

Growth Response and Ionic Relation in Two *Brassica* Species under Water Stress Conditions

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Abstract. A glasshouse study of *Brassica campestris* and *Brassica juncea* showed that the growth and the ionic parameters of both the species were significantly ($p < 0.01$) affected due to water stress. Shoot length of both the species decreased consistently with decrease in solute potential (ψ_s) in the root medium. Relative growth rate and dry mass was higher in *B. juncea* than *B. campestris*, but leaf area was less. Concentrations of K^+ , Ca^{2+} , P and S generally decreased with gradual increase in water stress. *B. campestris* was more susceptible to water stress than *B. juncea*.

Keywords: *Brassica* sp., water stress, growth, ionic parameters

Introduction

Plant growth is influenced by physical, chemical and biological components in the environment (Westwood, 1978). Water is essential at every stage of plant growth, from seed germination to plant maturation and yield (Reisdorph and Koster, 1999; Turner, 1991). World wide crop losses due to drought probably exceed the losses caused by all the other stresses (McWilliam, 1986). Physical process of water uptake leads to the activation of metabolic processes (Katembe *et al.*, 1998; Begum and Paul, 1993; Mondal and Paul, 1992).

Among the oil seed crops, *Brassica campestris* and *Brassica juncea* are grown in wide ecological niche. Both the crops are harvested at vegetative stage for the production of vegetables or at maturity for that of oilseeds. Owing to the capacity to thrive well under poor moisture conditions, mustard is seldom irrigated and is generally raised as a rainfed crop in Indo-Pak-Bangladesh subcontinent (Mondal and Paul, 1995). Water stress affects cell division and cell expansion process and, therefore, affects leaf area (Turner and Begg, 1981). Polyethylene glycol (PEG) is commonly used to induce water stress in laboratory experiments (Livingston and de Jong, 1990; Smith *et al.*, 1989). *Brassica* is a major oilseed crop and its drought resistance potential needs to be further studied. The present study was conducted to observe the effect of water stress on important macronutrients and growth of *B. juncea* and *B. campestris*.

Materials and Methods

Seeds of *B. campestris* (cv. BSA) and *B. juncea* (cv. BARD-1) were germinated using moist quartz sand with distilled water.

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Nutrient solution (Hoagland and Arnon, 1950) along with 5, 10, 15 and 20% polyethylene glycol (PEG)₆₀₀₀, having osmotic concentrations of -0.21, -0.24, -0.56 and -0.75 MPa were prepared. The osmotic potential of the nutrient solution was measured by vapour pressure osmometer, VAPRO, Wescor. One week old seedlings were foam-plugged in the lids of plastic pots containing 2.5 litre of nutrient solution that was continuously aerated and fresh nutrient solution was replaced weekly. The study was conducted in the glass house under sun light. The pH of the solution was adjusted to 6.0 ± 0.2 with HCl or KOH and was monitored regularly. The treatments were applied in quadruplicates. Two harvests were taken with three weeks interval after transplantation of seedlings to pots. Leaf area was measured on CI-202, CID Inc., USA. After recording fresh mass (FM), the plants were rinsed with deionized water, and were separated into shoot and root portions. Plant samples were dried at 65 °C. Dry mass (DM) of each sample was recorded and was grinded to pass a 40-mesh Wiley Mill. The ground samples of root and shoot were separately digested in 2:1 perchloric-nitric di-acid mixture (Rayan *et al.*, 2001). Relative water contents (RWC) were calculated according to Misra and Dwivedi (2004); relative growth rate (RGR) and leaf area ratio (LAR) were calculated using the formula given by Franklin *et al.* (1985). Potassium and calcium ions in the digested material were determined by atomic absorption spectroscopy and sulphur and phosphorus, by the method given by Verma *et al.* (1977) and Chapman and Pratt (1961), respectively. The data were statistically analyzed according to two factors randomized complete block design (RCBD) and the treatment means were compared using least significant difference (LSD) test (Gomez and Gomez, 1984).

