EVALUATION OF THE EFFECTS OF SALINITY ON SPINACH (*Beta vulgaris* var. *cicla*) GROWN IN A HYDROPONIC SYSTEM ALONG THE COAST OF NAMIBIA

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ABSTRACT

Salinity is a major obstacle to increasing crop production worldwide. The cultivation of vegetables along the Namibian coastal areas is mainly hampered by the low availability of freshwater and good fertile soil. Despite the unsuitability of the coastal areas for agricultural production the use of innovative farming techniques such as hydroponics and the use of vegetables that are adaptable to brackish and saline water could be a solution for sustainable agricultural productivity. This experiment was conducted at the SANUMARC shade net garden, in an open environment. A hydroponic floating system was used. The salinity concentrations of the water were 0 (control), 5 and 10 parts per thousand (ppt). This study evaluated the effects of salinity on the vegetative growth and quality, and also the yield potential of the Fordhook giant variety of spinach when harvested more than once over a long period. Results showed that salinity has a negative effect on the vegetative growth, but positive effect on the quality [sugar content, (Brix %)]. The yield for spinach decreased as the number of harvests increased, but there was a good potential for using 5 ppt saline water for spinach production as there was no significant difference in yield (kg) obtained when it was compared to the yield from the control group.

INTRODUCTION

Insufficient fresh water for the cultivation of vegetables has become a serious problem; both from the economic and biological point of view worldwide (Rumasz, Koszanski, Rokosz & Jaroszewoka, 2005). The increase in the salinisation of soil and irrigation water is one of the major obstacles to increasing crop production (Zeng, Shannon, & Grieve, 2002). It becomes a problem for the growth of vegetables when excess salt molecules accumulate in the root zone, as it negatively affects plant growth. The production of vegetables along the Namibian coastal areas is mainly hampered by low availability of freshwater and good fertile soil for agricultural use, which has been declining not only in Namibia but in many areas of the world (Abou-Hadid, 2000). This phenomenon has led to an increase in the use of lower quality water such as saline water, and techniques such as hydroponics for vegetable cultivation (Öztürk, Waisel, Khan, & Birkhäuser, 2006). The effects of using brackish and saline water are that it reduces the yields of vegetables; however choosing salt tolerant vegetables could minimize vegetable yield reductions caused by salinity. Salinity refers to the presence of soluble salts in the soil or water and generally, it affects plant growth by increasing osmotic tension in the soil, making it more difficult for the plants to absorb water and nutrients from the soil (Dimsey, 2006).

Coastal areas in Namibia remain unsuitable for growing most types of vegetables due to very low rainfall (estimated to be around 20 mm per annum), brackish and saline water and soil. The use of innovative farming techniques such as hydroponics and the use of vegetables that are adaptable to brackish and saline water could be a solution for sustainable agricultural productivity in the coastal areas. This study evaluated the effects, if any that salinity had on the plant height, number of leaves, leaf width and quality of spinach (*Beta vulgaris* var. *cicla*; variety: Fordhook giant – Swiss chard) in the first instance. Secondly, the yield of harvesting intervals done on the same plant was quantified to determine the growth potential of spinach over a long period in different levels of saline water. The main hypothesis of the study was that there was no significant difference in respect of plant height, number of leaves, leaf width and quality of spinach grown with saline water as compared to the plants grown in fresh water with zero level of salinity. The results have shown that salinity had a negative effect on the vegetative growth and a positive effect on the quality [sugar content (Brix %)] of the plants. The vegetables were grown in a hydroponic floating system in an open environment along the coast of Namibia. The experiment was undertaken at the Sam Nujoma Marine and Coastal Resources Research Centre (SANUMARC) located at the mouth of the Omaruru River north of Henties Bay in the Erongo Region.

METHODS

Seedlings of spinach were grown in nine hydroponic tables (length = 170 cm, width = 85 cm and depth = 25 cm) that were filled with 231 litres of water in three replicates. Two types of fertilizers, hygroponic (231 g) and calcium nitrate (165 g), were added to the water solution. The seedlings were subjected to salinity only 21 days after sowing, during transplanting. The salt concentrations in the solutions were 0 (control), 5 and 10 parts per thousand (ppt). Spacing between plants was 34 cm x 25 cm with 15 plants per hydroponic unit. The seedlings were secured or positioned by piercing the stems through a piece of sponge which was placed firmly into the fomolite sagex hole, with the roots floating in the solutions.

The measurements for plant height (cm), leaf width and number of leaves were taken at an interval of 14 days, from 7 days after transplanting, when plants had achieved steady growth stability. Similarly, the quality variables [sugar content (Brix %) and fresh weight (g)] were measured for every harvest at an interval of 14 days. In order to quantify the yield (g) for spinach over a period of one year, leaf harvesting was undertaken every 14 days per plant in each hydroponic unit. The first harvesting was undertaken 35 days after transplanting. Analysis of variance (ANOVA) was applied to the data using MS-Excel Statistical software to determine the effect of salinity on growth and quality of spinach. In this study all statistical decisions were made at the 95% probability level ($P \leq 0{,}05$).

