Effect of Salinity and Temperature on Yield, Mineral Ion Concentrations and Physiology in Hexaploid Triticale

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Abstract : The effect of salinity, 0 and 50 mM NaCl solution, and air temperature, 20/15 $\pm$ 3°C (day/night) as a low and 30/25 $\pm$ 3°C (day/night) as a high, on growth, yield, mineral ion concentrations and physiological characteristics in hexaploid triticale (X Triticosecale Wittmack) was analyzed employing two cultivars, Welsh and Currency. Salinity affected growth and yield more markedly at the high temperature than at low temperature. Currency showed relatively higher salt-tolerance in grain yield than Welsh at high temperature, while at low temperature, the position was reversed. The combined effect of salinity and high temperature decreased seriously the number of fertile spikes and grains per plant compared to other treatments. Osmotic potential was lowered by salinity and the lowest value was observed at high temperature. Stomatal resistance was increased and transpiration rate was decreased by salinity. The resistance was lower and transpiration was higher at high temperature than at low temperature irrespective of saline or non-saline irrigation. Photosynthetic rate was lowered by salinity at both levels of temperature, and the lowest rate was observed at high temperature. Salinity increased Cl^- and Na^+ concentrations in the leaves and the increment was great at the high temperature. Salinity decreased the concentrations of K^+ in Welsh, while increased in Currency irrespective of temperature levels. Concentrations of Ca^{++} and Mg^{++} were decreased by salinity at both levels of temperature.

Key words : Hexaploid triticale, Mineral ion concentrations, Physiology, Salinity, Temperature, Yield.

塩分と温度が六倍体ライコムギの収量、無機イオン濃度および生理に及ぼす影響 : KARIM, M.A. ・ 縄田栄治 ・ 重永昌二 (京都大学農学部)

要 旨 : 六倍体ライコムギの栽培における塩分と温度の複合的な影響を検討する目的で、50 mM の塩化ナトリウム水溶液をかんがい水として用い、昼/夜温を 20/15°C の低温または 30/25°C の高温条件で試験栽培した場合の収量、体内の無機イオン濃度、および光合成速度等の生理学的諸形質を解析した。試験は遺伝的背景の異なる 2 品種、Welsh おおび Currency を用いたガラス室内でのポット栽培試験によった。その結果、塩分の生育および収量に対する抑制的な影響は、低温区よりも高温区において顕著であった。種子収量を指標として比較した場合、高温区では Currency の方が Welsh よりも耐塩性が大であったが、低温区ではこの関係が逆転した。塩分と高温の複合的な影響により可稔穂数や個体当たりの種子数が著しく低下した。また、塩分は浸透ポテンシャル、蒸散速度および光合成速度を低下させるが、その低下はとくに高温区において著しくなること、さらに塩分は葉の Cl および Na イオン濃度を上昇させるが、それはとくに高温区において著しいこと、また K イオン濃度を Welsh においては低下させるが、Currency においては上昇させること、そして Ca および Mg イオン濃度を低下させることなどが明らかになった。

キーワード : 塩分濃度、温度、収量、生理、無機イオン濃度、六倍体ライコムギ。

It is common in the arid and semi-arid regions that as the crop growth season progresses, precipitation decreases, and temperature and evapotranspiration increase, resulting in rising salt concentration in the soil solution¹⁾. Thus, crops grown in these regions are affected by multiple environmental factors along with salinity.

It is usually found that salinity tolerance in plants is aggravated by the presence of other kinds of environmental stress, e. g. by water stress in triticale¹⁴⁾ and by high temperature in barley²³⁾. However, the number of available reports dealing with salinity tolerance in cereal

crop plants in the presence of other kinds of environmental stress, especially temperature stress, is small.

High temperature causes physiological disorders in plants which are responsible for accelerated growth processes, spikelet sterility and finally decreased grain yield^{2,10,11)}. Thus, it must have considerable influence on salinity tolerance in crop plants. Since salinity tolerance of plants varies remarkable within the species and at various growth stages¹⁹⁾, the results obtained from the experiments conducted on the combined effects of salinity and temperature on germination in non-cereal

crops^{4,7,9,17,20,21,25,26,31}), or at tillering stage in cereal crop²³), may not have a consistent relationship with the results at maturation in cereal crops. Moreover, because of the paucity of published experimental evidence the influence of salinity on both morphological and physiological characteristics in sereal crop plants at different levels of temperature remains to be demonstrated in a long term experiment study.

