

NaCl (mM)	Plant parts						Total dry matter	
	Roots		Stem		Leaves			
	Blackgram							
	B_1	B_2	B_1	B_2	B_1	B_2	B_1	B_2
0	1.46	1.43	9	7.41	10.89	9	39.76	33.14
50	1.36(93)	1.37(96)	6.6(73)	6.31(85)	6.91(63)	7.41(82)	30.01(75)	28.90(87)
75	0.92(63)	0.94(66)	6.31(68)	6.6(89)	5.96(55)	7.05(78)	25.59(64)	28.47(86)
100	0.66(45)	0.74(52)	3.59(40)	4.14(56)	4.1(38)	5.32(59)	14.15(36)	18(54)
LSD (0.05)	0.28		0.93		1.44		5.38	
CV %	16.82		10.02		9.92		13.29	
	Mungbean							
	M_3	M_4	M_3	M_4	M_3	M_4	M_3	M_4
0	1.63	1.63	8.37	9.33	5.81	6.65	27.40	30.61
50	0.97(59)	0.68(42)	4.89(58)	4.33(46)	5.46(94)	4.38(67)	14.93(55)	11.20(37)
75	0.80(49)	0.52(32)	4.09(49)	3.38(36)	4.38(75)	4.29(66)	11.51(42)	9.24(30)
100	0.65(40)	0.45(28)	2.53(30)	1.71(18)	3.44(59)	3.2(49)	6.84(25)	6(20)
LSD (0.05)	0.09		0.37		0.82		1.32	
CV%	11.81		12.18		11.73		17.53	

Footnotes are similar to those in Table 1.

Dry matter production in different plant parts

Roots

Salinity, in general, damaged roots of mungbean more than those of blackgram (Table 2). Barimash-1 and Barimash-2 of blackgram, Barimung-3 and Barimung-4 of mungbean produced 45, 52, 40 and 28% root dry weight, respectively (Table 2). The higher root mass of the relatively tolerant varieties of blackgram (Barimash-2) and mungbean (Barimung-3) than sensitive ones presumably contributed for higher shoot growth under saline condition. Although Gill (1990) reported that root dry weight was less affected by salinity than stem and leaf in greengram, the extent of salt induced damage of roots and shoot was not clear in this experiment. Perhaps, differences in experimental methods, salt concentrations, other environmental conditions and variety were responsible for the differences in salinity tolerance. Kumar and Bhardwaj (1981) observed that low concentrations of salinity stimulated root elongation in some mungbean genotypes. However the results of this experiment are in line with Balasubramanian and Sinha (1976) for cowpea and mungbean, and Sudhakar *et al.* (1990) for horsegram who reported that both shoot and root mass were decreased with the increasing levels of salinity.

Stem

Stem biomass production of blackgram was less affected by salinity than that of mungbean (Table 2). In blackgram, Barimash-2 showed less damage to salinity than did Barimash-1. Reduction of stem dry matter begun from 75 mM NaCl in Barimash-2, though a clear reduction was observed in Barimash-1 at the lower level of salinity. In mungbean, a considerable reduction in stem dry matter production was found in Barimung-4 than that in Barimung-3 at all levels of salinity and at both flowering and maturity. At 100 mM NaCl Barimash-1 and Barimash-2 produced 40 and 56% stem mass at maturity, while Barimung-3 and Barimung-4 produced only 30 and 18%, respectively. Salinity induced reduction in stem dry weight also reported earlier by Patil *et al.* (1996) for mungbean, and by Balasubramanian and Sinha (1976) for cowpea and mungbean.

Leaves

As usual, the absolute leaf dry matter accumulation increased with the increasing growing time (flowering vs. maturity). The relative dry matter in leaves decreased seriously with the longer exposure to salinity as well as with the increasing salinity levels. On an average blackgram performed better in this character than mungbean at flowering stage (data not shown). At maturity both the crops showed a more or less similar salt tolerance (in relative terms) in leaf production. At maturity Barimash-2 maintained higher absolute as well as relative leaf mass at all salinity levels compared to Barimash-1. In mungbean, Barimung-3 maintained higher leaf mass than Barimung-4. At maturity both Barimash-2 and Barimung-3 produced the highest relative leaf dry matter (59%) followed by Barimung-4 (49%) at 100 mM NaCl. Barimash-1 showed the least relative salt tolerance (38%) in leaf mass production at 100 mM NaCl salinity (Table 2).