Results and Discussion

B. campestris and *B. juncea* were grown for 6 weeks after transplanting the seedlings under water stress at ψ_s -0.21, -0.24, -0.56 and -0.76 MPa using PEG₆₀₀₀. Significant ($p < 0.01$) difference was observed in the growth and the ionic concentrations of both the species.

Shoot length of *B. campestris* decreased 27, 35, 51 and 78% than the control at ψ_s -0.21, -0.24, -0.56 and -0.76 MPa, respectively (Table 1), whereas that of *B. juncea* also decreased by 25, 32, 45 and 60% than the control in the same increasing order of ψ_s , respectively. The root length of *B. campestris* decreased 17, 31, 45 and 75% than the control at ψ_s -0.21, -0.24, -0.56 and -0.76 MPa, respectively and that of *B. juncea* also decreased 14, 17, 33 and 64% in the same order of water potential, respectively.

In *B. campestris*, shoot fresh mass (SFM) decreased 47, 72, 98 and 99% than the control at ψ_s -0.21, -0.24, -0.56 and -0.76 MPa, respectively. In *B. juncea*, SFM increased 4% as compared to the control at ψ_s -0.21 MPa but it decreased 72, 95 and 98% than the control at ψ_s -0.24, -0.56 and -0.76 MPa, respectively. In *B. campestris*, root fresh mass (RFM) decreased 48, 75, 98 and 99% than the control at ψ_s -0.21, -0.24, -0.56 and -0.76 MPa, respectively. In *B. juncea*, RFM also decreased 22, 66, 98 and 99% than the control at ψ_s -0.21, -0.24, -0.56 and -0.76 MPa, respectively. In *B. campestris* shoot dry mass (SDM) decreased 35, 55, 90 and 94% than the control at ψ_s -0.21, -0.24, -0.56 and -0.76 MPa, respectively; in *B. juncea* as well, SDM decreased 20, 60, 80 and 87% in the same sequence of ψ_s . In *B. campestris* root dry mass (RDM) decreased 35, 57, 90 and 95% than the

control at ψ_s -0.21, -0.24, -0.56 and -0.76 MPa, respectively. Also in *B. juncea*, RDM decreased 17, 47, 91 and 96% than the control in the same order of ψ_s , respectively.

In *B. campestris*, shoot and root length, SFM, RFM, SDM and RDM decreased with an increase in water stress. In *B. juncea*, shoot and root length, RFM, SDM and RDM also decreased with increasing water stress. In *B. juncea* SFM increased at low ψ_s (-0.21 MPa). According to Katembe *et al.* (1998), imbibition supports elongation of tissue and cell expansion; *B. juncea*, therefore, might have been able to manage low level of water stress to accumulate water in the shoots. No significant effect of moisture regime on roots length was found in mustard. In the present study, root and shoot length decreased with an increase in water stress in both the species. *B. campestris* was less susceptible to water stress for growth than *B. juncea*. According to Theodore and Xu (2000), under water deficiency, growth is readily inhibited and osmotic adjustment occurs slowly and wall loosening ability either does not increase substantially or actually decreases, leading to marked growth inhibition.

In *B. campestris* shoot relative growth rate (SRGR) decreased 9, 15, 36 and 46% than the control at ψ_s -0.21, -0.24, -0.56 and -0.76 MPa, respectively. In *B. juncea*, SRGR increased 5% than the control at ψ_s -0.21 MPa but SRGR decreased 9, 30 and 36% at ψ_s -0.24, -0.56 and -0.76 MPa, respectively. In *B. campestris*, root relative growth rate (RRGR) decreased 9, 19, 39 and 51% than the control at ψ_s -0.21, -0.24, -0.56 and -0.76 MPa, respectively. In *B. juncea* RRGR was less affected at ψ_s -0.21 MPa and it decreased 13, 32 and 43% than the control at ψ_s -0.24, -0.56

Table 1. Growth of *B. campestris* and *B. juncea* under water stress (means of 4 replications)