In the present study, the effect of salinity on grain yield, mineral ion concentration and physiological characteristics in hexaploid triticale was investigated at high (30/25 $\pm 3^{\circ}\text{C}$) and low (20/15 $\pm 3^{\circ}\text{C}$) temperature conditions. Hexaploid triticale (X *Triticosecale* Wittmack), an amphiploid between durum wheat (*Triticum turgidum* L.) and rye (*Secale cereale* L.), sometimes shows a higher yield than its parental species under marginal soils and environments³). Owing to this ability its cultivation is expected to expand to the arid and semi-arid regions where salinity co-exists with highly fluctuated temperature.

Materials and Methods

Seeds were germinated on a wet paper towel in a germination box and 7-day-old seedlings were transplanted singly into pots of 14 cm diameter and 13 cm height on December 6, 1991. All the pots were filled with the same amount of soil, which was prepared with washed sand and organic manure at a ratio of 3:1 by volume. The organic manure contained 2.3% N, 1.8% K_2O and 3.5% P_2O_5 . The pH and EC values of the prepared soil were 6.5 and 0.7 mS/cm, respectively. Two grams of granular fertilizer, which contained N, P_2O_5 and K_2O in the ratio of 14, 12 and 14, respectively, per pot, was also applied before transplanting. Currency, a complete type cultivar, and Welsh, a substitution type cultivar of hexaploid triticale, were used as experimental materials.

All the pots were irrigated with tap water for 45 days. After that, NaCl solution was applied every other day at an increment of 12.5 mM until a final concentration, 50 mM was attained. Another group of plants was irrigated with tap water only. The plants were grown inside a glasshouse without temperature and light control until the stem elongation stage. During this period the air temperature inside

the glasshouse fluctuated between 10 and 24 $^{\circ}\text{C}$ in the day time, and 0 and 10 $^{\circ}\text{C}$ at night. All plants were then transferred to phytotron of natural light on March 22, 1992. Both NaCl-treated and nontreated plants were divided into two groups. One group of the plants was kept at 20/15 $\pm 3^{\circ}\text{C}$ (day/night) for the low air temperature treatment and another group of the plants was kept at 30/25 $\pm 3^{\circ}\text{C}$ (day/night) for the high air temperature treatment. The humidity of the phytotron fluctuated between 45 and 60%. The NaCl-treatments were continued until the plants reduced maturity.

Osmotic potential was measured using the top third leaf on the main culm of the plants with an osmometer (OSM-1, Shimadzu Corp., Japan) after the sample leaves had been frozen and thawed on the 15th and 30th days after transferring the plants to the phytotron. On the same day, measurements of, photosynthetic rate, transpiration rate and stomatal resistance were also taken with a portable photosynthesis system (Model LI-6200, LICOR Inc., USA), using the top second leaf on the main culm. Leaves from all the treatments were collected three times, viz. 10 days after transferring the plants to the phytotron, 14 days after the first collection and at harvest to measure the concentrations of Cl^- , Na^+ , K^+ , Ca^{++} and Mg^{++} . Apart from Cl^- all the element concentrations were measured by atomic absorption spectrophotometry (Shimadzu, Atomic Absorption/Flame Spectrophotometer, Model-AA 610S, Japan). Cl^- was determined with an ion selective electrode (Orion Research, Ion analyzer, Model-720A, Japan). Four plants per treatment were allotted for the measurements of physiological characteristics and mineral ion concentrations.

Plant height, yield components and grain yield were measured at maturity of the plants. The spike with at least one matured grain was considered as a fertile spike. Number of grains per spike was calculated by dividing the total number of grains in a plant with the number of fertile spikes per plant. Ten plants per treatment were employed for these measurements. Data on both morphological and physiological characteristics were subject to statistical analysis.