Total dry matter

Clearly higher the salt concentration larger was the reduction in total dry matter production (TDM). The absolute amount of TDM was higher in blackgram than in mungbean (Table 2). In general TDM of mungbean was decreased more than that of blackgram. Within blackgram, Barimash-2 clearly showed higher relative salt tolerance in TDM production than that of Barishmash-1, and the trend was similar at both flowering and maturity. In mungbean, Barimung-4 showed more salt sensitivity than Barimung-3. At 100 mM NaCl Barimash-1 produced only 36% (% to the control), while Barimash-2 produced 54% TDM. On the contrary, Barimung-3 produced 25%, while Barimung-4 only 20% TDM (Table 2 and 3). The decline in vegetative growth might have been associated with the increased osmotic pressure in the root zone, and/or excess accumulation of toxic ions like Na^+ and Cl^- in the plant cells, which were associated with high substrate salt concentration (Prisco and OLeary, 1970). Patil *et al.* (1996) observed that leaf, stem, pod and total dry matter production at all growth stages in mungbean reduced by increasing salinity levels. Reduction in growth, total dry matter production and yield by salinity was also reported by a number of workers (Gill, 1990; Hafeez *et al.*, 1988; Sing *et al.*, 1994).

Yield and yield attributes

Salinity did not influence the days to commence flowering or maturity in either blackgram or mungbean varieties. In general both the crops took more or less similar time to flower, though blackgram took longer time to mature than mungbean. In contrast to this result Siddiqui and Kumar (1985) observed that flowering in pea was delayed by salinity. However, there is a general view that crop maturity period is shortened by environmental stress because of a limited source size due to leaf senescence (Levitt, 1972).

Pods plant^{-1}

Salinity led to a significant reduction in number of pods per plant over control (Table 3). At all levels of salinity, including control, blackgram had higher number of pods plant^{-1} than that of mungbean. The reduction was small in

Table 3. Effect of NaCl on yield components and grain yield of blackgram and mungbean varieties.

NaCl (mM)	Pods plant^{-1} (no.)		Seeds pod^{-1} (no.)		1000-grain wt. (g)		Grain yield (g plant^{-1})		Harvest index	
	Blackgram									
	B_1	B_2	B_1	B_2	B_1	B_2	B_1	B_2	B_1	B_2
0	71	69.50	4.28	4.24	35.02	33.72	10.99	10.69	0.31	0.32
50	70.63(99)	67.63(97)	3.91(91)	4.16(98)	31.48(90)	32.06(95)	9.08(83)	8.71(81)	0.32(103)	0.33(103)
75	60.63(85)	66.38(96)	3.88(91)	4.06(96)	31.19(89)	31.39(93)	7.27(66)	8.48(79)	0.29(95)	0.31(97)
100	28.88(41)	40.63(58)	4.32(100)	3.94(93)	26.32(75)	27.49(82)	3.46(31)	4.6(43)	0.24(79)	0.26(82)
LSD (0.05)	6.72		NS		3.79		0.57		0.05	
CV%	10.47		15.02		8.21		11.61		10.25	
	Mungbean									
	M_3	M_4	M_3	M_4	M_3	M_4	M_3	M_4	M_3	M_4
0	32	40	9.2	6.95	33.06	34.43	9.18	9.47	0.33	0.32
50	11.86(37)	7.5(19)	8.06(88)	5.63(81)	27.80(84)	25.05(73)	2.5(28)	1.28(14)	0.18(54)	0.11(35)
75	6.38(20)	5.13(13)	7.48(81)	5.12(74)	22.74(69)	24.72(72)	1.56(17)	0.72(7)	0.14(42)	0.08(25)
100	1.63(5)	2.25(6)	5.06(55)	3.06(44)	15.30(46)	23.14(67)	0.14(1)	0.54(5)	0.02(6)	0.07(22)
LSD (0.05)	8.06		0.87		0.05		0.97		0.07	
CV%	13.62		16.23		12		14.63		13.03	

Footnotes are similar to those in Table 1.

blackgram up to 75 mM NaCl. At the highest level of salinity, 59% and 42% reduction of pods were observed in Barimash-1 and Barimash-2, respectively. In mungbean a steeper slope of reduction of the number of pods plant^{-1} was found with the increasing salinity levels (Table 3). At 100 mM NaCl only 5% pods plant^{-1} were produced in mungbean. Ram *et al.* (1989) observed that increasing salinity significantly reduced the number of pods per plant in chickpea though the reduction was not significant in mungbean (Patil *et al.*, 1996; Hafeez *et al.*, 1988). Although we did not check the pollen viability or fertilization of flowers, it seems from the results that these factors might be responsible for serious reduction in pod set of the *Vigna* spp.