ψ_s (MPa)	Shoot length (cm)	Root length (cm)	Fresh mass (g/plant)		Dry mass (mg/plant)		Relative growth rate ($\mu\text{g/g/d}$)		Relative water content (%)	
			Shoot	Root	Shoot	Root	Shoot	Root	Shoot	Root
<i>B. campestris</i>										
Control	14.4 a	11.3 b	2.89 b	1.40 c	272.8 b	132.8 c	101.4 ab	98.9 a	90.6 ab	90.5 a
-0.21	10.5 c	9.4 c	1.53 c	0.73 d	176.8 c	85.7 e	92.2 bc	89.7 b	88.5 ab	88.3 ab
-0.24	9.3 d	7.8 e	0.80 e	0.35 e	123.2 e	57.4 f	86.4 c	80.3 c	84.6 b	83.7 b
-0.56	7.1 f	6.2 g	0.05 f	0.03 f	26.3 h	12.8 gh	64.8 de	60.7 de	47.8 d	50.9 c
-0.76	3.2 h	2.8 h	0.02 f	0.01 f	15.4 h	6.4 h	54.9 e	48.6 f	30.3 f	47.5 c
<i>B. juncea</i>										
Control	15.1 a	12.6 a	3.49 a	2.17 a	348.6 a	212.3 a	100.6 ab	99.1 a	90.0 ab	90.2 a
-0.21	11.4 b	10.8 b	3.62 a	1.70 b	280.4 b	176.1 b	106.0 a	100.1 a	92.3 a	89.6 ab
-0.24	10.2 c	8.4 d	0.99 d	0.74 d	138.1 d	111.2 d	91.2 bc	86.5 bc	86.1 b	85.1 ab
-0.56	8.3 e	6.9 f	0.16 f	0.04 f	70.5 f	18.1 g	70.2 d	66.9 d	55.5 c	53.4 c
-0.76	6.1 g	3.3 h	0.08 f	0.02 f	46.3 g	9.5 h	64.6 de	56.7 e	39.6 e	48.1 c

Means sharing similar letter(s) in a column do not differ significantly at $p < 0.01$

and -0.76 MPa, respectively. In *B. campestris*, shoot relative water content (SRWC) decreased 2, 7, 47 and 67% than the control at ψ_s -0.21, -0.24, -0.56 and -0.76 MPa, respectively. In *B. juncea*, SRWC increased 3% than the control at ψ_s -0.21 MPa but it decreased 4, 38 and 56% than the control at ψ_s -0.24, -0.56 and -0.76 MPa, respectively. In *B. campestris* root relative water content (RRWC) decreased 2, 8, 44 and 48% than the control at ψ_s -0.21, -0.24, -0.56 and -0.76 MPa, respectively; in *B. juncea* as well, RRWC decreased 1, 6, 41 and 47% than the control in the same sequence of ψ_s , respectively.

In *B. campestris* SRGR, RRGR, SRWC and RRWC decreased with an increase in ψ_s while in *B. juncea* SRGR, RRGR and RRWC increased at lower ψ_s (-0.21 MPa). Variations in relative growth rates in both the species are in conformity with the findings of Poorter (1989), that wide variation in relative growth rate was observed when the plant species were grown under stress conditions.

In *B. campestris*, leaf area ratio (LAR) decreased by 4, 12, 24 and 88% than the control at ψ_s -0.21, -0.24, -0.56 and -0.76 MPa, respectively (Fig. 1). In *B. juncea*, LAR decreased by 5, 9, 25 and 40% than the control in the same sequence of ψ_s , respectively. Leaf area is a valuable index in identifying plant growth and development. It is also related to light interception, transpiration and photosynthesis and thus it is considered the most important single determinant of dry matter accumulation

