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Response of Eggplant (*Solanum melongena*) to Diluted Seawater Irrigation

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Abstract. The rapid growth of the global population is driving an increasing demand for fresh water, particularly for domestic, industrial, and agricultural use. As freshwater resources become scarcer, exploring alternative water sources for agriculture is imperative to ensure food security. Therefore, this research was conducted to determine whether diluted seawater would impact the growth and productivity of eggplant. The effects of irrigation water with five different salt levels—0, 0.5%, 1.0%, 1.5%, and 2.0% %—were observed on eggplants (Calixto F1**)** that were grown in pots for three months. Response variables evaluated included plant height increment, leaf development, stem diameter increase, number of fruits harvested, and unit weight of fruits. The physicochemical properties of the irrigation water and growing media were also tested. The findings revealed that while the overall growth parameters were not significantly affected by the varying salt levels ($p>0.05$), a notable increase in fruit yield was observed at a 0.5% salinity level. This suggests that a minimal salt concentration in irrigation water can enhance eggplant productivity without compromising plant health. With these findings, this research presents an innovative approach to using diluted seawater as an irrigation strategy for eggplant cultivation. This approach offers a sustainable solution for agriculture in coastal and arid regions where freshwater is limited.

Keywords: growth; eggplant yield; saline irrigation; salinity level; seawater.

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INTRODUCTION

Water scarcity is a significant challenge for agricultural production, particularly in arid and semi-arid regions where freshwater resources are limited. With the increasing demand for food production to meet the growing population's needs (Chávez-Dulanto et al., 2021; Springmann et al., 2018; Alvarez et al., 2017), there is a need to explore alternative water sources for irrigation purposes. One potential solution is the use of seawater, which is abundant and readily available in many coastal areas. However, using seawater for irrigation can pose significant challenges due to its high salt content, which can be detrimental to plant growth and yield. While some varieties of different crops have been shown to tolerate saline water at certain levels (Hapsari and Trustinah, 2018; Juwarno et al., 2018; Roslim and Anandia, 2015), there is a need to investigate the potential use of seawater for growing different high-value crops such as eggplants *(Solanum melongena)*, and in specific geographical locations.

To determine the suitability of saline water irrigation for eggplant, various studies have been conducted, yielding differing conclusions. According to Suarez et al. (2021), a comprehensive analysis of heirloom cultivars within the Solanaceae family, including eggplant, tomato, and pepper, revealed significant variability in salt tolerance among these crops, emphasizing the diverse adaptive responses exhibited under saline conditions. Lima et al. (2015) found that eggplants experience reduced growth and fruit production when exposed to salinity levels exceeding 0.5 dS/m, supporting the view that this crop is highly sensitive to salinity. Similarly, Fu et al. (2010) concluded that eggplant is particularly vulnerable to saline environments. In contrast, Yasar et al. (2006) classified eggplant as moderately sensitive to salinity, suggesting a certain level of tolerance. Even more contradictory, Queiroz et al. (2013) reported that eggplant growth was not significantly affected by salinity levels between 0.5 and 6.0 dS/m when nutrient solutions were applied, indicating a higher threshold for salt tolerance.

The divergence in response to salinity validates that salinity tolerance varies depending on the genetic factors of the cultivars, adopted cultural management, and local edaphoclimatic conditions where the crop is grown (Moura and Carvalho, 2014; Oliveira et al., 2014; Lima et al., 2015). It emphasizes the need to investigate and identify cultivars with higher salinity tolerance in each particular region. It can also be noted that the majority of trials assessing the salt tolerance and stress response in eggplant varieties have typically utilized solutions made from diluted sodium chloride (NaCl) (Brenes et al., 2020; Wu et al., 2020; Bsoul et al., 2016). While this approach provides insights into how eggplants cope with sodium chloride specifically, it does not fully replicate the conditions of seawater, which contains a complex mix of salts, including magnesium, sulfate, potassium, and various other ions, in addition to NaCl (Ludwig,2022; Semiz & Suarez, 2019; Holt et al., 2014). As a result, the findings from trials using only NaCl may not accurately reflect the plant's response to real-world saline conditions, where multiple salts interact to influence plant physiology. Therefore, using seawater in trials could yield different and potentially more comprehensive results, providing a more accurate assessment of the eggplant's salt tolerance and stress adaptation in diverse saline environments.

Masbate, an island province in the Philippines, is an area that faces water scarcity (particularly during dry seasons) and could benefit from exploring alternative water sources for agricultural production. A study specifically conducted in this region could provide valuable insights into the potential benefits and drawbacks of using seawater for irrigation purposes in the area. To address the pressing issue of freshwater scarcity and its impact on agriculture, this study was conducted to evaluate the response of eggplant to irrigation with diluted seawater. The results of this research are expected to yield valuable insights into how eggplant, a key crop in the region, can be cultivated using alternative water sources. By analyzing the effects of varying salinity levels on plant growth and productivity, the study aims to provide empirical data that can guide local farmers in optimizing their irrigation practices under conditions of limited freshwater availability.

