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Variations in Growth and Physiology of barley under Chloride and Sulphate Salinity

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Abstract Sulphate salinity, in general, was found more detrimental than chloride salinity in all the four cultivars, 40048 Morocco '88', Sunbar, Maris mink and 6-Row of barley (*Hordeum vulgare* L.) grown in hydroponic cultures containing iso-osmotic chloride-, predominantly chloride- and sulphate-, and sulphate- salinity. Amongst the cultivars, 6-Row appeared to be more salt tolerant and Maris mink and Sunbar comparatively salt sensitive in respect of shoot/root length and their ratio, photosynthesis, transpiration, stomatal conductance to water vapour and sub- stomatal CO_2 concentration (in 2nd leaf). Even interaction effects of cultivar versus treatment were prominent in cultivar 6-Row and chloride alone in the above mentioned parameters, thereby, indicating the resistance of 6-Row under chloride salinity as well.

Key words Chloride, sulphate, salinity, growth physiology, *Hordeum vulgare* L.

Chloride and sulphate types of salinities are known to affect growth, development and yield attributes in crops (Manchanda *et al.* 1982, Lauchi & Epstein 1984, Manchanda & Sharma 1989) and influence rates of respiration, photosynthesis and other metabolic activities (Paek *et al.* 1988, Bhivare *et al.* 1988, Datta & Sharma 1990). This study was conducted with an objective to delimit the deleterious effects of chloride and sulphate salinity on growth and physiology of four cultivars of barley (*Hordeum vulgare* L.). In addition, efficiency and efficacy of hydroponic technique for rapid screening of salt tolerant cultivars of barley, for use in plant breeding programmes was also evaluated.

Materials and Methods

Seeds of 4 cultivars- 40048 Morocco '88', Sunbar, Maris mink and 6-Row barley (*H. vulgare*) were sown on July 4, 1990, in hydroponic solutions contained in hydroponic tubs (7 dm^3 grey plastic containers supplied by WCB Containers Ltd.) and supported by 23 mm thick polyurethane foam sheets. The 'phostrogen' based nutrient solution (i.e., 5 g phostrogen; 5 g KNO_3 and 2 ml of micronutrient) was immersed in 4 hydroponic tubs at the time of sowing. The 'phostrogen' based nutrient solution contained 6.8 mol m^{-3} K, 0.3 mol m^{-3} Na, 0.73 mol m^{-3} Ca, 0.92 mol m^{-3} Mg, 8.4 mol m^{-3} NO_3, 1.7 mol m^{-3} PO_4 and micronutrients (prepared by dissolving H_3BO_3 - 2.86 g L^{-1}; $MgCl_2.4H_2O$-1.80 g L^{-1} $ZnSO_4.7H_20$- 0.22 g L^{-1} ; $CuSO_4.5H_20$-0.08 g L^{-1}; H_2MoO_4- 0.02 g L^{-1} and Fe EDTA - 3.73 g L^{-1} following Gorham *et al.* (1984).

The iso-osmotic concentrations (O.P. = -0.45 to -0.46 MPa) of NaCl and Na_2SO_4 and their respective mixtures were supplied along with the 'Phostrogen' based nutrient solution on July 17, 1990. These treatments were T_1 (90 mM NaCl), T_2 (45 mM NaCl + 22.5 mM Na_2SO_4), T_3 (15 mM NaCl + 37.5 mM Na_2SO_4) and T_4 (45 mM Na_2SO_4) in 4 hydroponic tubs. The salt solutions were introduced in the hydroponic tubs slowly and gradually, mixed with the nutrient solution therein, in 4 days with the help of a peristaltic pump. Both nutrient as well as salt solutions were replenished every week. In addition to this, a constant EC and pH (8.1 to 8.2 mmhos cm^{-1} and 6.0 to 6.2, respectively) was maintained.

The experiment was terminated after 25 days of salinity stress. At harvest, the observations were recorded on shoot length, root length, num-

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Table 1 *Effect of chloride and sulphate on shoot length, root length and shoot/root ratio in 4 cultivars of barley*

	T1	T2	T3	T4	Mean	CD 5%
Shoot length (cm) :						
Morocco	19.1	8.7	6.3	5.5	9.4	Salt = 0.30
Sunbar	20.7	9.3	5.3	5.5	10.2	Cult = 0.30
Maris mink	19.3	7.8	6.2	5.6	9.7	SxC = 0.60
6 – Row	24.7	7.6	7.1	5.1	11.1	
Mean	20.9	8.4	6.2	5.4		
Root length (cm) :						
Morocco	43.4	26.2	24.9	21.1	28.9	Salt = 2.11
Sunbar	39.7	27.0	22.8	23.7	28.3	Cult = 2.11
Maris milk	45.3	24.5	26.7	20.8	29.3	SxC = 4.23
6 – Row	43.4	31.0	24.6	27.5	31.6	
Mean	43.0	27.2	24.7	23.3		
Shoot/root ratio :						
Morocco	0.44	0.33	0.25	0.26	0.32	Salt = 0.14
Sunbar	0.52	0.34	0.23	0.23	0.33	Cult = 0.14
Maris mink	0.42	0.31	0.23	0.27	0.30	SxC = 0.28
6 – Row	0.57	0.24	0.28	0.18	0.52	
Mean	0.48	0.38	0.24	0.23		

