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Salinity Effects on Mineral Nutrients and Performance of Turnip (*Brassica Rapa* L.) at Different Growth Stages

A. DEHDARI[1**]

[1]Department of Agronomy and Plant Breeding, College of Agriculture, Yasouj University, Yasouj, Iran

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ABSTRACT- In order to study the effects of different salinity levels on turnip (*Brassica rapa* L.), an investigation was conducted at Yasouj University, Iran, in 2010. The effects of four salinity levels including 1.92, 9.87, 19.6 and 21.94 ds m^{-1} (20:1 ratio of NaCl: $CaCl_2$ in Hoagland solution) on germination, vegetative and maturity stages of turnip (Baherghan landrace) were investigated. The results revealed that the measured traits at the germination stage were significantly affected by salinity treatments. The effect of salinity stress was only significant for leaf area, sodium and potassium contents at the vegetative stage. Salinity had significant effects on all the recorded traits of turnip roots, except for Ca^{2+}, Zn and Fe contents. Based on stress intensity values, salinity affected germination percentage (SI=1.0) on the second day and the seedling root length (SI=0.93) more than other measured traits. The results of SI (stress intensity) showed that salinity affected Na^{+} content more than other traits at the maturity stage (SI=0.74). Ca^{2+} showed an inverse response and had the lowest SI (SI=0.001). Based on this study, vegetative growth and root elongation stages were more tolerant and sensitive to salinity, respectively. In addition, seedling root length at germination stage and tissue Na^{+} content at subsequent growth stages were the most important traits, recommended to be used as selection criteria in turnip breeding programs.

Keywords: Morphological Traits, Proline, Salinity Tolerance, Stress Intensity, Turnip Root.

INTRODUCTION

Salinity is a common pollutant and stress factor for plants in arid and semiarid regions. Salinity is also one of the major obstacles against plant produce throughout the world. Sodium decreases soil permeability, which reduces the flow of water to plants and

* Assistant Professor
**Corresponding author

affects germination, seedling, vegetation and maturity stages (2). Chloride is thought to be more harmful to plants than sodium. Chloride increases the toxicity of heavy metals and osmotic stress which damage plant tissues (27). In general, high salt levels can reduce plant productivity by osmotic stress and ion toxicity, which in turn influence mineral nutrition, the decrease of CO_2 fixation and the inhibition of protein synthesis as secondary effects (1).

Turnip (*Brassica rapa* L.) is rich in vitamins, minerals (such as calcium, potassium, iron, copper, magnesium and zinc) and anti-oxidants. In Iran, it is used as a medicinal plant to reduce body temperature and fevers (25).

On the other hand, the salinity of soil and water resources is a serious threat in many parts of Iran. Estimated land areas affected by salinity vary between 16 to 23 M ha (25). In spite of extensive literature about the effects of salinity on different plant species, few reports have been reported on the reaction of turnip to salinity (8, 16, 18 and 21), and the available information does not cover all aspects of turnip growth stages. Presently, there is no available information on the effect of salinity on turnip plants in Iran. The present study was therefore initiated to investigate the influence of salinity on the germination, vegetation and maturity (especially enlarged root) stages of turnip characteristics.

MATERIALS AND METHODS

This study reports two separate experiments. In the first experiment, the seeds of an Iranian turnip landrace named Baherghan (a marketable landrace in Fars province) were exposed to surface sterilization in 0.5% sodium hypochlorite solution and rinsed with deionized water. Four different levels of salinity including NaCl and $CaCl_2$ (20:1 molar ratio) i.e. 1.92 (only half-strength Hoagland solution as control), 9.87, 19.6 and 21.94 ds m^{-1} were used. Each treatment comprised of three replications of fifty seeds per petridish (as one replicate) in a completely randomized design. The treatments were applied at sowing time. Data for germination was daily recorded. After 11 days, the seedlings were removed from the petri dishes and the shoots and roots were separated. The shoot's and root's length and their fresh and dry weights were measured.

