Plant Water Relations and Osmotic Adjustment in *Brassica* Species under Salinity Stress

Pratibha Singh, Narender Singh[1], Kamal Dutt Sharma and Mahender Singh Kuhad

Department of Botany and Plant Physiology
CCS Haryana Agricultural University, Hisar 125 004 India
[1] Department of Botany, Kurukshetra University, Kurukshetra,India.
nsheorankuk@yahoo.com

Abstract: This investigation was carried out to compare the physiological behavior of two cultivars of *Brassica* grown under saline irrigations. The plants treated with saline water (ECe 15 dSm^{-1}) resulted in a quick development of water saturation deficit at 0.08 days after salinization (DAS) followed by a sharp decline in water potential at (0.25 DAS). Subsequently, a marked increase in diffusive resistance and a greater decrease in transpiration rate were noticed at one DAS. The response of *Brassica* at vegetative stage under salinization proved to be biphasic process. The first phase was characterized by rapid changes in turgor potential or volume change and the second phase represented the increase in solute concentration. Using the 'b' value (*ln* OP= a+b *ln* RWC) for judging the osmotic adjustment, both the species maintained turgor potential under salinization and thus exhibited osmotic adjustment, however, cv. HC 2 had an edge over its counterpart for higher osmotic adjustment as well as higher cell wall elasticity (less negative) during critical early phase of salinization. On the basis above findings it was concluded that both the *Brassica* species showed biphasic behavior during salinization, but during critical early phase of salinization cv. HC 2 showed some characters of better adaptation than cv. Kranti. [Journal of American Science 2010; 6(6):1-4]. (ISSN: 1545-1003).

Keywords: Brassica, osmotic adjustment, relative water content, salinity, transpiration, water potential

Abbreviations: CD- critical difference; cv- cultivar; DAS- days after salinization; DR- diffusive resistance; Ψ_s - osmotic potential (OP); RWC- relative water content; TP- turgor potential; TR- transpiration rate; WSD- water saturation deficit.

1. Introduction

Glycophytic plants have low salt tolerance and comprise the majority of cultivated species. When confronted with salinity, plants may undergo regulation of osmotic potential. Osmotic adjustment is a fundamental response of plants to salinity (Wyn Jones and Gorham 1983) and is necessary for survival and growth under saline conditions. Osmotic adjustment in response to salinity and drought is a result of solute accumulation which occurs through uptake of solutes and/ or synthesis of organic compounds. It results from the accumulation of solutes within cells which lowers the osmotic potential and helps to maintain turgor of both shoot and root. This allows turgor driven processes such as stomatal movement and expansion of growth to continue though at reduced rate to progressively lower water potential. Osmotic adjustment of salt adapted cells is mediated primarily through the accumulation of Na^+ and Cl^-, to generate sufficient turgor for survival and growth in the saline environment (Hasegava *et al.* 1990).

Adverse effects of low external water potential (Ψw) can be remedied by uptake of electrolytes but such uptake also creates the danger of ion excess, which could reduce cell turgor or volume. Thus, ion regulation and osmoregulation are the subject of intensive research into possible mechanism of salt tolerance (Greenway and Munns 1980). Turgor potential for stomatal movement and cell enlargement is governed by the process of osmotic adjustment and elasticity of tissue (Wright *et al*. 1997). Accumulation of ions (Na^+, K^+ and Cl^-) contributed to osmotic adjustment in *Accacia nilotica* and helped to maintain a positive water balance through osmotic adjustment. (Nabil and Coudret 1995).

One of the strategies for maintaining agricultural productivity in area affected by salinity or saline water irrigation, is the use of genotypes having comparatively better osmotic adjustment and high salt tolerance. Hence this investigation was carried out to study the effect of salinity on osmotic adjustment, tissue elasticity and stomatal driven processes in two *Brassica* species to identify their variability for these traits, with the objective of improving crop performance under salinity stress.