The findings from this study could significantly contribute to the decision-making processes of both farmers and policymakers in Masbate and other regions facing similar challenges. By demonstrating the feasibility and potential benefits of using diluted seawater for irrigation, this research offers a practical solution that could be adopted in areas where freshwater is scarce. The data generated could inform the development of guidelines and policies that promote the efficient use of alternative water resources in agriculture, thus supporting the sustainability of local farming practices.

Moreover, this study has broader implications for addressing water scarcity on a larger scale. By exploring the use of seawater as an irrigation resource, it could pave the way for innovative agricultural practices that reduce dependency on freshwater, thereby alleviating the stress on this critical resource. In the long term, the successful implementation of such practices could enhance food security, promote sustainable agricultural production, and improve the resilience of farming communities in arid and coastal regions.

METHODS

Study Location and Experimental Design

To evaluate the response of eggplant to different salinity levels of diluted seawater irrigation, experimentation was carried out in the Crop Science research area at Dr. Emilio B. Espinosa Sr., Memorial State College of Agriculture and Technology (DEBESMSCAT), Cabitan, Mandaon, Masbate (12°16'48.29"N, 123°21'19.99"E) on March 14, 2022, to June 13, 2022. Randomized Complete Block Design (RCBD) was adopted as the experimental design, with five treatments and three replications. The treatments applied were the different levels of irrigation water salinity, such as Treatment A - Tap water (control), Treatment B - 0.5% salinity, Treatment C – 1% salinity, Treatment D - 1.5% salinity, and Treatment E - 2% salinity. Each experimental unit consisted of 10 eggplants planted in polyethylene bags.

Crop Management

In general, the growing and maintenance of the experimental crop were adopted from the eggplant production guide of the Department of Agriculture (2019). The eggplant utilized was Calixto F1 of EastWest Seed since it is the variety that is available in the market and commonly grown by local farmers. Eggplant seeds were sown, germinated, and raised in seedling trays using garden soil mixed with cattle manure.

Seedlings were transplanted into polyethylene pots four weeks after sowing. Sandy loam soil was used in planting and was fertilized with cattle manure.

Until the plants were established, they were irrigated with tap water. After two weeks, when the plants were already established, treatment applications were started. The pots were laid in double rows on the ground. With a spacing of 80 cm between plants, 10 seedlings were arranged per block, and a total of 150 seedlings were used for the study. Regular weeding and cultivation were done to control the growth of weeds and promote good water infiltration to the soil. The occurrence of insect pests was also monitored and controlled by manual picking.

Treatment Preparation and Application

The seawater used in the experiment was collected in the coastal area of Poblacion, Mandaon, Masbate, Philippines (12°13'25.26"N, 123°16'54.30"E). The homogeneity of properties of the seawater collected was maintained by storing it in a single container. The desired level of salinity used per treatment was attained by diluting seawater with tap water. To do this, a bucket of fresh water was gradually added and mixed with seawater until its salinity was raised to the proposed level. Saline irrigation for different treatments was first applied 14 days after transplanting. It was applied to the eggplants at seven-day intervals. The concentration of major ions (Salinity, K^+, Na^+, Ca^{2+}) in the seawater and the irrigation water applied to the experimental crops were measured using Horiba LAQUAtwin pocket water quality meters. Plants were watered early morning and late in the afternoon depending on the climate condition. On regular days, tap water was used as irrigation water.

Data Collection

The height, stem diameter, and number and size of leaves developed by five plants from each replicate (randomly selected) were measured/counted weekly after crop establishment. The total increment of each parameter was determined by subtracting the initial data (two weeks after transplanting) from the final data at the end of the study. When the skin of the fruits turned glossy and smooth, they were harvested manually every 4-5 days, and the total yield/plant (g) was calculated. The average fruit weight (g) was calculated using the data of all fruits from each replicate. The average number of fruits/plants was also recorded. After the final harvesting, soil samples were collected to measure the build-up of salts in the soil in each treatment. The soil samples taken were air-dried and crushed to pass through a 2-mm sieve. Saturated soil pastes were prepared and kept in a room for 24 hours. Saturation extracts were then taken, and their ionic properties were measured (Chaitanya et al., 2020).

Data Analysis

The experimental data collected were analyzed using the Statistical Tool for Agricultural Research (STAR) version 2.0.1 software. The growth and yield parameter observations were tested for normality of residuals and homogeneity of variances through the Shapiro–Wilk test and Bartlett's test, respectively. The difference between means was evaluated using a general linear model for Analysis of Variance (ANOVA) in single-factor RCBD, and Least Significant Difference (LSD) was employed for post-hoc analysis.