In the second experiment, the sterilized seeds were planted into pots (30×30×30 cm) containing truly washed riverbed sand. Seedlings were irrigated with half strength-Hoagland solution (11). Application of salinity treatments (9.9, 19.6 and 21.9 ds m^{-1}) in the Hoagland solution started gradually, when the fourth leaf of the seedling appeared (10-15 days after sowing date). The frequency of application was twice per week. For the non-salinity treatment (1.96 ds m^{-1}), the plants were irrigated only with half strength-Hoagland solution. Plants were grown in a greenhouse with average day/night temperatures of 28°C /22°C and relative humidity of 60-70 %. The photoperiod was 14 h with light sources being fluorescent-incandescent lamps with PAR of 414 µmol $m^{-2}S^{-1}$. Six uniform seedlings were kept in each pot as one replicate. Two months after applying the first salt treatment, three plants were harvested per each pot and leaf areas were measured. Leaves of plants in both control and salt treatments were separated and washed with distilled water. The proline content of samples was measured using Bates' (4) procedure. The dry weight of samples was recorded after 72 h in oven. One gram of each sample was weighed and incinerated at $500^{°c}$ for 4-5h and treated with 2N HCl.

Na^+ and K^+ were analysed by flame photometry, and Mg^{2+}, Ca^{2+}, Zn and Fe by an atomic absorption spectrophotometer (Model AA:3030).

At maturity, the three remaining plants in each pot were harvested and separated into shoots and roots. The number of leaves, shoot and root dry weight, root height and diameter, mineral content including Na^+, K^+, Mg^{2+}, Ca^{2+}, Zn and Fe for both roots and shoots were all determined as mentioned above.

Stress intensity (SI) for all traits was calculated using the Fisher and Maurer (1987) formula as SI=1- (Y_s/Y_p), where Y_p and Y_s are the mean amounts of traits in non-salinity stress (EC=1.92 ds m^{-1}) and high-salinity stress (EC=19.6 ds m^{-1}) conditions respectively.

Prior to analysis of variance, data for mineral contents were subjected to tests of normality using Q-Q plots (15). Collected data were then subjected to analysis of variance and the means were compared by the least significant difference test (LSD).

RESULTS

Effect of Salinity on Germination Stage

The results revealed that the measured traits at germination stage were strongly affected by salinity treatments (Table 1). Two days after sowing time, no seed germination was observed in high salinity levels (EC=19.6 and 21.94 dS m^{-1}) but, a high germination percentage (97.33%) occurred in non-saline (EC=1.92 dS m^{-1}) and moderate saline (66% in EC=9.87 dS m^{-1}) conditions (Figure 1a). During the later days, the seeds started to germinate at high salinity levels (data not showed). This result clearly showed that seed germination of turnip was delayed due to high salinity levels. By day 11, however, there was significant difference in the germination of the turnip plants grown under non-saline (99.33%), moderately saline (95.33%), and strongly saline (65.33% and 62% in EC=19.6 and 21.94 dS m^{-1}, respectively) conditions (Figure 1b).

Table 1.Mean square of salinity and error and SI for the measured traits at germination stage

SOV	Degree of freedom	Germination Percentage^A	Germination Percentage^B	Shoot Length	Root Length	Shoot dry wt.	Root dry wt.
Salinity	**3**	**7160.33****	**1147****	**17.321****	**29.453****	**0.0009****	**0.0007****
Error	**8**	**118.33**	**60**	**0.084**	**0.093**	**0.00009**	**0.00003**
SI	**------**	**1**	**0.38**	**0.91**	**0.93**	**0.05**	**0.20**

^{A} ,^{B} and ** show germination percentage at day 2, final germination percentage and significance at (P≤0.01) respectively.

The seedling root and shoot lengths and dry weights decreased significantly by increasing salinity levels (Figures 1c-f). The highest (5.003 cm, 3.75 cm, 0.033 g and 0.039 g for seedling root and shoot lengths and seedling root and shoot dry weights, respectively) and lowest (0.47cm, 0.053 cm, 0.004 g and 0.004 g for seedling root and shoot lengths and seedling root and shoot dry weights respectively) amounts of these traits were observed in the non-saline and strongly saline treatments respectively. Based on stress intensity values, salinity affected germination percentage (SI=1.0) more at the second day and for seedling root length (SI=0.93) as compared to the other measured traits (Table 1). In addition, shoot dry weight had the lowest SI value (0.049), indicating that this trait had the least change under salinity stress. These results are in accordance with the findings of Noreen and Ashraf (21) who found that salinity had negative and significant effects on the germination of turnip and radish. They reported a marked reduction of germination percentage, shoot fresh and dry weights and root fresh and dry weights when increasing salinity levels in their experiment.