Seeds pod^{-1}

The reduction in number of seed pod^{-1} due to salinity was not significant in blackgram though a serious reduction in mungbean was obvious (Table 3). In blackgram, the relative seed production pod^{-1} was 100 and 93 % in Barimash-1 and Barimash-2, respectively even at 100 mM NaCl. In mungbean, Barimung-3 produced higher number of seeds pod^{-1} at the control treatment as well as at all levels of salinity. The number of seeds pod^{-1} was 55 and 44% in Barimung-3 and Barimung-4, respectively. The result is in agreement with the earlier report on mungbean (Hafeez *et al.*, 1988), blackgram (Ashraf and Karim, 1990) and chickpea (Siddiqui and Kumar, 1985) that salinity reduced seeds per pod at higher salt concentration. From this experiment it is not clear whether the reduction in seed production in mungbean was due to the disturbance in fertilization or for the translocation of food reserve to the seed after fertilization. In blackgram it was, however, evident that salinity did not disturb the fertilization to form seeds.

1000-grain weight

Under control conditions, the 1000-grain weight of both blackgram and mungbean was more or less similar (Table 3). The 1000-grain weight decreased significantly with the increase in salinity levels and a greater reduction was obvious in mungbean than in blackgram. In blackgram, the reduction was only 25 and 18% in Barimash-1 and Barimash-2, respectively at the highest level of salinity, while in mungbean that was 54 and 33% in Barimung-3 and Barimung-4, respectively. In blackgram, a small reduction of the number of seeds per pod and a significant reduction of 1000-grain weight clearly indicated that salinity slowed the mobilization of assimilates to the seeds. Siddiqui and Kumar (1985), however, reported that more dry matter was partitioned into the seeds at higher level of salinity. Although a remarkable reduction in the size of seeds was observed at higher NaCl concentration in all the cultivars, the mungbean seeds were shrunk at 75 and 100 mM salinity. Our results are at par with those of Uprety and Sarin (1975) in pea, and Lauter and Munns (1981) in chickpea and cowpea. They reported that both number and size of seeds were reduced by the influence of salinity.

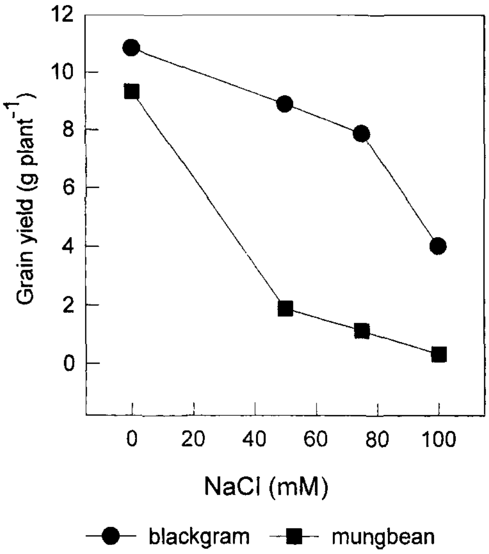

Fig. 1. Average grain yield of mungbean and blackgram as affected by different levels of salinity.

Grain yield

An inverse relationship was noticed between salinity levels and grain yield. Higher the salinity levels the lower was the grain yield per plant. However, Fig. 1 clearly indicates that blackgram was much more salt tolerant than mungbean in terms of grain production. Mean grain yield of blackgram decreased slowly with the increasing levels of salinity till 75 mM NaCl and then sharply from 10.8 g plant^{-1} at control to 4.0 g at 100 mM NaCl. In contrast, the grain yield of mungbean showed a drastic reduction even at 50 mM NaCl and reached from 9.3 g plant^{-1} at control to only 0.3 g plant^{-1} at 100 mM NaCl (Fig. 1). The grain yield of Barimash-1 and Barimash-2 was 31 and 43% (of the control) at 100 mM, while that was only 1 and 5% in Barimung-3 and Barimung-4 (Table 3). Although most of the yield contributing characters was affected by salinity, the serious reduction in number of pods plant^{-1} contributed the most for the yield reduction. The negative relationship between yield and salinity levels was also reported earlier for mungbean (Hafeez *et al.*, 1988; Dubey et al. 1992; Singh *et al.*, 1994), blackgram (Ashraf and Karim, 1990) and chickpea (Ram *et al.*, 1989).

Harvest index

Under non-treated conditions, both the crops showed a similar harvest index (HI). Salt treated plants showed significantly lower harvest index (HI) over the control (Table 3). The HI at 50 mM NaCl was similar to the control in blackgram, though that in mungbean decreased sharply. The findings confirmed the earlier result of Ram *et al.* (1989) that salinity decreased seed yield more than that of biological yield and thus affect H.I.

In conclusion, we have shown that between the two *Vigna spp.* blackgram (*V. mungo*) showed greater salt tolerance than mungbean (*V. radiata*) in terms of both absolute and relative growth performance. Grain yield of both *Vigna* spp. showed the highest salt sensitivity, while seeds pod^{-1} in blackgram, and 1000-grain weight in mungbean affected the least by salinity. In the next paper we will present whether the differential growth responses of the two *Vigna* species are related with their accumulation and distribution pattern of mineral ions in different plant parts.

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