2. Materials and Methods

This study was conducted as a short term experiment at vegetative stage of growth ***i.e*** 60 days after sowing by raising the cultivars Kranti and HC 2 of *Brassica* in china clay pots (15 cm diameter) under net house conditions. The pots were filled with 5 kg river sand each after thoroughly washing with distilled water. Two plants per pots were retained after thinning. The plants were supplied with Hoagland's solution at regular intervals. After sixty days of sowing, the plants were irrigated with saline water of ECe 15 dSm^{-1} prepared by using NaCl, $CaCl_2$ and Na_2SO_4 in the ratio of Na : Ca and Cl : SO_4 as 4:1 in Hoagland's solution. The sand medium of each pot was saturated with Hoagland's solution with ECe 2 dSm^{-1} and treated as control. The desired ECe level was maintained after observing the ECe of initial and final leachates. The sampling was done at 0.08, 0.25, 1, 2, 3, 6, 10 and 14 days after salinization (DAS). All the physiological observations were made on third fully expanded leaf from the top. Leaf diffusive resistance (DR) and transpiration rates (TR) were recorded by Steady State Porometer (Li-COR 1600, Lincoln, Nebraska, USA) at 11.00 h and were expressed in s cm^{-1} and µg cm^{-2} s^{-1} respectively from an average of eight replicates.

Leaf water potential (Ψ_w) was determined by using Plant Water Status Consol (Model 3000, Soil Moisture Equipment Corporation, Santa Barbara, CA, USA) and expressed in '-bars'. Osmotic potential (Ψ_s) of leaf given in '-bars' was measured with Vapour Pressure Osmometer (Model 3100 B, Wescor, Inc. Logan, Ultah, USA). Water saturation deficit (WSD) was determined according to Weatherly and Slatyer (1957). ΔTP/ ΔRWC was calculated according to the method described by Elston *et al.* (1976). The data was analyzed by calculating the critical difference (CD) and the significance was tested at 5% level.

3. Results and Discussion

Salt stress resulted in a marked reduction in transpiration rate (TR), water potential (Ψ_w), and osmotic potential (Ψ_s) of leaf, whereas the diffusive resistance (DR) and water saturation deficit (WSD) increased significantly (Fig. 1, 2, 3, 4, 5). Largest decrease in leaf Ψ_w and lowest WSD values were achieved at 0.25 DAS and 0.08 DAS, respectively, in both the cultivars. Subsequently a sharp decline in transpiration rate accompanied with increase in diffusive resistance was observed at one DAS. This points to rapid changes in turgor potential caused by saline water. The decrease in osmotic potential was progressive with passage of time. This points to second phase where increase in cellular concentration of the osmotically active solutes (osmolytes) which brings a new steady state i.e. enabled the plants to maintain turgor. Similarly, decrease in Ψ_w and Ψ_s was reported in *Brassica* (Burman ***et al***. 2003). Among the cultivars, HC 2 exhibited high absolute value of TR and less DR under controlled and saline conditions. As a result of this there was greater decrease in Ψ_w and increase in WSD under salinity over control than in cv. Kranti.

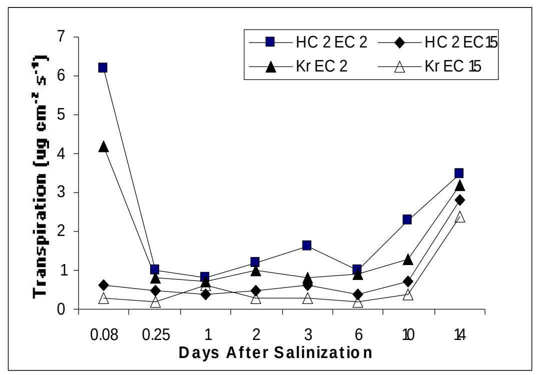

Figure. 1. Effect of salinity on Leaf transpiration rate in *Brassica* species (CD at 5% = 0.51)

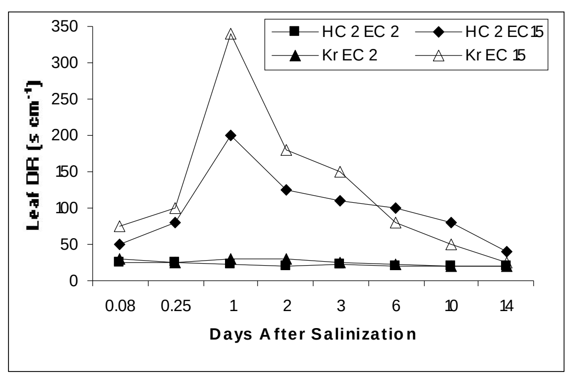

Figure. 2. Effect of salinity on Leaf Diffusive resistance in *Brassica* species (CD at 5% = 12.4**)**

Table 1. Effect of salinity on osmotic adjustment ('b' values) of leaf in *Brassica* species

Cultivars	*ln* OP = a+b *ln* RWC						
	Days after salinization						
	0.25	1	2	3	6	10	14
Kranti	1.14	1.16	1.10	1.25	1.36	1.28	1.39
HC 2	1.16	1.17	1.16	1.21	1.23	1.22	1.33