RESULTS AND DISCUSSION

Salinity effect on plant height

The plant height for the control group was significantly greater ($P \leq 0{,}05$) when compared to plants that were subjected to 10 ppt saline water (Figure 1). This implies that there was an inverse relationship between salinity concentration and growth rate, because as the saline water concentration increased, the plant growth rate decreased. However there was no significant difference ($P \geq 0{,}05$) in plant heights between the control group and plants that were subjected to 5 ppt saline water (Figure 1). Therefore salinity has a negative effect on the vegetative growth of spinach as it suppresses its growth when the salinity increases (Evans, 2006). This has also been observed in maize plants and pepper plants that were treated with NaCl (Izzo, Scagnozzi, Belligno & Navari-Izzo, 1993; Yildirim and Güvenc, 2006). Similar results were obtained by Sterling (2009), who revealed that high concentrations of salts causes slow growth in plants and reduces the vegetable and fruit size compared to their average sizes.

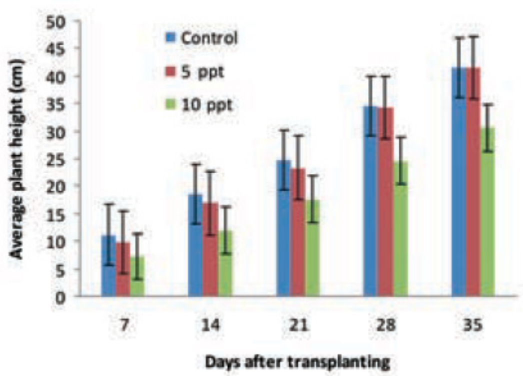


Figure 1. The effect of salinity on spinach plant heights.

Salinity effect on the number of leaves

The number of leaves decreased as salinity levels increased from the 7th to 14th day after transplanting, but increased significantly from the 21st to 35th days after transplanting (Figure 2). There was a significant difference ($P \leq 0{,}05$) recorded between the number of leaves for the control group when compared to plants that were subjected to 5 and 10 ppt saline water. However there was no negative effect of salinity on the number of tillers/leaves, since plants that were subjected to 5 and 10 ppt saline water at the end of the experiment had more leaves than the control group. The leaf number per plant was much less sensitive to salt concentrations, since at 5 and 10 ppt there was more at the end of the experiment than in the control.

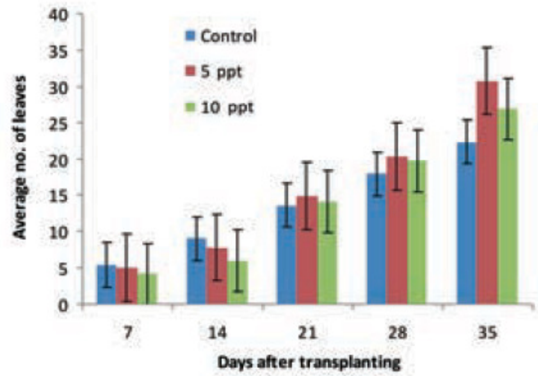


Figure 2. The effect of salinity on the number of spinach leaves.

Salinity effect on the leaf width

The leaf width in the control group increased significantly ($P \leq 0.05$) compared to plants subjected to 5 and 10 ppt saline water. Therefore as salinity reduced plant growth, the leaf width was retarded and thus led to the reduction in leaf area for most plants that were subjected to 5 and 10 ppt saline water compared to the control plants. However, the plants that were subjected to 5ppt had wider leaf widths at harvesting, 35 days after transplanting. This result is supported by those of Houimli, Denden, & El-Hadj (2008) who revealed that salinity decreased the length and leaf area of pepper plants.

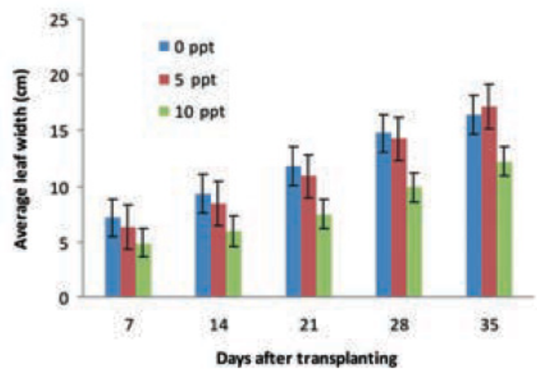


Figure 3. The effect of salinity on spinach leaf width.