Results

1. Responses of plant morphological characteristics

Plants grown at the high temperature (30/25 $\pm 3^\circ\text{C}$) matured about three weeks earlier than the plants grown at the low temperature (20/15 $\pm 3^\circ\text{C}$). The plants treated with NaCl matured 7 and 10 days earlier than the control plants at the low and the high temperature, respectively. Plants grown at the high temperature showed white leaf tips, chlorotic bands and blotches on the leaves. The main-culm-panicle in some plants was grayish in color and sterile. Salt water irrigated plants showed more severely the above symptoms than non-saline irrigated plants. Although the maximum tillering stage of the plants was over before transferring the plants to the phytotron, many new (late) tillers were initiated after the transferring. Most of these late tillers were

initiated after the booting stage of the plants. The number of the late tillers was remarkably large in the plants kept at the high temperature compared to the plants kept at the low temperature. Most of the late tillers were sterile although some had seeds. The progression of phenological development in these tillers was rather faster than usual and the spikes were quite small in size.

The effect of salinity at both the high and the low temperatures on plant height, yield components and grain yield is presented in Table 1. Salinity affected the plant height, irrespective of temperatures. The shortest plants were observed at the high temperature, however. But relative tolerance to salinity in plant height (% to the control at the respective temperature) was similar under both high and low temperature conditions.

The number of grains per plant was reduced by salinity irrespective of levels of

Table 1. Effect salinity and temperature on the plant height, yield components, grain yield and harvest index in hexaploid triticale.

Treatments		Plant height		Total grains		Fertile spikes		Grains /spike		100-grain weight	
NaCl (mM)	Temp. ($^\circ\text{C}$)	(cm)		/plant (no.)		/plant (no.)		(no.)		(g)	
		W	C*	W	C	W	C	W	C	W	C
0	20/15	101a	119a	354a	359a	9.1a	7.5b	39a	48a	4.47a	4.75a
50	20/15	90b	101b	300b	281b	8.6a	6.7b	35b	42b	3.62b	3.84b
		(89)	(85)	(85)	(78)	(95)	(89)	(90)	(88)	(81)	(81)
0	30/25	88b	106b	106c	162c	8.8a	9.5a	12c	17c	3.41b	3.41c
50	30/25	81c	90c	65d	91d	5.9b	5.4c	11c	17c	2.46c	2.99d
		(92)	(85)	(61)	(56)	(67)	(57)	(92)	(100)	(72)	(88)

Treatments		Grain yield		Harvest index	
NaCl (mM)	Temp. ($^\circ\text{C}$)	/plant (g)			
		W	C*	W	C
0	20/15	15.18a	16.44a	0.44	0.45
50	20/15	10.78	10.26	0.43	0.43
		(71)	(62)		
0	30/25	3.52c	5.11c	0.18	0.25
50	30/25	1.55d	2.64d	0.13	0.21
		(44)	(52)		

* W : Welsh, C : Currency

Different letters within a column indicate a significant difference at 5% level. Lettering was made separately for each cultivar. Values in parentheses within a column indicate percentage values to the 0 mM NaCl irrigated plants at the respective level of temperature. Grains/ spike (no.) was calculated by dividing the total number of fertile spikes/ plant (grain producing spikes per plant).

Fig. 1. Effect of salinity and temperature on the osmotic potential measured two times in hexaploid triticale. The 1st and 2nd measurements were conducted on 15th and 30th days after transferring the plants to the phytotron on March 22, 1992 from the glasshouse at the stem elongation stage, respectively. 20CX0 and 20CX50 : 0 and 50 mM NaCl irrigation was applied to the plants at 20/15°C (day/night) temperature, respectively. 30CX0 and 30CX50 : 0 and 50 mM NaCl irrigation was applied to the plants at 30/25°C (day/night) temperature, respectively. Different letters at each measurement on a same day indicate a significant difference at 5% level.

temperature. But the combined effect of salinity and the high temperature remarkably reduced the number in both cultivars. Salinity had no influence on the production of fertile spikes per plant at low temperature, while salinity reduced the number greatly at high temperature in both Welsh and Currency. Although the plants kept at high temperature produced remarkably lower number of grains per plant than those kept at low temperature, the number of grains per spike (calculated) was slightly lowered by salinity only at low temperature. Weight of 100-grain was reduced by salinity at both levels of temperature and the reduction was pronounced by the combined effect of salinity and high temperature. However, the relative tolerance to salinity in 100-grain weight (% to the control at the respective temperature) in Welsh was lower at high temperature than at low temperature, while Currency showed the opposite result (Table 1). Both salinity and temperature affected the grain yield seriously in the plants. The yield was drastically reduced by the combined effect of salinity and the high temperature compared to that of salinity and low temperature. At the high temperature the reduction in grain yield by the influence of salinity was higher in Welsh than in Currency, while at the low temperature the result was reversed when compared by the percentage values to the control. The combined effects of

salinity and the high temperature lowered the harvest index seriously in the plants of both Welsh and Currency. At the low temperature the influence of salinity on harvest index was a small.

