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The Response of Fordhook Giant / Swisschard (*Beta vulgaris var Cicla*) and Mustard (*Brassica Juncea*) Spinach Vegetables to Irrigation with Saline Water

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Authors' contributions

This work was carried out in collaboration between both authors. Author MVD designed the study, collected the data, performed the statistical analysis and wrote the protocol and the first draft of the manuscript. Author MTM reviewed the content. Both authors read and approved the final manuscript.

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ABSTRACT

Saline irrigation water is becoming an important water source as fresh water is fast becoming a scarce resource in many areas of the world, including Eswatini, especially in arid and semi-arid regions. A study to test the response of two varieties of spinach (fordhook giant and mustard) to salinity was conducted in a field pot experiment at the Faculty of Agriculture at the Luyengo Campus of the University of Eswatini. The treatments were laid in a randomized block design (RCBD). The experiment consisted of four treatments, each replicated twelve times. Treatments were salinity levels of 0.0 dS/m, 1.5 dS/m, 2.0 dS/m and 3.5 dS/m. All the treatments were subjected to similar agronomic practices. Spinach was grown and observed for a period of five weeks. Plant height was measured and the number of leaves counted weekly throughout the experiment. Significant differences ($P < 0.05$) between salinity treatments were obtained for plant height beginning in week 2 but were more pronounced in week 3, 4 and week 5. No significant differences were obtained for the number of leaves. There were however, clear significant differences between spinach irrigated with none saline irrigation water compared to saline irrigation water. It was concluded that irrigating spinach with saline water of more than 2.0 dS/m drastically reduce plant growth but not the number of leaves under the conditions of the experiment.

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1. INTRODUCTION

Crops in Eswatini are mainly grown in the Lowveld region (Fig. 1) which receives the lowest rainfall in the country averaging about 480 mm per year. The region lacks surface river water and therefore most crops are irrigated using ground water supplies. High quality fresh water is in increasing demand throughout the world especially in arid and semiarid regions where agriculture depends on irrigation and fresh water use exceeds sustainable supply [1,2]. Under drought conditions, high quality surface water supplies may not be available in sufficient quantities to meet crop needs and may be supplemented with poorer quality ground water [3].

Where groundwater is extracted and used for irrigation, it is saline making the production of many crops a challenge [4,5]. It is reported that photosynthesis, together with cell growth, is among the primary processes affected by salinity [6]. Spinach is a vegetable grown by many people in the rural Lowveld of the country. It is susceptible to drought conditions, and, because of climate change, it is necessary to optimize water application to crops.

High-salinity conditions in agricultural soil and in irrigation water is one of the most serious challenges faced by agricultural crops in the world [7]. The response of plants to salinity is complex and involves changes in morphology, physiology, and metabolism. Salinity effects on plants could include cellular water deficit, ion toxicity, nutrient deficiencies, and oxidative stress, leading to growth inhibition, molecular damage, and even plant death [8].

Spinach is an important leafy green vegetable that contains large quantities of bioactive compounds and nutrients that are not common to most other vegetables, such as ρ-coumaric acid derivatives that exhibit strong antioxidant activity and glucuronic acid derivatives of flavonoids [9,10,11]. These nutrients make it one of the most commonly grown vegetable in the rural areas.

Spinach was identified by [12] as a moderately salt-sensitive vegetable. Researchers have found that salt stress in spinach reduced germination, root elongation, seedling growth, chlorophyll content and photosynthesis, and increased membrane permeability [13,14,15]. According to [16], they reported that the tolerance threshold for spinach is 2.0 dS/m, but Pasternak and De Malach [17] found that irrigating with saline water of 4.0 dS/m on sandy soils did not result in yield reduction.