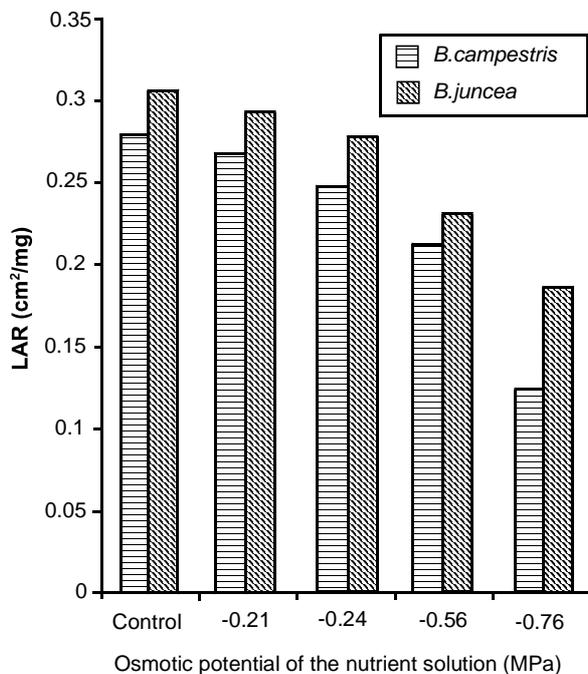


Fig. 1. Effect of water stress on leaf area ratio (LAR) in *B. campestris* and *B. juncea*.

and yield (Chan *et al.*, 1998; Noggle and Fritz, 1983). Water stress caused a drastic decrease in leaf area and shoot length, probably due to the decrease in cell enlargement (Hsiao, 1973). In *B. juncea*, relatively more leaf area contributed towards an increase in dry mass as compared to *B. campestris*. Leaf is a site of metabolic processes involved in photosynthesis and Janick (1979) found that growth occurs only in living cells by metabolic processes involved in the synthesis of proteins, nucleic acids, lipids, and carbohydrates at the expense of metabolic energy provided by photosynthesis and respiration. Therefore, the difference in LAR of both the species may be due to difference in the genetic make up.

In *B. campestris* and *B. juncea*, K^+ , Ca^{2+} , P and S had antagonistic relations with the increase in water stress (Fig. 2a-d). However, in shoots and roots of *B. juncea*, K^+ increased 4 and