2. Responses of plant physiological characteristics

Values of osmotic potential measured on 15th and 30th days after transferring the plants to the phytotron from the glasshouse are presented in Fig. 1. The potential was lowered by salinity irrespective of the levels of temperature. However, the lowest value in the plants was observed by the combined effect of salinity and the high temperature in both Welsh and Currency. The values in the control plants were similar at both high and low temperature.

Results of stomatal resistance, transpiration rate and photosynthetic rate measured on the 15th and 30th days after transferring the plants to the phytotron are presented in Fig. 2. The stomatal resistance was increased by salinity at both the levels of temperature. However, the combined effect of salinity and the low temperature increased the resistance significantly. The transpiration rate was lowered by salinity, irrespective of temperature levels. The lowest transpiration was measured from the plants under the combined conditions of salinity and the low temperature. Salinity decreased the photosynthetic rate seri-

Fig. 2. Effect of salinity and temperature on the stomatal resistance, transpiration rate and photosynthetic rate measured two times in hexaploid triticale. The 1st and 2nd measurements were conducted on 15th and 30th days after transferring the plants to the phytotron on March 22, 1992 from the glasshouse at the stem elongation stage, respectively. Footnotes for the legend are same as in Fig. 1. Different letters at each measurement on a same day indicate a significant difference at 5% level.

ously at both levels of temperature. However, the lowest photosynthesis was measured from the plants treated with the combination of salinity and high temperature in both Welsh and Currency.

3. Mineral ion concentrations in the leaves

Concentrations of Cl^- , Na^+ and K^+ in the leaves are presented in Fig. 3 and those of Ca^{++} and Mg^{++} are in Fig. 4. The concentrations of Cl^- and Na^+ increased with the increasing period of the salt water irrigation at both the levels of temperature. However, the concentrations of these two ions were increased greatly by the combined effect of salinity and high temperature. Accumulating

tendency of K^+ in the leaves by the influence of salinity and temperature was not similar in the two cultivars. At the respective levels of temperature, salinity decreased the concentration of K^+ in Welsh, while K^+ increased in Currency in comparison to the control plants. Concentrations of Ca^{++} and Mg^{++} were decreased by salinity irrespective of the levels of temperature (Fig. 4). However, the difference in the concentrations of Ca^{++} and Mg^{++} of the control and NaCl treated plants became greater with the increasing period of saline water irrigation. The lowest concentrations of these two ions were detected under the combined conditions of salinity and low temperature.

Fig. 3. Effect of salinity and temperature on the concentrations of Cl^- , Na^+ and K^+ in the leaves of triticale plants measured on different days after transferring the plants to the phytotron on March 22, 1992 from the glasshouse at the stem elongation stage. The ion concentrations are expressed on a dry weight basis. Footnotes for the legend are same as in Fig. 1. Different letters at each measurement on a same day indicate a significant difference at 5% level.

Discussion

Although the relative salt-tolerance (% of grain yield to the control) of the two cultivars was affected by the influence of different levels of temperature in the present study, most of the morphological and physiological characteristics of the two cultivars showed a similar pattern of response to salinity and temperature stress. Consequently, emphasis will be given to discuss the general response of triticale plants to salinity under low and high temperature conditions instead of the cultivar variation.

Results indicate that Currency was more

tolerant to salinity than Welsh at the high temperature, while at the low temperature the result was opposite. Perhaps the smaller reduction in grain yield in Currency at high temperature was attributed to the smaller reduction in 100-grain weight in the former cultivar than the latter. On the other hand, the smaller reduction in fertile spikes and number of grains per plant in Welsh contributed to the less reduction in grain yield in Welsh at low temperature. The variable relative salt-tolerance showed by the two cultivars at the low and high temperatures indicates that cultivars may change their rank of salt-tolerance by the influence of temperatures.

Fig. 4. Effect of salinity and temperature on the concentrations of Ca^{++} and Mg^{++} in the leaves of triticale plants measured on different days after transferring the plants to the phytotron on March 22, 1992 from the glasshouse at the stem elongation stage. The ion concentrations are expressed on a dry weight basis. Footnotes for the legend are same as in Fig. 1. Different letters at each measurement on a same day indicate a significant difference at 5% level.