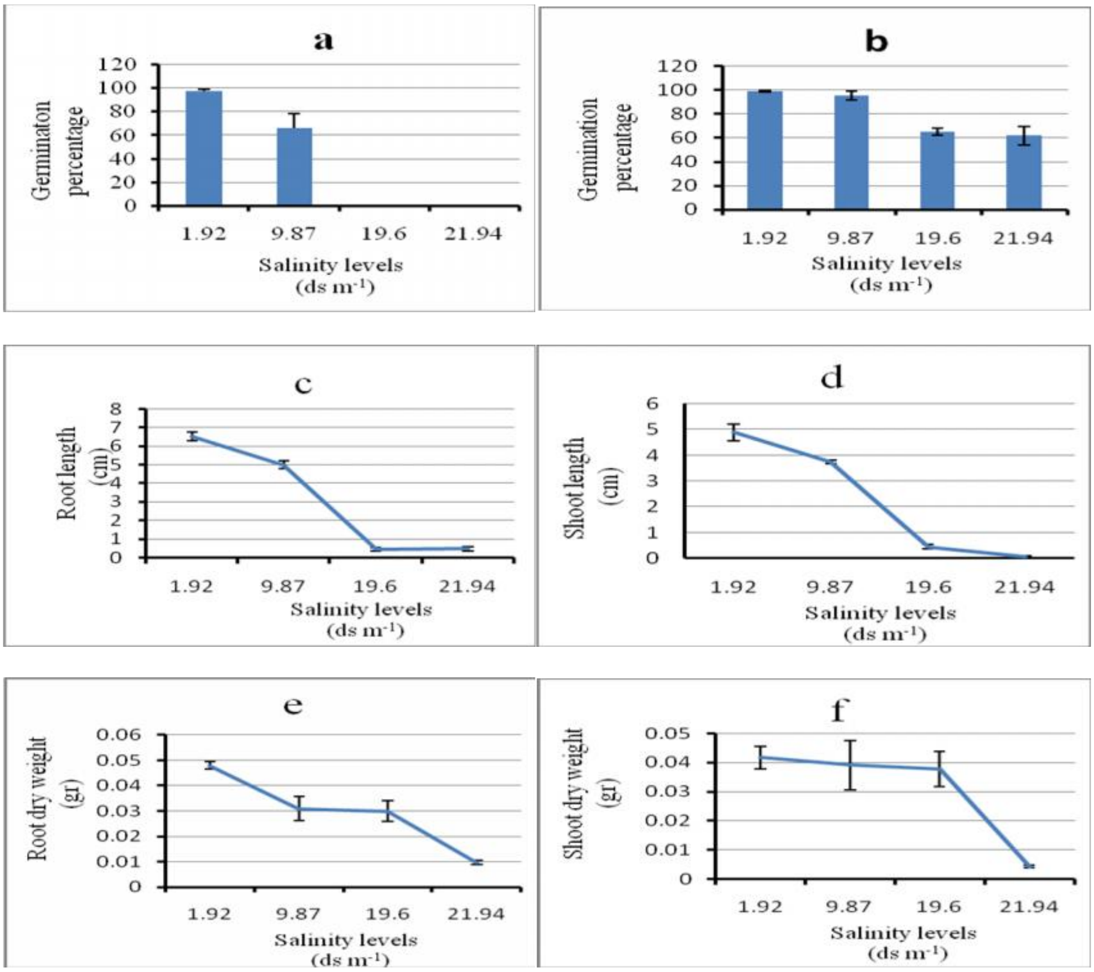

Fig. 1. Means and standard errors of salinity levels for measured traits at germination stage. a) germination percentage at day 2, b) final germination percentage, c) average of root length, d) average of shoot length, e) root dry weight of seedling, and f) shoot dry weight of seedling

Effect of Salinity on Vegetative Stage

The effect of salinity stress was only significant for leaf area, and sodium and potassium content (Table 2). This may be due to fact that turnip is relatively tolerant to salinity at the vegetative growth stage. Leaf area decreased significantly as salinity levels increased

