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Respiration, Quantum Yield of Photosynthesis and Transpiration of Two Mungbean Genotypes Differing in Salt Tolerance

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Abstract. The mechanism of salt tolerance in relation to individual leaf growth, transpiration, dark respiration rate, and quantum yield was studied at 0, 50 and 100 mM NaCl solution. At high salt concentration the leaves of BM21 showed higher reduction in growth than those of BM 01. The relative reduction (% of control) of Tr and Dr were less in BM01 than in BM21. The dark respiration rates were less than 1 µmol (CO_2)/m^2/s and accounted for 19 and 32% increase (% of control) at the highest PFD in BM01, while it was 31 and 44% in BM21, respectively at 50 and 100 mM NaCl. More reduced quantum yield in BM21 than BM01 reflects more maintenance costs of energy in repairing injured tissue, enzyme reactions and ion movement.

Keywords: salt tolerance, mungbean, respiration, quantum yield, transpiration

Introduction

The basis of decline in plant growth under saline conditions is poorly understood. It has been suggested that decrease in growth with salinity may be due to increased respiration rate resulting from higher energy requirement (Orcutt and Nilsen 2000; Schwarz and Gale, 1981; Gale, 1975) and reduction of quantum yield of photosynthesis (Seemann and Critchley 1985; Yeo, 1983). Some persons have attributed the depression in growth rate to the combined effects of salinity on photosynthesis and the pattern of carbon allocation (Masojidek and Hall, 1992; Brugnoli and Lauteri, 1991). Another possibility is that increased salinity reduces the photosynthetic surface area available for CO_2 assimilation, i.e., the salinity may reduce the expansion of the leaf surface (Orcutt and Nilsen, 2000). There is increasing evidence that salinity changes photosynthetic parameters, including osmotic and leaf water potential, transpiration rate and leaf temperature (Faruqui, 2002; Kabir, 2002; Islam, 2001; Sultana *et al.*, 1999). In the present study, we compare the effect of NaCl salinity on the components of carbon accumulation in two mungbean genotypes, BM01 and BM21, which differ in their salinity tolerance: dark respiration, quantum yield, transpiration rate and the extension growth of individual leaves.

Materials and Methods

Mungbean seeds of two genotypes, BM01 (tolerant) and BM21 (susceptible), were sown in earthen pots in the vinylhouse at the Environmental Stress Research Site of the Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur. Each pot was filled with 12 kg air-dried soil. Compost (1/4th of the soil volume) and 0.27, 0.28, 0.20 g urea, TSP and MP, respectively, per pot were uniformly incorporated into the soil.The pots were irrigated with tap water until the seedlings were well established. Afterwards tap water in control group and 12.5 mM NaCl solution in salt-treated groups were applied up to three days and 25 mM for the next three days for hardening of seedlings before applying actual treatments. When the trifoliate appeared i.e., ten days after emergence (DAE), the required amount of respective salt solutions (50 and 100 mM) per treatments were applied to 25 pots till harvest.

Dark respiration (0 µmol/m^2/s) was measured using a portable photosynthesis system (LICOR-6200) assembled with an Infrared Gas Analyzer (IRGA) and data logger following the procedure described by Kubota and Hamid (1992) and the leaf chamber was covered with black cloth. The quantum yield for net CO_2 exchange was derermined at intercellular CO_2 concentration which were saturating for photosynthesis and over a photon flux density (PFD) range of 0 and 50 µ mol/m^2/s (photosynthetically active radiation). Each measurement was replicated 3 times. The light source was artificial halogen lamp (OSRAM, HQI-TS 150/NDL). Leaf area was measured with a leaf area meter (Model AAM-7, Hayashi Dehnco Co Ltd., Tokyo, Japan). Specific leaf area (SLA) for individual leaf was calculated as the dry weight per unit leaf area (Leidi and Saiz, 1997).

Results and Discussion

Leaf growth. Salinity reduced the growth of leaves in both the genotypes (Fig.1) and the reduction was more in BM21 as