The accelerated maturity caused by both salinity and high temperature obviously influences the processes of growth and development of the grains^{2,8,12,29,33}. The accelerated maturity caused by salinity in triticale plants was reported earlier by Francois et al.⁸), although the consequent influence on grain growth had not been well analyzed. However, it was observed in the present study that temperature played a major role in the acceleration processes with which the plants at high temperature matured, about three weeks earlier than the plants at the low temperature, irrespective of the saline or the non-saline irrigation.

The combined effect of salinity and the high temperature reduced the number of grains per plant remarkably. It was observed that many spikelets were empty under the high temperature conditions, irrespective of the saline or the nonsaline irrigation. Yohida et al.³⁴) reported that the causes of nonfertilization in rice plant at high temperature were the disturbance of pollen shedding, decreased viability of pollen

grains, decreased percentage of well-pollinated spikelets and impaired germination of shed pollen grains on the stigma. The ability of the pistil to be fertilized, however, remained unaffected by relatively high temperature level. The effect of salinity on spikelet fertility in the present study was not pronounced, especially at high temperature. However, in another study we observed that high concentrations of salinity (100 and 200 mM NaCl) applied at the booting and inflorescence emergence stages caused spikelet sterility in triticale plants (Karim et al., unpublished). Perhaps the tremendous effects of high temperature on fertility obscured the influence of salinity on this characteristics in the present study. Salinity decreased remarkably the number of fertile spikes per plant at the high temperature compared to that at the low temperature. The similar number of grains per spike in the NaCl-treated and nontreated plants at the high temperature was due to the low production of the fertile spikes per plant, along with the remarkably decreased number of grains per

plant in former conditions.

The difference of the harvest indices between the control and the salt water irrigated plants at low temperature was much less than the difference at high temperature. The discrepancy in the values of the two conditions was due to remarkable reduction in grain yield compared to straw yield under high temperature conditions¹³⁾.

The osmotic potential was lowered seriously by salinity at the both levels of temperature. However, the potential was decreased remarkably by the combined effect of salinity and high temperature compared to that of salinity and low temperature. Salinity decreases osmotic potential in crop plant, e.g. triticale¹⁴⁾, broadbeans¹⁶⁾ and barley⁶⁾. It is reported that under saline conditions, plants absorb various kinds of mineral ion and accumulates metabolites for osmotic adjustment, and the saturation of these ions and metabolites in plant cells could be responsible for lowered osmotic potential^{2,6)}.

Stomatal resistance was increased, and transpiration and photosynthesis were decreased by salinity under both the levels of temperature. The resistance was lower and consequently the transpiration rate was higher at high temperature than at low temperature²⁾. Although the stomatal resistance of the salt-affected plants was higher at low temperature than at high temperature, the photosynthetic rate was, however, higher at low temperature. It was observed, in a previous experiment using the same two cultivars, that after 38 days of 50 and 100 mM NaCl applications, photosynthetic rate in Currency was not affected at all although the rate was decreased in Welsh. Stomatal resistance did not change under the influence of salinity in Welsh, but in Currency the rate increases. However, the transpiration rate was decreased by salinity in both cultivars¹⁴⁾. The findings of the previous and present studies appear to suggest that stomatal resistance of triticale plants under conditions of salinity and the high temperature were not primarily responsible for the seriously affected photosynthetic rate. Previous reports indicate that salinity affects photosynthesis, not only due to its effects on stomatal closure but may also be due to its interference with photosynthetic reactions in chloroplasts, presumably by interfering with

photophosphorylation^{5,18,22)}. However, there are different opinions on the response of photosynthesis in crop plants to salinity. Photosynthesis under saline conditions was not the limiting factor for growth in barley²⁴⁾, triticale¹⁵⁾ and pistachio³²⁾. On the contrary, salinity impaired the growth and lowered the rate of photosynthesis in *Phaseolus vulgaris*²⁷⁾ and mustard²⁸⁾. It is also reported that the low photosynthetic rate under stressed conditions is associated with low demand for photosynthates in the sink^{24,30)}. Perhaps the combined effect of salinity and the high temperature decreased the demand for photosynthates in the sink, viz. reproductive development, including grains. It was mentioned before that most of the late tillers were initiated in the plants after the booting stage and the number of the late tillers was remarkably higher at high temperature than at low temperature. The production of significant number of those tillers at the later part of plant growth was obviously resulted from the reduced reproductive development.