Ors and Suarez [1] observed that irrigation water salinity of up to 9 dS/m did not cause any yield loss in spinach during the first set of experiments, indicating that this cultivar is considerably more salt tolerant than spinach varieties reported in the literature. Severe salinity caused yield loss and decreased all gas exchange and vegetative parameters. They found that spinach was considerably more salt tolerant under cool season late winter conditions than under warmer climatic conditions. The increase in temperature between two of their experiments was 12.5°C while the relative yields decreased by 31% at the same salinity treatment of 9 dS/m.

A widely practiced approach for predicting the reduction in crop yield due to salinity has been described in the FAO Irrigation and Drainage Paper N°29 [18]. In equation form, it is stated as;

$$\frac{Y_a}{Y_m} = 1 - (EC_e - EC_{etreshold})\frac{b}{100} \quad (1)$$

for conditions where $EC_e > EC_{e\ threshold}$ where:

Y_a- actual crop yield
Y_m- maximum expected crop yield when $EC_e < EC_{e\ threshold}$
EC_e- mean electrical conductivity of the saturation extract for the root zone [dS/ m]
$EC_{e\ threshold}$- electrical conductivity of the saturation extract at the threshold of EC_e when crop yield first reduces below Y_m [dS/ m]
b- reduction in yield per increase in EC_e [%/ (dS/ m)]

The equation presumes that, under optimum management conditions, crop yields remain at potential levels until a specific, threshold electrical conductivity of the soil water solution is reached. When salinity increases beyond this threshold, crop yields are presumed to decrease linearly in proportion to the increase in salinity. The threshold salinity value proposed for spinach being 3.2 dS/m respectively.

The current study aims to assess the effects of different salinity levels on spinach (Fordhook giant and Mustard) growth, physiology, and nutritional value. Plant height and number of leaves were measured and counted weekly after transplanting throughout the experiment as determinants for the crop response to salinity.