(Figure 2g). Maximum and minimum leaf areas were observed in non-salinity (2.144 m^2) and high salinity (1.362 m^2) levels, respectively. Leaves plays a key role in photosynthesis and the final production of turnip, therefore, this reduction decreases turnip growth and root yield. A marked reduction in shoot potassium content was observed as a result of salt stress, but there were no significant differences among moderate, and high salinity levels (Figure 2h). High Na^+ concentrations in external solutions cause a decrease in K^+ concentration in the tissues of many plant species (12). These decreases could be due to the antagonism of Na^+ and K^+ at uptake sites in roots, the effect of Na^+ on K^+ transport into the xylem (17), or the inhibition of uptake processes (26). Potassium has an important role in stomatal regulation, osmoregulation, energy status, charge balance, protein synthesis, and homeostasis of plants (5 and 19). Thus, the reduction of potassium content by salinity will impair gas exchange and ultimately, plant performance.

Table 2. Mean square of salinity and error and SI for the measured traits at vegetative stage

SOV	df	Leaf area	proline	Shoot dry wt	Na^+	K^+	Ca^{2+}	Mg^{2+}	Zn^{2+}	Fe^{2+}
Salinity	3	39165709.7**	0.261^{ns}	0.59^{ns}	473.91**	25.38*	0.0006^{ns}	0.0001^{ns}	0.00003^{ns}	0.0044^{ns}
Error	8	2601816.1	0.131	0.22	11.22	5.59	0.0007	0.0002	0.00024	0.0024
SI	- -	0.32	0.34	0.21	0.86	0.27	0.03	0.01	0.06	0.18

*,** **and** ^{ns} **significant (at P≤ 0.05, and P≤ 0.01) and non-significant, respectively**

In contrast to leaf area and potassium content, salinity increased shoot sodium content (Figure 2i). An increase in sodium content of plant tissues as result of salt stress has also been reported by many researchers (2, 6 and 7). In contrast to wheat (7), salinity had no significant effect on proline accumulation. It is concluded that proline had no important role in the osmotic adjustment of turnip under osmotic stress. Osmotic adjustment in turnip may occur as a result of other components and minerals as well. For example Meng et al. (20) reported high accumulation of glutathione in diploid and tetraploid turnips by salinity.

The results of SI (Table 2) showed that salinity affected Na^+ content more than other traits at vegetative growth stage (SI=0.861) and Mg^{2+} had the lowest SI value (SI=0.013).

There is little information about the effect of salinity on the vegetative growth stage of turnip. Petropoulos et al. (23) found that increasing salinity levels within the irrigation water did not affect the foliage weight of turnip in the first year, but caused a significant reduction in the second year of their experiment.

