GREEN HOUSE EVALUATION OF THE EFFECTS OF SALINITY ON GERMINATION, GROWTH AND QUALITY OF VEGETABLES GROWN IN A HYDROPONIC SYSTEM ALONG THE COAST OF NAMIBIA

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ABSTRACT

The production of vegetables along the Namibian coast is hampered by scarce freshwater and poor quality soil for agricultural use, which has been declining not only in Namibia, but in many areas of the world. This has led to an increase in the use of brackish or saline water. The problem with using saline water is that it reduces the growth, yield and quality of many crops. Proper crop selection is one way to mitigate quality and yield reductions caused by salinity. A green house experiment tested the effect of five parts per thousands (ppt) or 10 ppt saline water on different varieties of cabbage, broccoli, lettuce and spinach for seed germination, plant growth, leaf yield and quality of leaf vegetables grown in a floating hydroponic system. Results have shown that the presence of salt in the water had a negative effect on seed germination, vegetative growth and yield, but positive effect on the quality of leaf vegetables based on sugar content.

INTRODUCTION

Salinity is one of the major obstacles to increasing crop production worldwide (Abou-Hadid, 1998, Zeng *et al*., 2002, Turan *et al*., 2009). It refers to the presence of soluble salts in 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). The production of vegetables along the Namibian coast is hampered by scarce freshwater and poor quality soil for agricultural use, which has been declining not only in Namibia, but in many areas of the world (Abou-Hadid, 1998). This phenomenon has led to an increase in the use of lower quality water such as brackish or saline water (Öztürk *et al*., 2006). Production techniques such as hydroponic systems could be used as alternatives for growing vegetables. The problem is that saline water reduces the growth, yield and quality of many crops. According to Abou-Hadid (1998) saline water can be successfully used for economic crop production by following the best management practices to reduce the negative effects of salinity on crop productivity or by cultivating salt tolerant varieties. In the latter case, choosing a suitable salt-tolerant crop can minimise crop losses caused by salinity.

In Namibia the coastal area receives less than 20 mm of rain a year, while the northeastern parts of the country receive an average of 600 mm of rain a year. Thus, the coastal area remains unsuitable for growing most crops due to very low rainfall, limited fresh water and highly saline ground water. Despite the unsuitability of the coastal area for agricultural production, the use of hydroponic systems and crop varieties adapted to the saline environment could be an alternative solution. Proper crop selection is one way to moderate quality and yield reduction caused by excessive salinity. It is therefore important to know which vegetables adapt well to the saline environment. Crops vary considerably in their capacity to withstand the adverse effects of salinity. To efficiently utilise the saline water and space along the coastal areas of Namibia for agricultural purposes, there is a need to identify crop varieties that can adapt the saline conditions of these coastal areas. Therefore, the objective of the study was to evaluate what effect, if any; saline water (5 or 10 ppt) has on germination, growth and quality of leaf vegetables grown in a hydroponic floating system. Vegetables such as cabbage (*Brassica oleracea* var. *capitata*), broccoli (*Brassica oleracea* var. *botrytis*), lettuce (*Lactuca sativa L.)* and spinach (*Beta vulgaris* var. *cicla*) were the object of study in this experiment. The study was done at the Sam Nujoma Marine and Coastal Resources Research Centre (SANUMARC) located at the riverbank of the Omaruru River north of Henties Bay in the Erongo region.

MATERIALS AND METHODS

A greenhouse experiment was conducted on four vegetable types with different varieties (Table 1) grown in a hydroponic floating system.

Table 1. Vegetables and varieties used in the experiment

Vegetable Types	Varieties
1. Cabbage (*Brassica oleracea* var. *capitata*)	a. Africa Green b. All Power c. Tropicana
2. Broccoli (*Brassica oleracea* var. *botrytis*)	a. Amazer b. Ironman
3. Lettuce (*Lactuca sativa L.*)	a. Edition b. Great Lakes c. Tropical Emperor
4. Spinach (*Beta vulgaris* var. *cicla*)	a. Viroflay b. Fordhook Giant (Swiss chard)

The study period was from February to June 2009. Eighteen hydroponics tables (length = 170 cm, width = 85 cm and depth = 25 cm) were used for the experiment. All hydroponic units were filled with 150 litres. Each unit was fertilised with 143 g of specialised hydroponics fertiliser (chloride free) and 114 g calcium nitrate as recommended. Each hydroponic unit had 25 plants. The spacing between the plants were 30 cm x 15 cm. The experiment consisted of three treatments laid out in a randomised complete block design with three replications.