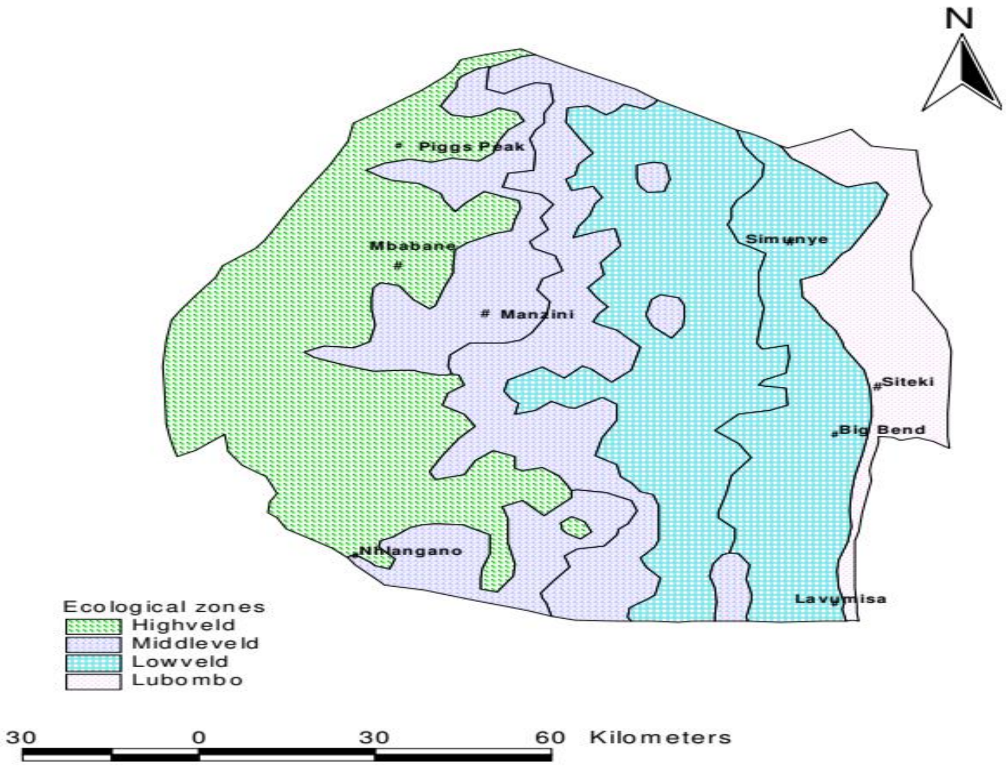

Fig. 1. Ecological zones of the Kingdom of Eswatini

2. MATERIALS AND METHODS

2.1 Plant Materials and Treatments

Two spinach varieties; Fordhook giant and Mustard spinach were planted in 4 L pots each filled with potting mixture (40% sand and 60% compost). The pots were laid out in a completely randomized block design (CRBD) arrangement in a greenhouse located in the Agricultural and Biosystems Engineering farm of the University of Eswatini at Luyengo campus. The farm is located in the Middleveld of Eswatini at 21°34′S and 31°12′E at an altitude of about 730 m above sea level [19].

The experiment consisted of three salinity treatment; 1.5 dS/m, 2.0 dS/m, and 3.5 dS/m. The control had 0.0 dS/m salinity. There were twelve replicates for each treatment.

2.2 Growth and Physiology Measurements

Plant measurements taken during and at the end of the experiment to determine the salinity effects on the crops included plant height (cm) and the number of leaves on a random sample of five plants in each replication. The survival percentage of the crop was also monitored. Shoot and fresh mass measurements were not taken and hence no dry matter analysis was done.

2.3 Statistical Analysis

A complete randomized block design was used for this experiment. Each biological replicate contained one pot and each treatment (CRBD) contained twelve replicate pots. Treatment means were separated by the Student's t test at the 0.05 level of probability using the ANOVA. The least significant difference between means was assessed using the Duncan's LSD test.

3. RESULTS AND DISCUSSION

3.1 Growth and Physiological Responses

The results revealed that there are significant differences among the three salinity levels (1.5 dS/m, 2.0 dS/m, and 3.5 dS/m) when compared to the control which had no salinity on growth (plant height) as shown in Table 1. However, when compared among themselves the differences were not significant in the first week of measurement. It is only in the second week whereby the highest salinity level showed significantly lower growth compared to the other two levels. The results collaborated with those found by [20] using sea water as a medium of salinity and those reported by [21].

From the third week onwards, differences between the salinity treatments were clearly noticeable with growth being severely reduced with increases in salinity. However, there was no clear pattern among the three salinity levels. These findings were similar to those reported by [22] in a study with lettuce.

There were no noticeable variety differences among the treatments. The growth of mustard spinach was slightly better than that of Fordhook giant at low salinity levels.

Visual observation showed that levels of salinity beyond 2.0 dS/m affected the leaf colour of both varieties of spinach. Fordhook giant leaves were yellowish in colour with the mustard spinach leaves having purple streaks along the margins. Both varieties had some leaf burns at the tips and edges of affected leaves. The change in leaf colour could as a result of a reduction in chlorophyll in the plant a phenomenon observed in a study by [23]. The main noticeable effects of salinity in the spinach are reduced growth rate that resulted in smaller leaves, shorter stature, and sometimes fewer leaves.

The number of leaves for each variety of spinach is shown in Table 2. During the first week of measurement both varieties had the similar number of leaves. Even though there was a noticeable decline in the number of leaves with increased in salinity levels. Fordhook giant was mostly affected compared to mustard which seemed to be tolerant.

These data are similar to those found by other researchers who found that the adverse impact of salinity on spinach yield was associated with smaller leaves rather than a lesser number of leaves. Previous studies have found that spinach chlorophyll content was reduced by sodium chloride (NaCl) solution [24] with high concentration of 200 or 172 mM [13,14,25], while chlorophyll fluorescence was unaffected [13,25].

In this study it is important to note that the researcher did not determine specifically whether the reduction in growth of the spinach due to salinity was as a result of osmotic effects or specific ion effects (the accumulation of chloride, sodium and or boron in the plant causing damage).