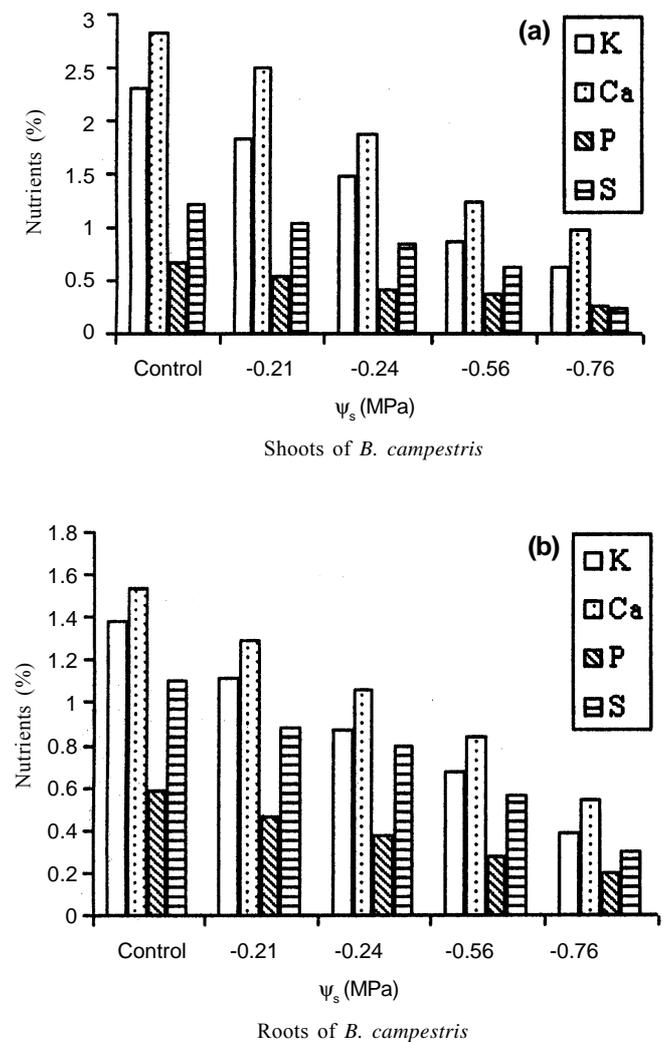


Fig. 2a-b. Nutrient relations in (a) shoots and (b) roots of *B. campestris* under water stress conditions.

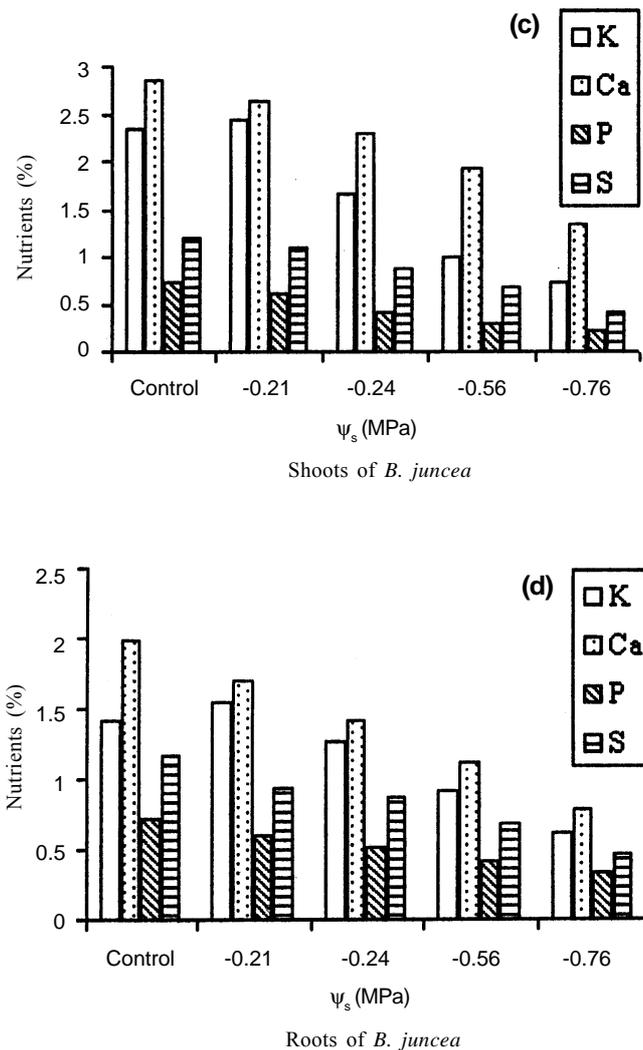


Fig. 2c-d. Nutrient relations in (c) shoots and (d) roots of *B. juncea* under water stress conditions.

8%, respectively than the control at ψ_s -0.21 MPa. The entry of water molecules is initially a passive transport. Active transport of water correlates with metabolic processes of growth. Reduced entry of water molecules may become a cause of low concentration of Ca^{2+} , K^+ , S and P in the shoot and root system. *B. juncea* may have the ability to accumulate K^+ ions in shoots and roots at a low water stress. Fricke *et al.* (1994) found that epidermal cells are virtually unable to produce organic solutes and rely heavily on inorganic ions (mainly K^+) for osmotic adjustment. Talbott and Zeiger (1996) also observed that potassium uptake occurred during stomatal opening but this ability was lost at higher water stress.

By generating external osmotic stress, with the application of PEG₆₀₀₀ on the growth of *B. campestris* and *B. juncea*, it can be assumed that lesser availability of water caused lesser flow of

nutrients from the roots to the shoots. However, in *B. juncea*, compared to *B. campestris*, at low ψ_s growth of shoots and roots improved in the form of dry mass and K^+ concentration.

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