Two experimental groups were watered with 5 ppt (0,0078 dSm-1) and 10 ppt (0,016 dSm-1), while the control group was watered with fresh tap water (0 ppt). Since there was no seed germination with sets watered with 5 and 10 ppt saline water, only seedlings subjected to fresh water were transplanted in all 18 hydroponic units. That means the seedlings which were watered with fresh tap water were only subjected to 5 and 10 ppt treatments when transplanted 21 days after sowing. From here on five plants of each variety, in all replicates, were randomly selected and measured for plant height (cm) every 14 days, while the number of leaves were counted every 30 days. The fresh weight (kg) and quality (sugar content: Brix %) were measured at harvest. The quality was determined using a reflactometer instrument. The analyses of variance (ANOVA) was applied to the data as a statistical tool to determine the effect of salinity on germination, growth and quality of the vegetables. The statistical decisions for significance were made at a 95 % probability level ($P < 0{,}05$).

RESULTS AND DISCUSSION

Seed germination

Results showed that salinity had an effect on seed germination (no germination took place in 5 ppt or 10 ppt water for all tested vegetables), while the germination in the control groups ranged between 61 % and 93 % of the seeds sown. Miyamoto *et al.* (1985), observed a decline in the germination of tomato and carrot seeds at salinities of 12 and 18 dSm–1 (approximately 7 680 ppt and 11 520 ppt), respectively and virtually zero at 23 dSm-L (equivalent to 14 720 ppt). Salinity has a critical influence on the seed germination and growth establishment of plants (Katembe *et al.*, 1998) and usually retards seed germination and growth of higher plants (Saffan, 2008). Qu *et al.*, (2007) observed a decrease in germination percentages with an increase in salinity when they tested the seed germination of the geographically widespread halophyte shrub *Halocnemum strobilaceum*. Similar results have been observed by Yildirim and Güvenc (2006) on the germination and emergence of pepper cultivars. According to Sosa *et al.* (2005) salinity can affect the germination of seeds either by creating osmotic potentials that prevent water uptake, or by toxic effects of specific ions. In normal circumstances, the physical process of water uptake leads to the activation of metabolic processes as the dormancy of the seed is broken following hydration (Katembe *et al.*, 1998). Therefore, the presence of salinity slows down the water uptake of seeds, which in turn inhibits their germination.

Plant height

Figure 1 indicates the average plant height of the different varieties of broccoli, cabbage, lettuce and spinach. The vegetative growth (plant height) of control plants for most vegetables increased significantly ($P \leq 0{,}05$) after transplanting, compared to plants subjected to 5 ppt and 10 ppt saline water. This implies that there is an inverse relationship between salinity concentration and growth rate, because as saline water concentration increases, the plant growth rate decreases (Mwazi *et al.*, 2011). For example, in this experiment plants that utilised 10 ppt saline water at the end, only reached about half or less the height of plants in the control group. One of the effects induced in plants by salt stress is growth reduction, as revealed by plant height reduction, and observed in maize (Izzo *et al.*, 1993) and pepper plants (Yildirim and Güvenc, 2006) treated with NaCl. Similar results were obtained by Izzo *et al.* (2008) for sunflowers treated with seawater and Tantawy *et al.* (2009) observed that increasing the level of salinity, significantly reduced the plant height and leaf area in tomato plants. Zapryanova and Atanassova (2009) revealed that salinity inhibits plant height in ornamental plants such as *Tagetes patula* and *Ageratum mexicanum*. Zeng and Shannon (2000) also revealed that plant stands of rice were reduced by salinity. However, for most vegetables there were no significant difference ($P \geq 0{,}05$) in plant height between varieties of the same vegetable subjected to 5 ppt and 10 ppt water respectively. There was only a significant difference ($P \leq 0{,}05$) in plant height for spinach varieties, whereas the Fordhook giant variety performed well compared to the Virofly variety (Figure 2).