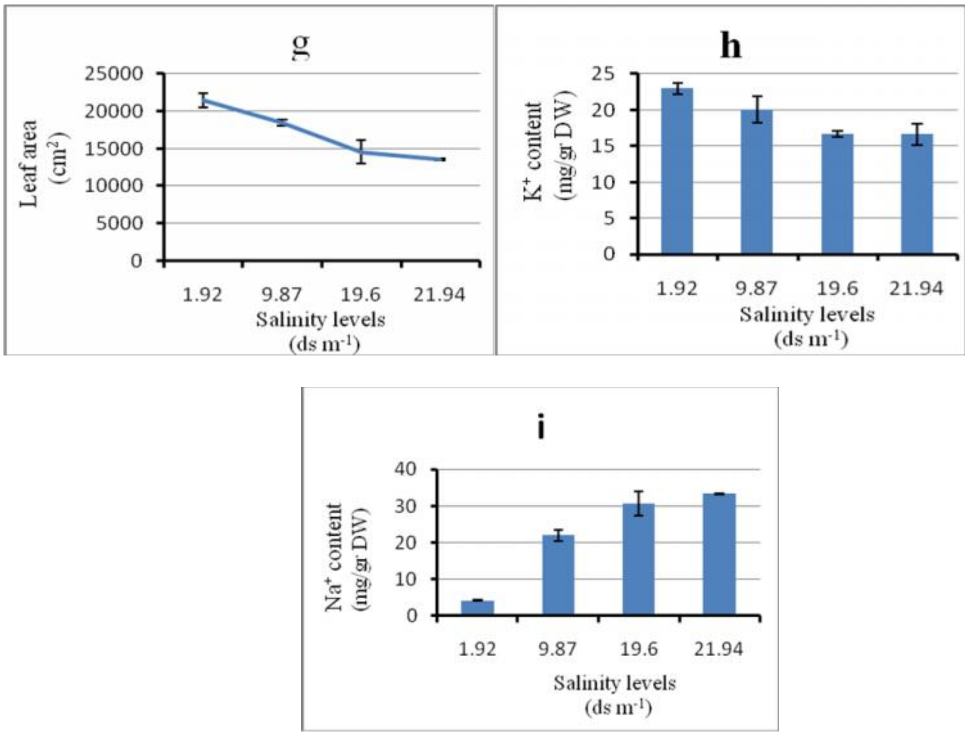

Fig. 2. Means and standard errors of salinity levels for measured traits at vegetative stage g) leafarea, h) shoot K^+ content, and i) shoot Na^+ content

Effect of Salinity on Shoot Traits at Maturity Stage

The effect of salinity was significant only for sodium, potassium and zinc contents (Table 3). However, it did not affect the shoots dry weight, leaf number, Ca^{2+}, Mg^{2+} and Fe^{2+} contents at the end of turnip growth stage. The effect of salinity on sodium and potassium at this stage was similar to the vegetative growth stage (Figures 3j and 3k). No clear response was found to the effect of salinity on zinc content; however, lowest and highest amounts of zinc content were obtained in high-stress and non-stress conditions respectively (Figure 3-l). Similar to the vegetative growth stage, Na^+ content was affected more than other traits (SI= 0.86) and Mg^{2+} had the lowest change (SI=0.009) by salinity (Table 3).

Table 3. Mean square of salinity and error and SI for the shoot measured traits at maturity stage

SOV	Degree of freedom	Leaf number	Shoot dry wt	Na^+	K^+	Ca^{2+}	Mg^{2+}	Zn^{2+}	Fe^{2+}
Salinity	**3**	**0.905^{ns}**	**24.710^{ns}**	**546.19****	**25.670***	**0.0013^{ns}**	**0.0001^{ns}**	**0.0006***	**0.0116^{ns}**
Error	**8**	**1.12**	**24.48**	**27.25**	**4.25**	**0.001**	**0.00004**	**0.0001**	**0.0055**
SI	**-----**	**0.01**	**0.20**	**0.86**	**0.28**	**0.01**	**0.009**	**0.18**	**0.08**

*, ** and ^{ns} significant (at $P \leq 0.05$, and $P \leq 0.01$) and non-significant, respectively