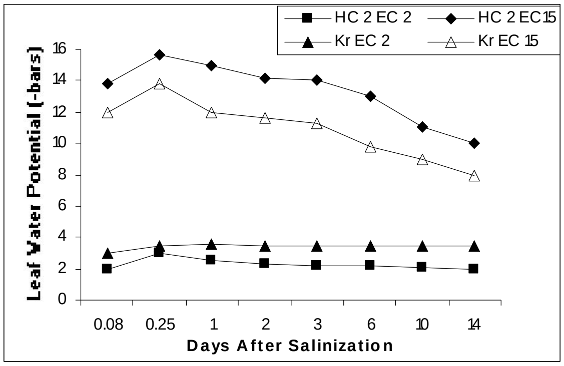

Figure. 3. Effect of salinity on Leaf water potential in *Brassica* species (CD at 5% = 0.52)

Table 2. Effect of salinity on cell wall elasticity (ΔTP/ ΔRWC) of leaf in *Brassica* species

Cultivars	ΔTP/ ΔRWC							
	Days after salinization							
	0.08	0.25	1	2	3	6	10	14
Kranti	1.95	0.80	0.46	0.36	0.24	0.09	0.02	0.08
HC 2	1.51	0.56	0.44	0.37	0.31	0.24	0.11	0.04

The ‘b’ value (*ln* OP= a+b *ln* RWC) is used for judging the osmotic adjustment (Singh *et al.*1996). Using this criterion, the osmotic adjustment was shown by both cultivars, but cv. HC 2 had edge over cv. Kranti during early phase of salinization (Table 1). Turgor maintenance by osmotic adjustment (Kumar *et al*. 1984, Li *et al*. 1993, Wright *et al*. 1997) had been dealt extensively under low water potential. The relationship between RWC and turgor potential (TP) showed that under salinization cv. HC 2 had less RWC as well as low TP compared to cv. Kranti; whereas under normal condition cv. Kranti possessed less RWC but higher TP (Table 2). The reason of discrepancies needs further investigations

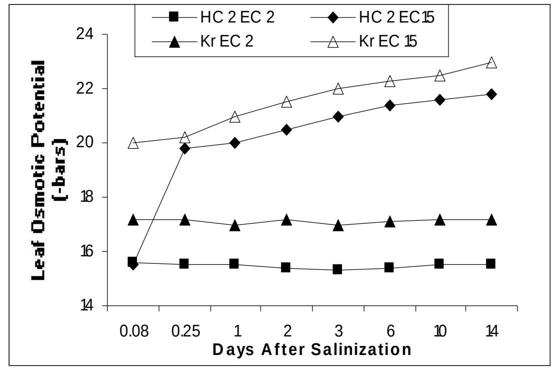

Figure. 4. Effect of salinity on Leaf osmotic potential in *Brassica* species (CD at 5% = 0.06**)**

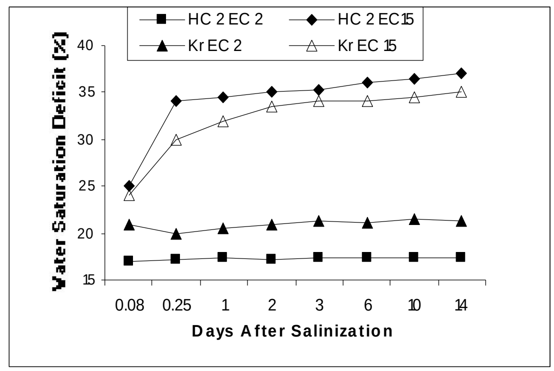

Figure. 5. Effect of salinity on Leaf water saturation deficit in *Brassica* species (CD at 5% = 0.33)

. The relationship between TP and transpiration rate showed that cv. HC 2 had less turgor but higher transpiration rate than cv. Kranti in normal and salinity treated plants. It indicates that cv. HC 2 comes under spender type, whereas cv. Kranti behaved as conservative type. The relationship between diffusive resistance and transpiration rate also support the above facts. This might probably be of cv. HC 2.

Differences in turgor maintenance may arise either from difference in solute accumulation and /or through differences in cell wall elasticity (Morgan 1984). Higher values of TP/RWC indicate the less cell wall elasticity (Table 2). Cell elasticity was greater in cv. Kranti than cv. HC 2 in later phase of salinization (3 to 14 DAS). However, during early phase of salinization (0.08 to 2 DAS), cv. HC 2 had high cell wall elasticity. A decline in Ψ_p/ RWC with decreasing Ψ_s in *Brassica juncea* for maintaining Ψ_p through maintenance of more elastic cell wall was reported by Kumar and Elston (1992).