Mineral ion concentrations in the leaves were increased by high temperature, although salinity decreased the concentrations of Ca^{++} and Mg^{++} in both cultivars, and K^+ in Welsh. The remarkable increase in the concentrations of Na^+ and Cl^- at the expense of the reduction of Ca^{++} and Mg^{++} presumably created ionic imbalance in the plant growth processes^{2,13)}. The higher accumulation of these ions at high temperature than at low temperature was probably associated with the high transpiration rate in the former conditions. Mozafar and Oertli²³⁾, however, reported in barley plants, though salinity increased the concentration of Na^+ in the plant at the tillering stage, the concentration was decreased in respective salinity treatments when the root temperature was increased from 10°C to 25°C. Concentration of K^+ was decreased by salinity at 10°C but was not affected at 25°C, and concentration of Ca^{++} was increased by salinity with the increased temperature levels. Perhaps barley has different mechanisms of accumulation of the element from triticale under combined conditions of salinity and temperature stress.

Based on the results obtained in this experiment, it is concluded that the marked harmful effect of salinity on the growth and yield of

triticale plants at high temperature compared to that at low temperature was closely associated with the shortened period of grain development, lowered contribution of the yield components, lowered photosynthetic rate and reduced photosynthetic area, with the appearance of chlorotic bands and blotches on the leaves, and ionic imbalance in the growth processes.

References

1. Abdulrahman, F.S. and G.S. Williams III 1981. Temperature and salinity regulation of growth and gas exchange of *Salicornia fruticosa* (L.) L. *Oecologia* 48 : 346—352.
2. Blum, A. 1988. Plant Breeding for Stress Environments. CRC Press, Florida. p. 223.
3. CIMMYT 1985. Triticale—a crop for marginal environments. CIMMYT Research Highlights, COMMYT, Mexico : 72—87.
4. Coons, J.M., R.O. Kuehl and N.R. Simons 1990. Tolerance of 10 lettuce cultivars to high temperature combined with NaCl during germination. *J. Am. Soc. Hortic. Sci.* 115 : 1004—1007.
5. Cramer, G.R. and R.S. Nowak 1992. Supplemental manganese improves the relative growth, net assimilation and photosynthetic rates of salt-stressed barley. *Physiol. Plant.* 84 : 600—605.
6. Delane, R., H. Greenway, R. Munns and J. Gibbs 1982. Ion concentration and carbohydrate status of the elongating leaf tissue of *Hordeum vulgare* growing at high external NaCl. I. Relationship between solute concentration and growth. *J. Exp. Bot.* 33 : 557—573.
7. Fowler, J.L. 1991. Interaction of salinity and temperature on the germination of crambe. *Agron. J.* 83 : 169—172.
8. Francois, L.E., T.J. Donovan, E.V. Mass and G.L. Rubenthaler 1988. Effect of salinity on grain yield and quality, vegetative growth, and germination of triticale. *Agron. J.* 80 : 642—647.
9. ——— and J.R. Goodin 1972. Interaction of temperature and salinity on sugar beet germination. *Agron. J.* 64 : 272—273.
10. Friend, D.J.C. 1965. Ear length and spikelet number of wheat grown at different temperatures and light intensities. *Can. J. Bot.* 43 : 345—353.
11. ———, J.E. Fisher and V.A. Helson 1963. The effect of light intensity and temperature on floral initiation and inflorescence development of Marquis wheat. *Can. J. Bot.* 41 : 1663—1674.
12. Hoshikawa, K. 1962. Studies on the ripening of wheat grain. 4. Influence of temperature upon the development of the endosperm. *Proc. Crop. Sci. Soc. Japan.* 30 : 228—231.
13. Karim, M.A., E. Nawata and S. Sigenaga 1992. Dry matter production and distribution of mineral ions in different parts of the plant in hexaploid triticale under salt stress conditions. *Jpn. J. Crop. Sci.* 61 : 439—446.
14. ———, ———, and ——— 1993. Effects of salinity and water stress on the growth, yield and physiological characteristics in hexaploid triticale. *Jpn. J. Trop. Agric.* 37 : 46—52.
15. ———, and S. Shigenaga 1992. Effect of NaCl on the growth and physiology in triticale plants. *Rep. Soc. Crop Sci. Breed. Kinki* 37 : 22—28.
16. Katerji, N., J.W. van Hoorn, A. Hamdy, N. Bouzid, S.E. Mahrous and M. Mastrorilli 1992. Effect of salinity on water stress, growth and yield of broadbeans. *Agric. Water Mang.* 21 : 107—117.
17. Khan, M.A. and I.A. Ungar 1984. The effect of salinity and temperature on the germination of polymorphic seeds and growth of *Atriplex triangularis* Willd. *Am. J. Bot.* 71 : 481—489.
18. Lepold, A.C. and R.P. Willing 1984. Evidence for toxicity effects of salt on membranes. In Staples, R.C. and G.H. Toenniessen eds., *Salinity Tolerance in Plants : Strategies for Crop Improvement*. Wiley-Interscience, New York. 67—76.
19. Maas, E.V. and G.J. Hoffman 1977. Crop salt tolerance—current assessment. *J. Irrig. Drain. Div. Am. Soc. Civ. Engrs.* 103 : 115—134.
20. Maftoun, M. and A.R. Sepaskhah 1978. Effect of temperature and osmotic potential on germination of sunflower and safflower and on hormone-treated sunflower seeds. *Can. J. Plant Sci.* 58 : 295—301.
21. Mahmoud, E.A. and M.J. Hill 1981. Salt tolerance of sugar beet at various temperatures. *N.Z. J. Agric. Res.* 24 : 67—71.
22. Melesse, T. and K. Caesar 1992. Stomatal and non-stomatal effects of salinity on photosynthesis in faba beans (*Vicia faba* L.). *J. Agron. Crop Sci.* 168 : 345—353.
23. Mozafar, A. and J.J. Oertli 1992. Root-zone temperature and salinity : Interacting effects on tillering, growth and element concentration in barley. *Plant Soil* 139 : 31—38.
24. Munns R., H. Greenway, R. Delane and J. Gibbs 1982. Ion concentration and carbohydrate status of the elongating leaf tissue of *Hordeum vulgare* growing at external NaCl. II. Cause of the growth reduction. *J. Exp. Bot.* 33 : 574—583.
25. Rivers, W.G. and D.J. Weber 1971. The influence of salinity and temperature on seed germination in *Salicornia bigelovii*. *Physiol. Plant.* 24 : 73—75.
26. Rozema, J. 1975. The influence of salinity, inundation and temperature on the germination of some halophytes and non-halophytes. *Oecol. Plant.* 10 : 341—353.