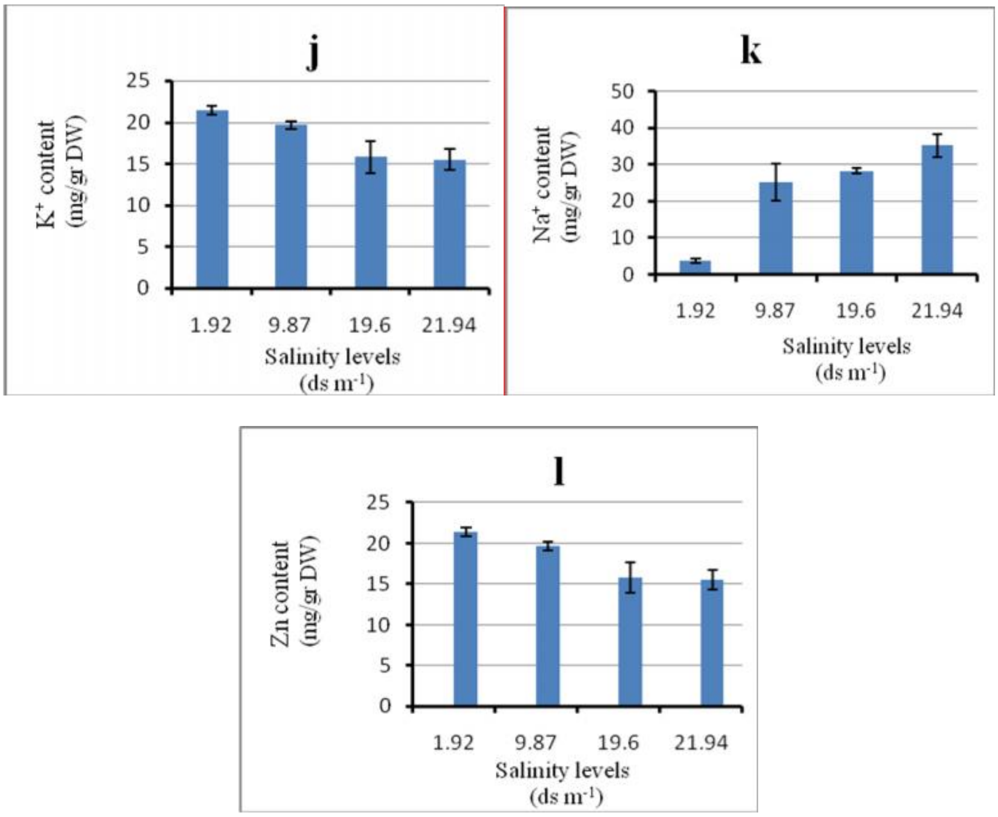

Fig. 3. Means and standard errors of salinity levels for measured traits on foliage tissue at maturity stage. j) shoot K^+ content, k) shoot Na^+ content, and l) shoot Zn content

Effect of Salinity on Turnip Root and Root Traits

Turnips are grown mainly for their enlarged root; it is therefore necessary to investigate the effect of salinity on turnip root yields and mineral content. Salinity had a significant effect on all traits of turnip root, except for Ca^{2+}, Zn^{2+} and Fe^{2+} contents (Table 4). High reductions were detected in root fresh and dry weights, root diameter, height and potassium content by salinity (Figures 4m-q). Minimum amounts of these traits were obtained under the highest salinity treatment (EC=21.94 dS m^{-1}). Root Na^+ content increased by increasing salinity levels (Figure 4p). Maximum amount of root Mg^{2+} content was observed under moderate salinity levels (EC=9.87 dS m^{-1}), indicating that low salinity concentrations may signal Mg^{2+} uptake from turnip roots.

The results of SI (Table 4) showed that salinity affected Na^+ content more than other traits at this stage (SI=0.74) while Ca^{2+} had the lowest SI (SI=0.001).

Table 4. Mean square of salinity and error and SI for the root measured traits at maturity stage

SOV	Degree of freedom	Root dry wt.	Root diameter	Root height	Na^{+}	K^{+}	Ca^{2+}	Mg^{2+}	Zn	Fe
Salinity	3	122.14**	2.40*	2.81**	250.13**	17.520**	0.0006^{ns}	0.0005**	0.00007^{ns}	0.0059^{ns}
Error	8	6.81	0.04	0.22	5.04	1.82	0.0007	0.00003	0.00009	0.01413
SI	-----	0.38	0.32	0.38	0.74	0.27	0.001	0.001	0.30	0.04

*, ** and ^{ns} significant (at P≤ 0.05, and P≤ 0.01) and non-significant, respectively