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*Author for correspondence; E-mail: m58abdulaziz@yahoo.com compared to BM01. However, the genotypes exhibited striking difference in leaf appearance in response to the salt stress. Leaf appearance rate of BM01was insensitive to salt stress, while the appearance rate of BM21 decreased due to salinity. Genotype BM21 failed to produce 8th leaf under saline condition. Green leaf area followed the same trend as leaf fresh and dry weight (Fig. 1). Leaf area per plant was higher in BM21 than in BM01 at all the treatments but the reduction due to salinity was higher in BM21 than that in BM01. Green leaf area per plant was reduced by 43% and 56% over the control in BM01 and BM21, at 100 mM NaCl, respectively. It indicated that leaves of BM21 were more sensitive to salinity than those of BM01. BM01 had a higher SLA than genotype BM21 except under control conditions (Fig. 1). The reduction of SLA at 50 mM was 8 and 34% in BM01 and BM21, while it was 24 and 40% at 100 mM NaCl, respectively. Leaf expansion was inhibited less in BM01 as shown by higher SLA, leaf area and total leaf number at harvest. Beadle (1993) and Leidi and Saiz (1997) found higher relative growth rate in genotypes with leaves of higher SLA (less carbon invested per unit

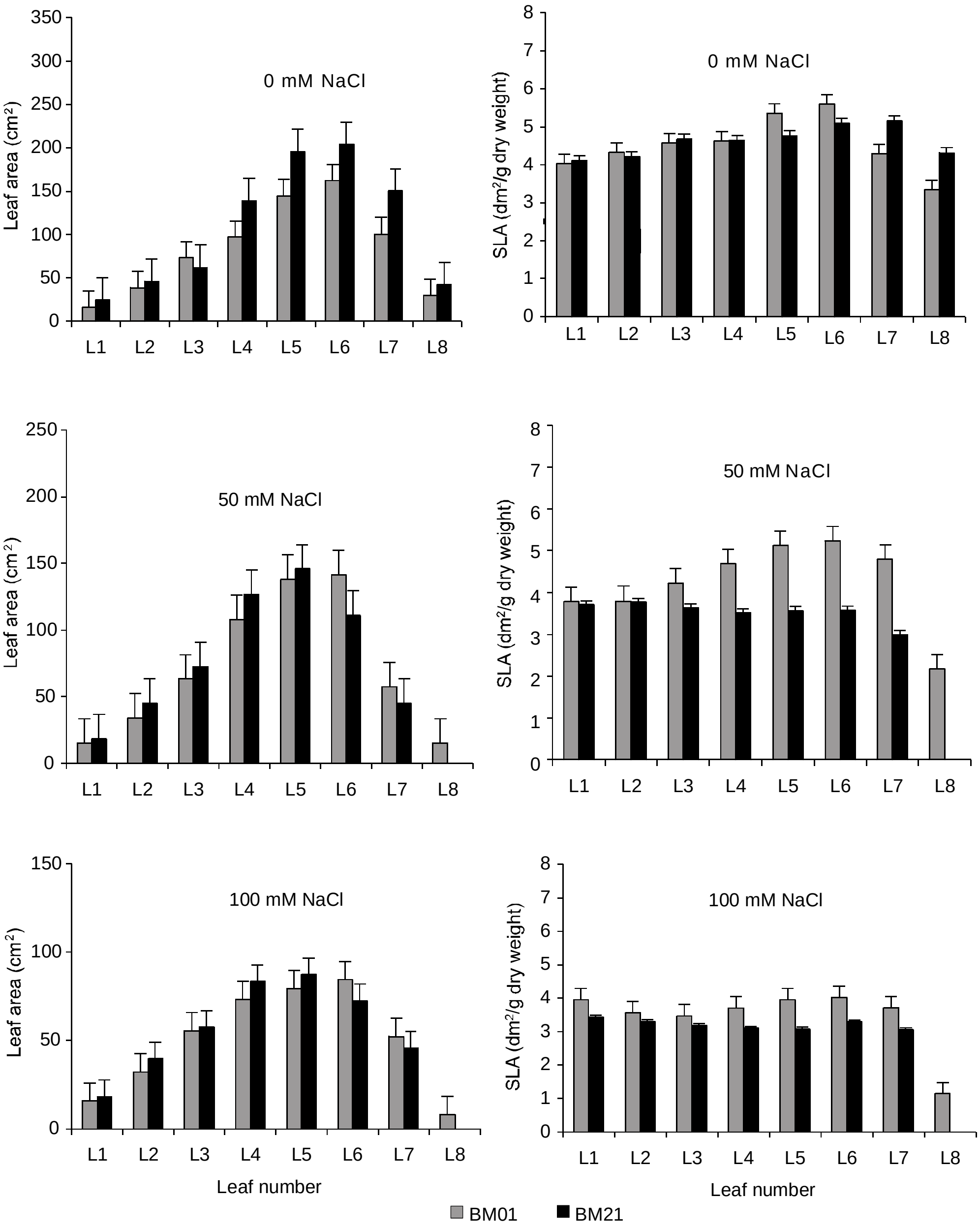

Fig. 1. Leaf area and specific leaf area of individual leaf of BM01 and BM21 as affected by salinity. Error bars represent standard error. Error bars fit within the plot symbol if not shown. SLA = specific leaf area.