27. Seemann, J.R. and C. Chritchley 1985. Effects of salt stress on the growth, ion content, stomatal behaviour and photosynthetic capacity of a salt-sensitive species, *Phaseolus vulgaris* L. *Planta* 164 : 151—162.
 28. Singh, M.P., S.K. Pandey, M. Singh, P.C. Ram and B.B. Singh 1990. Photosynthesis, transpiration, stomatal conductance and leaf chlorophyll content in mustard genotypes grown under sodic conditions. *Photosynthetica* 24 : 623—627.
 29. Spiertz, J.H.J. 1974. Grain growth and distribution of dry matter in wheat plant as influenced by temperature, light energy and ear size. *Neth. J. Agric. Sci.* 22 : 207—220.
 30. Thorne, J.H. and H.R. Koller 1974. Influence of assimilate demand on photosynthesis, diffusive resistances, translocation, and carbohydrate level of soybean leaves. *Plant Physiol.* 54 : 201—207.
 31. Vinizky, I. and D.T. Ray 1988. Germination of guar seed under salt and temperature stress. *J. Am. Soc. Hortic. Sci.* 113 : 437—440.
 32. Walker, R.R., E. Torokfalvy and M.H. Behboudian 1988. Photosynthetic rates and solute partitioning in relation to growth of salt-treated pistachio plants. *Aust. J. Plant Physiol.* 15 : 787—798.
 33. Wardlaw, I.F. 1970. The early stages of grain development in wheat : response to light and temperature in a single variety. *Aust. J. Biol. Sci.* 23 : 765—774.
 34. Yoshida S, T. Satake and D.S. Mackill 1981. High-temperature stress in rice. IRRI research paper series no. 67. IRRI, Manila, Philippines. p. 15.
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