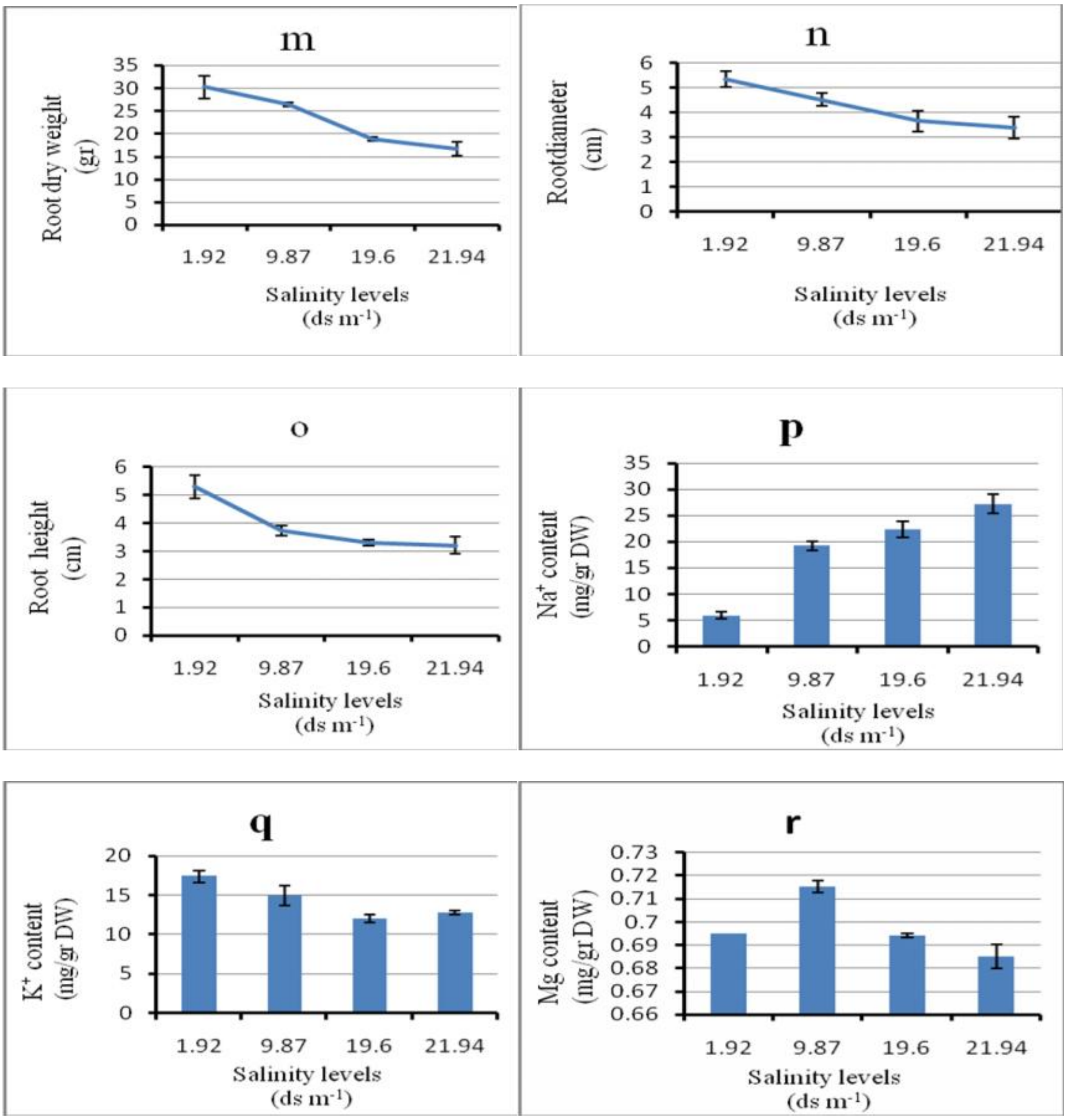

Fig. 4. Means and standard errors of salinity levels for measured traits on root (root) tissue at maturity stage. m) root dry weight, n) root diameter, o) root height, p) root Na^{+} content, q) root K^{+} content, and r) root Mg content

DISCUSSION

This study provides important information about the impacts of salinity on different turnip growth stages. Like other plant species, both growth and productivity of turnip were stunted or limited by saline conditions. The results also showed that different growth stages of turnip plants reacted differently to salinity stress. Based on this study, the root elongation stage was more sensitive to salinity than other turnip growth stages. Francois (8) reported that turnips were more salt tolerant at germination than subsequent stages of growth.

The enlarged turnip root was affected more than other tissues by salinity, probably because high concentrations of salt particles surrounding the roots caused local dehydration (27) and led to root damage, inhibiting its growth and development. In agreement with the present work, Osawa in 1961 (cited by 24) concluded that turnip tops are significantly more salt tolerant than roots. Francois (8) reported that for each unit of increase in salinity (above the salinity threshold) root and shoot biomass productions reduced 8.9% and 4.8% respectively. In contrast to Francois (8), the effect of salinity on the final germination percentage in the current study was significant.

In contrast to other plant species (7), salinity had no significant effect on Ca^{2+} at different growth stages. However, similar to other plant species reported by Cramer et al. for barley (6), Huand Schmidhalter for wheat (12) and Awada et al. for beans (3) the present study found that the adjustment of Ca^{2+} in turnip tissues may have occurred by applying $CaCl_2$ as one component of the saline solution. In contrast, Ashraf and Naqvi (2) reported that supplemental Ca^{2+} in the presence of salinity had positive effects on the growth of *Brassica juncea* and *B. napus*, but not of *B.carinata* and *B. rapa,* thereby demonstrating genotypic differences to the addition of Ca^{2+} in plant-growth responses. Also, salinity was found to have no significant effect on Fe content. Based on previous literature (22), salinity can differentially affect the micronutrient concentrations in plants. For instance, in contrast to the present work, Verma and Neue (28) concluded that salinity increased Fe content in the shoots of lowland rice, but decreased Fe content in barley and corn as a consequence of salinity conditions (10).