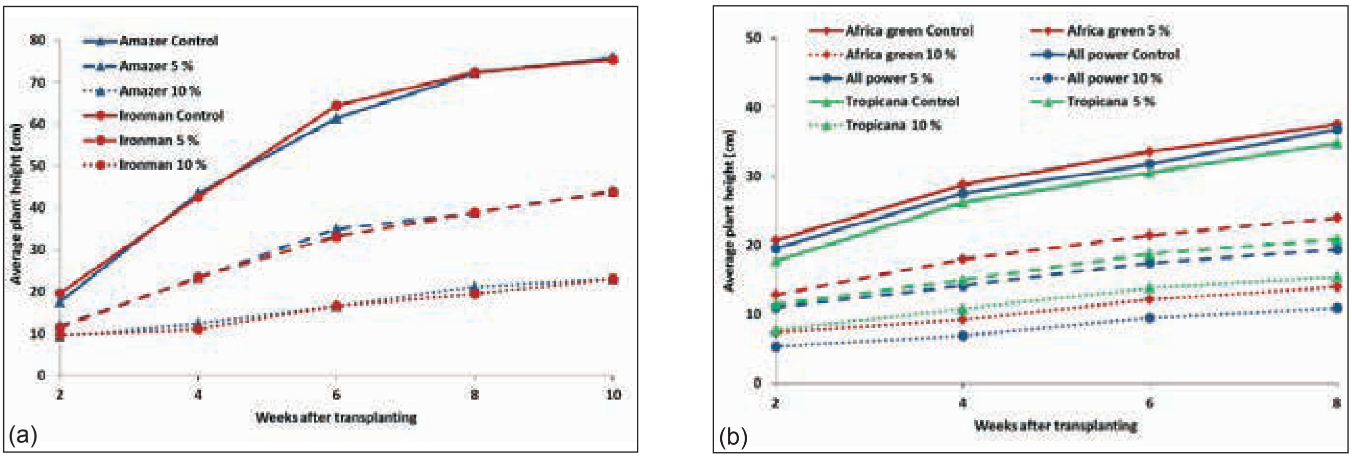

Figure 1. The effect of 5 ppt and 10 ppt saline water on plant height (cm) of (a) broccoli and (b) cabbage varieties.

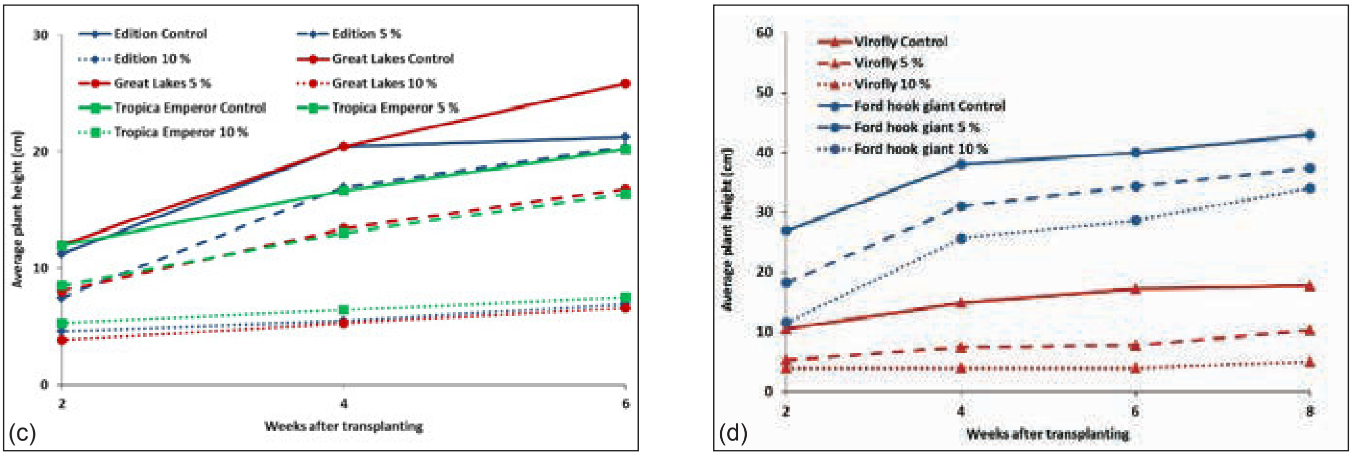

Figure 2. The effect of 5 ppt and 10 ppt saline water on plant height (cm) of (c) lettuce and (d) spinach varieties.

Leaves

Table 2 shows the average number of leaves for each vegetable per variety watered with different levels of salinity after being transplanted. The number of leaves for most vegetables decreased significantly ($P \leq 0{,}05$) with an increase in salinity concentration after being transplanted compared to the control plants. The results are supported by those of Hanen *et al.* (2008), who observed that the leaf number per plant decreased with the increase in salt concentration when they investigated tomato plants. Saffan (2008) revealed that leaf dry biomass decreased in response to salinity, whereas Houimli *et al.* (2008) revealed that salinity decreased the length and leaf area of pepper plants. Therefore, as salinity reduced plant growth, the formation of leaves was inhibited and led to less leaf yield for most plants subjected to 5 ppt and 10 ppt saline water compared to control plants.