of area) under saline condition. This seemed the case of BM01, BM21 under salt stress, as plants of this genotype showed expanding L6, L7 and L8. Genotype BM21 showed a delay in the generation of new leaves with only half of the plants reaching the 7th leaf stage. Sharma (1998) concluded from his study that salinity led to increased leaf diffusive resistance and consequently a decrease in transpiration and increase in leaf temperature. The shift in temperature may play a vital role for tissue desiccation. In addition, increased ionic concentrations in the leaves further aggravated the leaf growth along with tissue dehydration (Leidi and Saiz, 1997; Mangal and Lal, 1988).

Transpiration rate and diffusive resistance. In general, the transpiration rate (Tr) decreased and diffusive resistance (Dr) of both the genotypes increased with increasing levels of salinity (Fig. 2). A weak negative linear relationship ($y = -0.2627x + 3.2283$, $R^2 = 0.4112$) was observed between Tr and Dr. The genotype BM01 showed higher Tr rate and lower Dr than that of BM21 under salt stress condition. The relative reduction (% of control) of Tr and Dr was less in BM01 than that in BM21. Higher transpiration rate of BM01 than that of BM21 indicates that BM01 plants maintained a better water relation than BM21 under salt stress conditions (Orcutt and Nilsen, 2000; Hagemeyer, 1997;). Subbarao *et al.* (1990) observed higher Tr rate in tolerant pigeonpea genotype than salt sensitive one. He reported that the tolerant genotype was able to maintain high transpiration rates, possibly because of the high ability of root system to uptake soil moisture to meet the demands of water required for transpiration under salinity stress. Reduced transpiration rates under salt stress were also observed (Flowers and Yeo, 1995; Munns, 1993; Waisel, 1991).