The plant treated with saline water resulted in decreased turgor potential in both the cultivars (Table

3). Salinity induced reduction in turgor potential and water retention in *Brassica* (Wright *et al*. 1997) has been reported earlier. No doubt, both cultivars maintained turgor potential under saline condition by decreased Ψ_s (Table 3) due to accumulation of inorganic and organic solutes. The cv. Kranti had higher turgor potential because of increased DR and decreased transpiration and reverse was observed in cv. HC 2. As a result of this, cv HC 2 tried to maintain the hydrostatic pressure gradient and thus helped in regulation of various physiological processes which may lead to less reduction in yield. Gutknecht *et al*. (1978) explained that more hydrostatic pressure has no effect on turgor regulation and is the pressure gradient which is essential for maintaining various physiological processes under saline conditions.

Corresponding Author:
Dr.Narender Singh
Associate Professor,
Department of Botany,
Kurukshetra University,
Kurukshetra,Haryana 136119,India.
E-mail: nsheorankuk@yahoo.com

References

1. Burman, U., Garg, B.K. and Kathju, S. Water relations, photosynthesis and nitrogen metabolism of Indian Mustard (*Brassica juncea*) grown under salt and water stress. J. Plant Biol. 2003; 30**:** 55-60.
2. Elston, J., Karamanos, A.J., Kassam, A.H. and Wadsworth, R.M. The water relation of field bean crop. Philosophical transactions of the Royal Society of London, Series B 1976; 273: 581-591.
3. Greenway, H. and Munns, R.. Mechanisms of salt tolerance in non halophytes. Ann. Rev. Plant Physiol. 1980; 31: 149-190.
4. Gutknecht, J., Hastings, D.F. and Bisson, M.A. Ion transport and turgor pressure regulation in giant algal cell. In: Giebisch, G..Tosteson, D.C. Vasing, H.H. eds. Membrane Transport in Biology. III. Transport across Biological Membranes. Springer, Berlin- Hiedelberg- New York. 1978: 125-174
5. Hasegawa, P.M., Binzel, M.L., Reuveni, M., Watad, A.A. and Bressan, R.A. Physiological and molecular mechanisms of ion accumulation and compartmentation contributing to salt adaptation in plant cells. Hort. Biotech. 1990; 14**:** 295-304.
6. Kumar, A. and Elston, J. Genotypic differences in leaf water relations between *Brassica juncea* and *B. napus*. Ann. Bot. 1992; 70: 3-9.
7. Kumar, A., Singh, P., Singh, D.P., Singh, H. and Sharma, H.C. Differences in osmo-regulation in *Brassica* species. Ann. Bot. 1984; 54: 537-541.
8. Li, X., Feng, Y. and Boersma, L. Comparison of osmotic adjustment responses to water and temperature stresses in spring wheat and sudangrass. Ann Bot. 1993; 71**:** 303-310.
9. Morgan, J.M. Osmo-regulation and water stress in higher plants. Annu. Rev. Plant Physiol. 1984; 35**:** 299-319.
10. Nabil, M. and Coudret, A. Effect of sodium chloride on growth, tissue elasticity and osmotic adjustment in two *Acacia nilotica* sub species. Physiol. Plant. 1995; 93**:** 217-224.
11. Singh, D.P., Sangwan, V.P., Pannu, R.K. and Choudhary, B.D. Comparison of osmotic adjustment in leaves and siliquae of oilseed *Brassicae*. Indian J. Plant Physiol. 1996; 1(4): 284-285.
12. Weatherley, P.E. and Slatyer, R.O. Relationship between relative turgidity and diffusion pressure deficit. Nature. 1957; 179**:** 1085-1086.
13. Wright, P.R., Morgan, J.M. and Jessop**,** R.S. Turgor maintenance by osmo regulation in *Brassica napus* and *B. juncea* under field condition. Ann. Bot. 1997; 80: 313-319.
14. Wyn Jones, R.G. and Gorham, J. Aspects of salt and drought tolerance in higher plants. In: Kosuge, T. Meredith, C.P. Hollaender, A. eds. Genetic Engineering of Plants. An Agricultural Prospective. Plenum Press, New York. 1983: 255-370

9/30/2009