Table 2. Shows the effects of 5 ppt and 10 ppt saline water on the number of leaves of all tested vegetables

VEGETABLE TYPE	VARIETIES	AVERAGE NUMBER OF LEAVES								
		One month after being transplanted			Two months after being transplanted			Three months after being transplanted		
		Control	5 ppt	10 ppt	Control	5 ppt	10 ppt	Control	5 ppt	10 ppt
Broccoli	Amazer	5	5	5	14	10	8	20	19	13
	Ironman	5	5	4	16	13	9	22	20	13
Cabbage	Africa Green	7	6	5	23	19	13	-	-	-
	All Power	5	4	3	22	16	9	-	-	-
	Tropicana	5	5	4	22	18	14	-	-	
Lettuce	Edition	7	8	6	9	9	8	-	-	-
	Great Lakes	7	6	6	10	11	8	-	-	-
	Tropica Emperor	6	6	4	8	9	6	-	-	-
Spinach	Fordhook Giant (Swiss chard)	9	7	6	10	10	8	-	-	-
	Virofly	6	5	5	7	7	6	-	-	-

Quality

Table 3 shows the average sugar content (Brix %) and fresh weight (g) as quality parameters for all the tested vegetables. The quality based on sugar content, increased with the increase in salinity levels, while fresh weight decreased. Most vegetables subjected to 5 ppt and 10 ppt saline water had the highest percentage of sugar content (Brix %) with a significant difference ($P \leq 0{,}05$) from the control plants. Plants in the control group had the highest fresh weight (g) compared to plants that utilised 5 ppt and 10 ppt saline water. Saline water therefore had an effect on the fresh weight of vegetables tested, with a high significant difference ($P \leq 0{,}05$). Yildirim and Güvenc (2006) observed that salt stress significantly decreased quality in terms of the fresh weight of pepper cultivars, and the average fruit weight also showed a negative response to salinity (Tantawy *et al.*, 2009). The quality observed by Mizrahi and Pasternak (1985) for lettuce grown with saline water, did not significantly differ in taste from its control.

Table 3. Effects of 5 ppt and 10 ppt saline water on vegetable quality, based on sugar content (Brix %) and fresh weight (g)

VEGETABLE TYPE	VARIETIES	AVERAGE SUGAR CONTENT (brix %)			AVERAGE FRESH WEIGHT (g)		
		Control	5 ppt	10 ppt	Control	5 ppt	10 ppt
Broccoli	Amazer	7	7	3	300	140	14
	Ironman	8	3	2	248	90	16
Cabbage	Africa Green	5	5	7	1027	485	167
	All Power	5	5	5	981	328	117
	Tropicana	5	6	8	940	427	215
Lettuce	Edition	2	4	5	80	141	55
	Great Lakes	2	5	5	77	94	86
	Tropica Emperor	2	5	3	105	135	37
Spinach	Fordhook Giant (Swiss chard)	6	7	8	112	96	82
	Virofly	3	5	7	105	80	76

CONCLUSION

The results of the experiment clearly show that the presence of salt in the water had a negative effect on seed germination No germination took place where seeds were watered with 5 ppt and 10 ppt saline water. Vegetative growth was also negatively affected. A significant difference ($P \leq 0{,}05$) for plants that utilised 5 ppt and 10 ppt saline water were recorded, compared to the control groups. The only positive effect on the quality of vegetables was based on sugar content. Most vegetables had a high sugar content, except for all broccoli varieties – the sugar content decreased with the increase of the salt concentration in the solutions. For most vegetables there was no significant difference ($P \geq 0{,}05$) between varieties of the same vegetable, except for spinach. A significant difference ($P \leq 0{,}05$) was measured between the Fordhook Giant and Viroflay varieties in terms of plant height, number of leaves and quality based on sugar content and fresh weight. The reduction in plant growth has been attributed to less water uptake due to the osmotic effect.

However, this study indicated the potential of growing vegetables at the coast of Namibia utilising water of poor quality (saline water), while in turn achieving high quality vegetables based on sugar content even though the vegetative growth and fresh weight reduced significantly for most vegetables. It is assumed that, because of good quality vegetables produced with saline water, better prices might be obtained on the market, which could compensate for the decreased mass. Therefore, the success of growing vegetables using saline water in a hydroponic system at the coast, will contribute to increased food security and sustainable vegetable productions.

The main advantages of the hydroponic system is its water saving production system. These systems could be utilised more frequently in desert agriculture at the coast and other parts of the country. This could be regarded as an adaptation option considering that Namibia is an arid and semi-arid country and also to counteract the predicted climate change impacts on water resources due to high evaporation as result of temperature rise. High yields will also be possible in places where the soil is infertile, as is the current situation at the coast of Namibia. The plants mature faster, yielding an earlier harvest of vegetables, which also means early vegetables on the market.

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