The effect of salinity on Mg^{2+} content was significant only for the root tissue. Although many studies have analyzed plant tissues for Mg^{2+}, the reports are contradictory, and few salinity–nutrient studies have directed any attention to this nutrition as affected by salinity (9). A study by Dehdari et al. (7) revealed that the Mg^{2+} concentration in wheat leaves was reduced by salinity but no correlation was found between wheat biological yield and Mg^{2+} accumulation under saline conditions.

The effect of salinity on Zn^{2+} in this work was not significant except for the shoot tissue at maturity stage; however, clear explanations cannot be provided by the observed data from Zn^{2+} since the results of previously reported research on several plant species are different. For example, salinity increased Zn^{2+} concentration in rice shoots (28), but decreased it in corn (10) and did not affect it at growing and mature leaves of wheat (13 and 14).

CONCLUSIONS

This study focuses on the effects of salinity on important traits of turnip at different growth stages. Root elongation stage was more sensitive to salinity. Therefore, irrigation with saline water will be more harmful for turnip plants at this stage. In addition based on stress intensity values and the idea that traits most highly affected by stress could be used as selection criteria, seedling root length at germination stage and tissue Na^+ content at subsequent growth stages are the most important traits recommended for consideration in turnip breeding programs.

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اثر شوری بر مقدار مواد معدنی و عملکرد شلغم (*Brassica Rapa* L.) در مراحل مختلف رشد

اشکبوس دهداری[1]*

[1]بخش زراعت و اصلاح نباتات، دانشکده کشاورزی، دانشگاه یاسوج، جمهوری اسلامی ایران

چکیده- به منظور بررسی تاثیر سطوح مختلف شوری بر خصوصیات شلغم، آزمایشی در گلخانه تحقیقاتی دانشگاه یاسوج اجرا شد. در این آزمایش اثر چهار سطح شوری شامل: شوریهای ۱/۹۲، ۹/۸۷، ۱۹/۶، ۲۱/۹۴ دسیزیمنس بر متر (حاصل از کلریدسدیم و کلریدکلسیم به نسبت ۲۰ به ۱ در محلول هوگلند) در مراحل جوانه زنی، رشد رویشی و رسیدگی مورد بررسی قرار گرفت. نتایج نشان داد که ویژگی های اندازه گیری شده در مرحله جوانه زنی به شدت تحت تاثیر شوری (P≤۰/۰۱) قرار گرفتند. در مرحله رویشی تاثیر شوری فقط برای صفات سطح برگ، مقادیر سدیم و پتاسیم برگ معنی دار شد. در مرحله رسیدگی تأثیر شوری بجز برای صفات کلسیم، روی و آهن برای بقیه صفات معنی دار گردید. بر اساس مقادیر شدت تنش در مرحله جوانه زنی درصد جوانه زنی(SI=۱) و طول ریشه چه(SI=۰/۹۳) بیشترین تاثیر از شوری داشتند. در مرحله رسیدگی میزان سدیم بیشتر از سایر صفات تحت تاثیر شوری قرار گرفت (SI=۰/۷۴) در حالی که میزان کلسیم کمتر از سایر صفات به شوری واکنش نشان داد(SI=۰/۰۰۱). به طور کلی نتایج حاصل از این پژوهش نشان داد که مراحل رشد رویشی و غده دهی به ترتیب متحملترین و حساسترین مراحل نسبت به شوری بودند. بعلاوه می توان از صفات طول ریشه چه در مرحله جوانه زنی و مقدار سدیم در مراحل بعدی بعنوان معیارهای انتخاب در برنامه های اصلاحی تحمل به شوری در شلغم استفاده نمود.

کلمات کلیدی: پرولین، تحمل به شوری، شدت تنش، ریشه (غده) شلغم، ویژگی های مورفولوژیکی

*استادیار

**مکاتبه کننده