ber of leaves, leaf area, and the chlorophyll (a + b) were measured with the help of UV-260 Spectrophotometer (Jeffrey & Humphery 1975). Net photosynthesis, transpiration, sub-stomatal CO_2 concentration and stomatal conductance to water vapour were recorded with IRGA on 2nd and 3rd leaf from top of the plant (fully expanded leaf) between 10 am to 12 noon, from 3 replicates, 2-days before the harvesting. The data were statistically analysed following two factorial completely randomized design.

Results and Discussion

Effect of type of salinity

Shoot length was gradually but significantly reduced by chloride and sulphate salinity. The reduction was drastic from T_1 to T_2 but thereafter, it was less upto T_4. Root length and shoot/root ratio also showed the same trend. The shoot was affected more than the root. There was no significant variation in leaf number amongst the treatments. Leaf area declined severely after treatment T_1, but did not vary much in T_2, T_3 and T_4 treatments (Tables 1 & 2). These phenological observations showed that sulphate was more deleterious than the chloride salinity in barley. All these parameters gradually reduced with increasing concentrations of Na_2SO_4 in NaCl, and Na_2SO_4 alone. These results were in conformity with those of Lauchi & Epstein (1984), who observed similar effects on the growth and leaf elongation in sorghum. Similarly, Meiri *et al.* (1971), Terry & Waldron (1984) and Bhivare & Nimbalkar (1984), have also observed more reduction in leaf thickness, shoot/root ratio and leaf area in Na_2SO_4 as compared to NaCl in forage crops and *Phaseolus vulgaris* L.

The chlorophyll (a + b) contents, net rate of photosynthesis and sub-stomatal CO_2 concentration in both 2nd and 3rd leaf, rate of transpiration, stomatal conductance to water vapours, particularly in 2nd leaf, followed the same trends as for different morphological parameters. These parameters, in general, declined sharply in sulphate alone, as compared to chloride salinity and were in accordance with the results of Bhivare *et al.* (1988). The fact that these parameters are affected more under sulphate than chloride salinity lent support to declining trends observed under sulphate salinity, with respect to transpiration, sub-stomatal CO_2 concentration and stomatal conductance to water vapour in this study (Table 3). The less availability of CO_2 in sub-

Table 2 *Effect of chloride and sulphate salinity on number of leaves, leaf area and chlorophyll (a+b) contents in 4 cultivars of barley*

	T1	T2	T3	T4	Mean	CD 5%
Number of leaves :						
Morocco	8.7	8.2	9.0	8.2		Salt = 0.30
Sunbar	8.0	9.7	9.0	7.2	8.6	Cult = 0.30
Maris mink	8.2	9.0	8.7	7.7	8.5	SxC = 0.60
6–Row	9.0	8.7	8.0	7.5	8.4	
Mean	8.5	8.9	8.7	7.7	8.3	
Leaf area (cm^2) *:*						
Morocco	19.4	8.9	10.7	9.0	12.0	Salt = 1.1
Sunbar	19.1	10.3	9.7	8.3	11.8	Cult = 1.1
Maris milk	18.2	8.8	8.7	9.8	11.4	SxC = 2.1
6–Row	19.1	10.3	9.7	8.3	11.8	
Mean	18.9	9.3	8.7	8.7		
Chl (a+b) (μg/g fresh weight) (2nd + 3rd leaves) :						
Morocco	900.3	467.4	662.9	673.4	676.0	Salt = 12.5
Sunbar	1546.8	991.2	495.9	695.9	932.5	Cult = 12.5
Maris mink	1339.1	806.7	605.7	556.4	827.0	SxC = 25.0
6–Row	1290.9	1114.0	576.3	603.4	896.2	
Mean	1269.3	844.8	585.2	632.3		

stomatal cavities in sulphate than chloride salinity would certainly have accentuating effects on rate of photosynthesis as the CO_2 availability was curtailed more under sulphate than under chloride salinity. However, the results with respect to stomatal conductance were not consistent in both the leaves, but, as far as sulphate alone was concerned, it depicted low conductance of water vapours, as compared to other treatments, in both the leaves. These results would automatically evince more toxicity under sulphate than under other treatments. However, higher rate of transpiration and stomatal conductance to water vapour, particularly in T_2 and T_3 treatments in 3rd leaf from top of the plant, were quite intriguing. The aforementioned results are in consonance with those of Meiri *et al.* (1971), who reported sulphate salinity depressed transpiration, though, chloride salinity was more deterrent than sulphate in *Phaseolus vulgaris* L. cv. brittle wax. Seeman & Critchley (1985) also observed substantial decline in stomatal conductance, chlorophyll/unit area, intracellular CO_2 concentration and photosynthetic CO_2 fixation under NaCl salinization, in *P. vulgaris* cv. Hawkesbury wonder. Plaut *et al.* (1990) also observed a well marked decrease in leaf conductance to water vapour, intercellular partial CO_2 pressure [$P(CO_2)$] and that CO_2 assimilation was mainly controlled by stomatal conductance in *Vigna unguiculata* (L) under NaCl salinization.