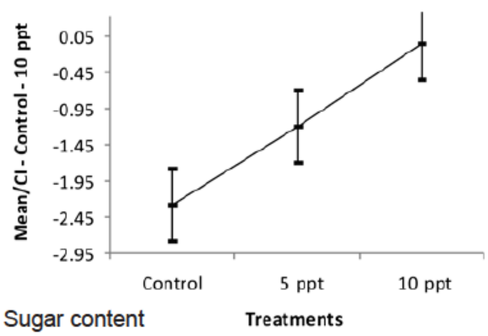
Salinity effect on the quality

The quality of the plant (based on sugar content) increased significantly ($P \leq 0{,}05$) with the increase in salinity levels

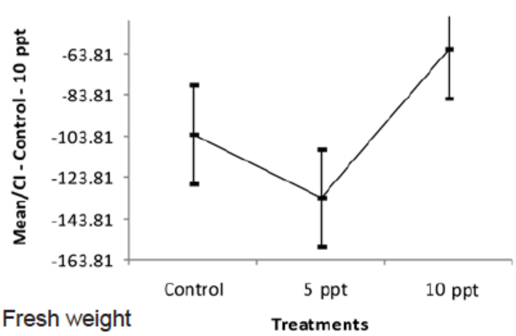
(Figure 4A). Fresh weight (Table 1) in all treatments varied whereas in some cases it decreased as salinity concentrations in the solutions increased, while on the other hand fresh weight for plants that utilized 5 ppt had more weight than the control group. There was a significant difference ($P \leq 0,05$) in terms of fresh weight for the control group when compared to plants that were subjected to 10 ppt saline water as shown in Figure 4B. However, when comparing sugar content from harvests 1 to 4, there was a decrease in quality as the first harvest had better quality than the other harvests, while the weight also decreased as the number of harvests increased in all treatments. This implied that spinach leaves decreased in quality (both sugar content and fresh weight) as more harvests were undertaken on the same plant. Yildirim and Güvenc (2006) and Tantawy, Abdel-Mawgoud, El-Nemr & Chamoun (2009) observed that salt stress significantly decreased fresh weight of pepper cultivars and the average fruit weight showed negative a response to salinity.

Table 1. The effect of salinity on the quality [sugar content (Brix %) and fresh weight (g)]

Treatments	Average sugar content (Brix %) per harvest				Average fresh weight (g) per harvest			
	Harvest 1	Harvest 2	Harvest 3	Harvest 4	Harvest 1	Harvest 2	Harvest 3	Harvest 4
Control	2	2	2	2	190	115	60	86
5 ppt	4	3	2	2	198	143	71	64
10 ppt	6	5	3	3	103	88	41	41



A: Sugar content



B: Fresh weight

Figures 4A and 4B. Confidence limit showing the significant difference for the quality (sugar content and fresh weight) of Fordhook giant spinach variety.

The quality observed by Mizrahi and Pasternak (1985) on spinach that was grown with saline water did not significantly differ in taste from its control. The decrease in quality could be attributed to the depletion of nutrients in the solutions. Because the first harvest could have benefited from the application of fertilizers that were applied during transplanting. However after each harvest there was no application of fertilizers done in order to boost the nutrient status in the solutions which could have been absorbed by the plant for the earlier development of leaves or vegetative growth. Therefore the application of fertilizer, especially nitrogen may play an important role for better yield of spinach (Ishaque, Iqbal, Saleem & Waseem, 2009).

Yield potential of spinach leaf

The average yield of the plants in all the treatments decreased as more harvests were undertaken (Figure 5). In the first harvest, the average yield per plant harvested was 190 g for control group, 198 g for 5 ppt and 103 g for plants that were subjected to 10 ppt saline water which was about half the yield obtained from the control group. The above result signifies that there is an opportunity for prospective vegetable farmers to use 5 ppt saline water since there was no significant difference compared to the control group for harvests 1 to 3. The decrease in harvest 4 could be attributed to a nutrient deficiency as the fertilizer was only applied at the beginning of the experiments.

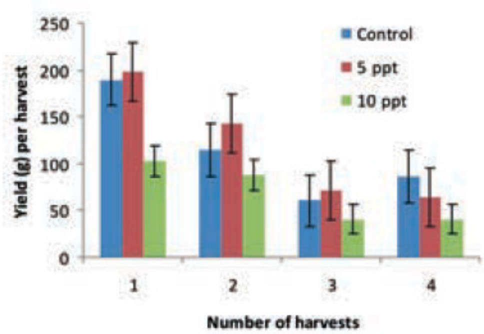


Figure 5. The yield potential for spinach at different harvests when grown in different water treatments.

CONCLUSION

It can be concluded that saline water can be utilized sustainably for the production of spinach using hydroponic floating systems along the Namibian coastal area. The results have shown that spinach has some tolerance to saline water with 5 ppt, since there was no significant difference measured for plant height, number of leaves and leaf width when compared with the control group. In addition, spinach with good quality [sugar content, (Brix %)] was obtained from plants that were subjected to an even higher salinity level (10 ppt) though there was a reduction in terms of growth. A spinach plant grown in a hydroponic floating system can be harvested several times, achieving good yields as long as fertilizer is added after every harvest. Otherwise the yields will be reduced as more harvests are made, due to the deficiency of nutrients from the water solution. Therefore the hypothesis that there is no significant difference in terms of plant height, number of leaves, leaf width and quality of spinach grown with saline water as compared to the plants grown in fresh water with zero level of salinity was accepted. Spinach was successfully grown with saline water (5 ppt) and even obtained a greater plant height, more leaves, similar leaf width and with better quality (sugar content) in both 5 and 10 ppt.

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