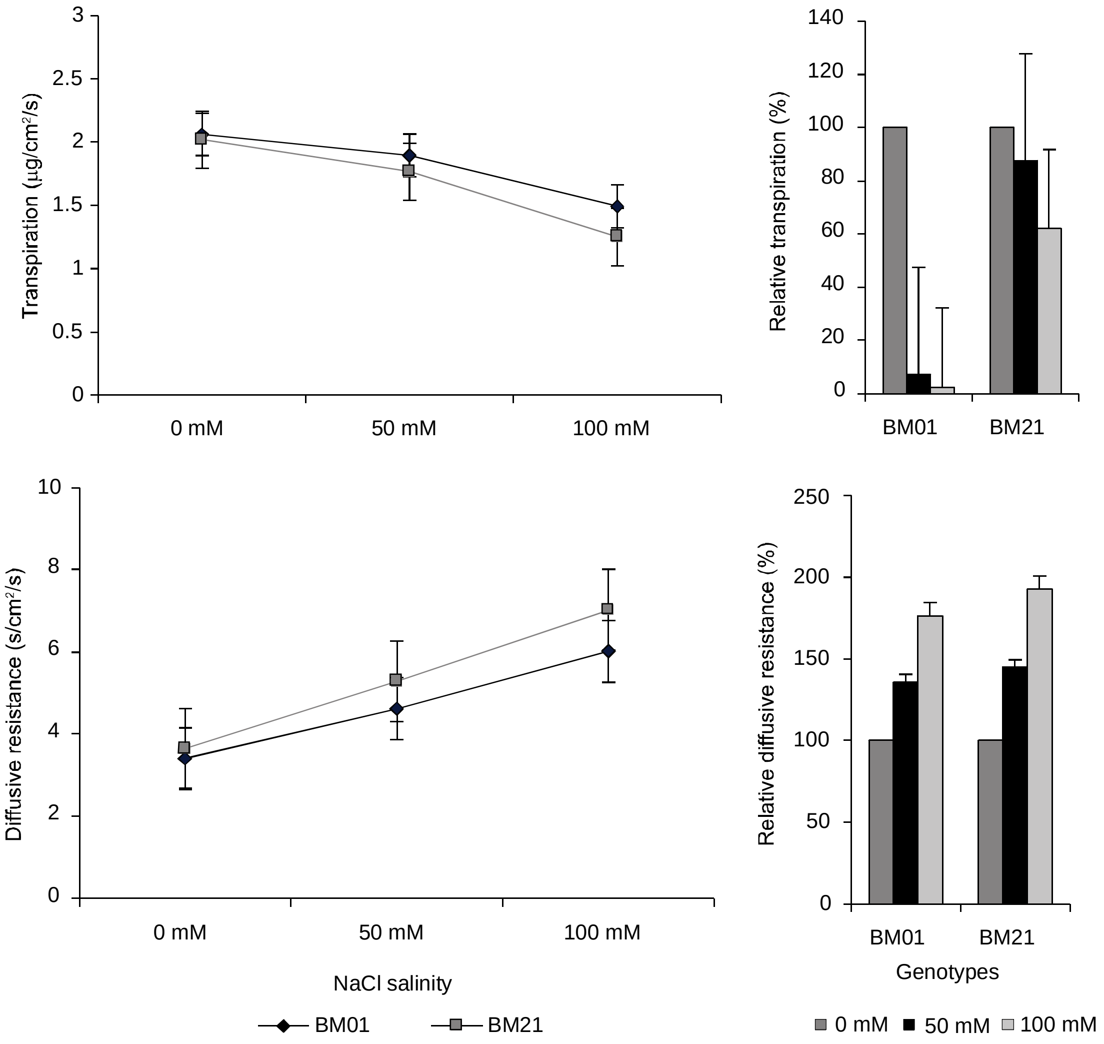

Fig. 2. Transpiration rate, diffusive resistance and their relative values of BM01 an BM21 as affected by salinity. Error bars represent standard error. Error bars fit within the plot symbol if not shown.

Dark respiration rate. The dark respiration rate measured at 0 PFD increased with increasing salinity levels in both the genotypes (Table 1). This increased respiration is generally refered to as salt respiration (Islam, 2001; Datta and Sharma, 1990; Schwarz and Gale, 1981). The respiratory energy may be consumed in repairing the injured tissues and in conducting the active transport processes. Therefore, it has been proposed (Ahmed *et al.*, 1989) that growth inhibition under saline conditions as compared with non-saline condition is partly due to shortage of energy since a considerable amount of energy is consumed in osmotic adjustments. BM21 showed higher relative respiration than BM01. The dark respiration rate was less than 1 µmol (CO_2)/m^2/s and accounted for 19 and 32% increase (% of control) in BM01, while it was 31 and 44% in BM21 at 50 and 100 mM NaCl, respectively. Higher relative respiration in BM21 under salt stress indicates more consumption of respiratory energy in repairing the injured tissues and in conducting the active transport processes. Earlier reports indicated that salinity has little effect on dark respiration of salt tolerant plant (Ahmed *et al.*, 1989; Schwarz and Gale, 1981).

Quantum yield. Quantum yield was estimated from the slope of the PFD response curves in the linear regression between 0 and 50 µmol/m^2/s PFD. A reduction in photosynthetic efficiency with salt stress was observed in the quantum yield for CO_2 fixation (µmol CO_2 fixed/mol absorbed quanta, photosynthetically active radiation) for BM01 and BM21 (Table 1). The quantum yield of leaves from BM01 grown at 100 mM NaCl was approximately 50% below that of control plants, while it was 74% in BM21. Determination of quantum yields at high CO_2 concentration precluded interference from stomatal closure resulting from salinity stress (Seemann and Critchley, 1985; Yeo, 1983). The reduction in quantum yield of photosynthesis with salt stress may constitute at least a partial basis for the reduction in the rate of photosynthesis over the CO_2 saturtion portion of the Pn curve. Salt might have a direct effect upon processes involved in light harvesting, electron transport and/or photophosphorylation resulting in decrease in the quantum efficiency of photosynthesis (Seemann and Critchley, 1985). Another possibility is that the reduced quantum yield reflects energy utilization associated with ion movement. Energy costs of ion movement have been estimated by Yeo (1983), and in some cases it is calculated that ion transport in glycophyte, is in fact, more costly than that in halophyte (Gale *et al.*, 1967). Therefore, more reduced quantum yield in BM21 than BM01 reflects more maintenance costs of energy in repairing injured tissue, enzyme reactions and ion movement (Cheeseman, 1988).

Table 1. Quantum yield (µmol CO_2 fixed/mol absorbed quanta, photosynthetically active radiation (PAR)) and dark respiration of BM01 and BM21 under saline conditions.

NaCl salinity	Quantum yield*		Dark respiration	
(mM)	BM01	BM21	BM01	BM21
0	0.0972	0.1160	-2.82	-3.02
	(100)	(100)	(100)	(100)
50	0.0646	0.0510	-2.28	-2.06
	(66)	(55)	(119)	(131)
100	0.0532	0.0298	-1.97	-1.69
	(50)	(26)	(133)	(144)

* = quantum yield was determined between 0 and 50 µmol/m^2/s at 30 °C and saturating CO_2 (Seemann and Critchley, 1985)

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