Effect on the cultivars

The response on the four cultivars to these types of salinities indicated, that as far as phenological parameters were concerned, there was no difference in leaf number and leaf area (Tables 1 & 2). However, root length, shoot length and shoot/root ratio were higher in 6-Row, as compared to Maris mink and Sunbar. Furthermore, different physiological parameters like Chl (a+b), net photosynthesis, transpiration, substomatal CO_2 concentration and stomatal conductance to water vapour were severely affected in both 2nd and 3rd leaf, either in Sunbar or Maris mink, and by and large, it was highest in 6-Row and Morocco (Tables 2 & 3). The results showed that salt resistance amongst these cultivars was 6-Row > Morocco 40048 > Sunbar Maris mink.

Table 3 *Effect of chloride and sulphate salinity on photosynthesis, transpiration, sub-stomatal CO2 concentration and stomatal conductance to water on 2nd and (3rd leaf) of 4 barley (Hordeum vulgare) cultivars*

	T_1	T_2	T_3	T_4	Mean	CD 5%
Photosynthesis (μ mol $Co_2/m^2/s$)						
Morocoo	8.82 (7.74)	5.19 (9.32)	2.51 (2.82)	3.11 (3.32)	4.90 (5.80)	Salt = 0.46 (0.44)
Sunbar	7.39 (4.42)	3.69 (4.15)	1.57 (1.70)	3.08 (2.08)	3.93 (3.08)	Cult = 0.46 (0.44)
Maris mink	3.56 (4.15)	4.77 (3.45)	2.24 (2.69)	1.65 (1.52)	3.05 (2.95)	SxC = 0.92 (0.83)
6–Row	12.57 (5.52)	1.87 (3.70)	2.39 (3.20)	3.28 (2.79)	5.0o2 (3.75)	
Mean	8.08 (5.41)	3.88 (5.16)	2.17 (2.60)	2.78 (2.43)		
Transpiration (m mol H_2O/m2/S)						
Morocco	8.67 (8.87)	7.77 (13.47)	8.83 (9.23)	8.60 (7.50)	8.51 (9.76)	Salt = 0.84 (0.74)
Sunbar	7.23 (4.50)	11.10 (09.73)	9.07 (10.80)	7.60 (6.33)	8.75 (7.84)	Cult = 0.84 (0.74)
Maris mink	4.03 (5.33)	6.40 (0.5.60)	5.73 (07.10)	6.10 (4.80)	5.56 (5.70)	SxC = 1.68 (1.48)
6-Row	15.20 (6.67)	5.27 (06.43)	11.23 (11.27)	9.47 (8.30)	10.29 (8.16)	
Mean	8.78 (6.34)	7.68 (08.81)	8.72 (09.60)	7.94 (6.73)		
Sub-stomatal Co_2 concentration (ppm)						
Morocoo	2.28.0 (243.3)	189.7 (194.0)	135.7 (130.0)	143.7 (138.3)	174.3 (176.4)	Salt = 5. 8 (4.3)
Sunbar	250.0 (243.3)	186.0 (169.0)	139.3 (139.7)	187.0 (183.7)	189.6 (183.9)	Cult = 5.8 (4.3)
Maris mink	198.0 (210.7)	194.7 (214.7)	144.7 (150.7)	134.0 (132.0)	167.8 (177.0)	SxC = 11.6 (8.6)
6-Row	273.0 (241.0)	182.0 (163.7)	133.7 (126.0)	167.7 (168.7)	189.1 (174.8)	
Mean	237.2 (234.6)	188.1 (185.3)	137.3 (136.6)	158.1 (155.7)		
Stomatal conductance to water vapour (mol $H_2O/m^2/S$)						
Morocco	175 (195)	277 (452)	168 (175)	166 (130)	196 (238)	Salt = 39 (29)
Sunbar	348 (111)	241 (183)	165 (211)	129 (95)	220 (150)	Cult = 30 (29)
Maris mink	158 (192)	137 (116)	96 (126)	97 (74)	122 (127)	SxC = 78 (58)
6–Row	600 (129)	288 (102)	221 (237)	162 (148)	317 (154)	
Mean	320 (157)	236 (213)	163 (187)	138 (122)		

Salinity versus cultivar interaction

The analysis of data on salinity versus cultivar interactions presented in Tables 1 to 3 revealed, that shoot and root length, shoot/root ratio, net photosynthesis, transpiration, sub-stomatal CO_2 concentration and stomatal conductance to water vapour in 2nd leaf were highest in cultivar 6-Row in T_1. However, their higher values were observed in cultivar Morocco in T_1 or T_2 in the 3rd leaf, thereby, indicating more salt resistance of Morocco or 6-Row barley cultivars in either chloride alone or predominantly chloride salinity (T_1 or T_2 treatments).

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