Table 1. Results of weekly plant height (cm) measurements for both varieties for the three different salinity levels tested

Week	Variety	Salinity level			
		0.0 dS/m	**1.5 dS/m**	**2.0 dS/m**	**3.5 dS/m**
	FDHK	6.9a	4.3b	4.5b	4.6b
1	MSTD	6.8a	4.6b	4.5b	3.7b
	Mean	6.8	4.5	4.5	4.1
	FDHK	9.2a	7.7b	6.9b	4.9c
2	MSTD	10.3a	7.6b	6.2b	4.5c
	Mean	9.7	7.6	6.5	4.7
	FDHK	11.2a	11.2a	9.7b	5.5c
3	MSTD	12.8a	11.8a	8.1b	5.8c
	Mean	12.0	11.5	8.9	5.7
	FDHK	15.3a	13.1b	11.1c	6.3d
4	MSTD	16.3a	15.6a	12.2b	6.0c
	Mean	15.8	14.3	11.7	6.1
	FDHK	21.2a	14.3c	17.7	6.5d
5	MSTD	19.7a	18.8a	16.0b	6.1c
	Mean	20.5	16.5	16.8	6.3

Numbers followed by the same letter in the same row are not significantly different at ($P < 0.05$). Mean separation by the LSD method

Table 2. Results of the average weekly number of leaf measurements for both varieties at the three different salinity levels tested

Week	Variety	Salinity level			
		0.0 dS/m	1.5 dS/m	2.0 dS/m	3.5 dS/m
	FDHK	2.5	2.0	2.2	2.3
1	MSTD	2.5	2.9	2.2	2.1
	Mean	2.5	2.5	2.2	2.2
	FDHK	4.0a	2.1b	1.7b	1.7b
2	MSTD	3.2a	3.9a	2.7a	3.0a
	Mean	3.6	3.0	2.2	2.3
	FDHK	4.0a	3.1b	2.1b	2.1b
3	MSTD	3.4a	3.6a	2.7a	3.1a
	Mean	3.7	3.3	2.4	2.6

Numbers followed by the same letter in the same row are not significantly different at (P < 0.05). Mean separation by the LSD method

Table 3. The result of the effect of salinity on spinach survival percentage

Fordhook giant spinach (FDHK)					
Salinity (dS/m)	**Week 1**	**Week 2**	**Week 3**	**Week 4**	**Week 5**
0.0	100	75	75	75	75
1.5	100	92	83	83	83
2.0	100	75	42	42	17
3.5	100	83	42	42	42
Mustard Spinach (FDHK)					
0.0	100	100	100	92	92
1.5	100	100	100	100	100
2.0	100	100	83	58	50
3.5	100	92	58	58	58

3.2 The Survival Percentage of Spinach to Salinity Levels

The effect of salinity on spinach survival is shown in Table 3. The variety Fordhook giant spinach was found to be highly susceptible to salinity compared to mustard spinach as its survival was greatly reduced above salinity levels of 2.0 dS/m. It was also naturally affected by the environment. Delfine et al. [26] showed that salt accumulating in spinach leaves reduced chlorophyll content and hence photosynthesis, first by decreasing stomatal and mesophyll conductance's to CO_2 diffusion and then impairs ribulose-1, 5-biphosphate carboxylase / oxygenase. An increase in salt concentration in the irrigation water may result in an increased salt accumulation in the growing media which limits the plant's ability to absorb water and nutrients.

4. CONCLUSION

It was concluded that the growth and number of leaves of spinach were affected by the salinity level of the irrigation water. Increasing the salinity level beyond 2.0 dS/m had significant effects for both Fordhook giant and mustard spinach. Significant differences in plant response to salinity levels were only observed from week three and beyond. The growth of mustard spinach was better than that of fordhook giant at low salinity levels indicating a slight tolerance. It may be recommended that farmers grow Mustard spinach as the first choice followed by Fordhook giant under similar conditions.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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