RESULTS AND DISCUSSION

Ionic Analysis

Table 1 shows the measurement of the three most abundant ions in seawater - sodium, calcium, and potassium. The initial ionic content of the irrigation water used was also recorded for comparison. It is worth noting that as the salinity level decreases, the count of each parameter also decreases. This can be attributed to the dilution of seawater with freshwater to achieve the desired salt level for each treatment.

Table 1. Salt content of the irrigation water

Treatment	Salinity (%)	K^+ (ppm)	Ca^{2+} (ppm)	Na^+ (ppm)
A	0	19.33	17.66	15.33
B	0.5	83.17	44.50	45.00
C	1.0	151.67	180.00	668.33
D	1.5	160.00	214.00	793.33
E	2.0	193.33	306.67	1015.00
Pure Seawater	2.95	218.33	591.67	1433.33

Table 2. Accumulated salts in the soil.

Treatment	Salinity (%)	K^+ (ppm)	Ca^{2+} (ppm)	Na^+ (ppm)
Initial content	0	98.22	115.00	46.33
A	0.06	103.33	116.43	74.83
B	0.22	115.00	308.33	223.33
C	0.21	126.67	386.50	174.33
D	0.21	111.50	256.67	135.00
E	0.24	102.83	483.33	246.67

The measured amount of potassium is slightly lower compared to reported counts from other countries (Mackenzie, 2023). Conversely, the calcium and sodium concentrations in the samples were found to be higher than those reported. It can also be noted that the control samples, which used tap water, also contained ions despite being derived from a surface water source (specifically the Mabigo run-of-the-river type dam). This is likely due to potential contamination from weathering, erosion, and agricultural activities in the dam's watershed. The content in treatment A slightly differed from the content of control treatment used by de Oliveira et al. (2016), which has K^+, Ca^{2+}, and Na^+ content of 13.8 ppm, 9.2 ppm, and 64 ppm, respectively.

Table 2 provides insights into the impact of diluted seawater irrigation on the ionic content and salinity of the soil, as determined through soil saturation extract measurements. Although there was minimal soil contamination in A treatment potentially caused by irrigation water splashing from an adjacent plant, the soil can still be considered non-saline at this level based on the classification by Zhang et al. (2019). The soil medium contains a substantial quantity of ions and nutrients, which can be attributed to the application of organic fertilizers to the soil. Animal manure is a common organic fertilizer that gradually releases nutrients to the soil as it undergoes decomposition.

The results demonstrate a significant change in salinity levels in the treated soil compared to its initial status. However, despite the application of different salinity levels, it can be noted that the amount of salt retained in the soil from each treatment was almost identical at the end of the experiment.

Growth parameters

The effects of various irrigation water salinity levels on the growth and production of eggplants were assessed throughout a 12-week growing period and an eight-week data collection period. Table 3 lists the average stem diameter, height, leaf count, fruit weight, and count of fruits per plant. Overall, none of the treatments had an impact on the growth parameters of the crop.

Throughout the experiment, a decreasing trend in the average stem diameter of the eggplants was observed as the salinity level increased, with values ranging from 1.05 cm to 0.94 cm. However, these variations were not significant ($p>0.05$), suggesting that the stem diameter was not affected by the different levels of salinity. Parkash and Singh (2020) reported a comparable trend and nearly identical stem size in two salinity stress trials of eggplant that they conducted. Their findings support the notion that eggplant is capable of maintaining stem growth and structural integrity under varying levels of salinity stress.

The results in the height increment of the plants indicated a noticeable trend. As the salt concentration in the irrigation water increased, the measurements showed a decline in the height of the eggplants. Similar results on eggplant seedlings exposed to different irrigation water electrical conductivity were reported by Sousa et al. (2022). However, despite the observed differences among the various treatments, significance ($p>0.05$) was not detected. This implies that the level of salt concentrations employed did not have a negative impact on the height development of eggplant.

The findings by Al-Zubaidi (2018) demonstrate that high salinity levels (8 and 12 dS/m) significantly reduce key growth parameters in eggplants, including plant height. A similar trend was observed in the present study, despite the lack of significant differences. This could be attributed to the wider range of salinity treatments in the previous experiment, while the present study used a narrower range of zero to two percent salinity. The number of leaves developed and matured in each treatment did not exhibit any apparent trend ($p>0.05$), with values fluctuating from 25.07 to 21.73 pieces, where the highest and lowest were obtained by the D and B treatments, respectively. It appears that the different levels of salinity of irrigation water applied did not have a significant effect on the number of leaves.

Table 3. The effects of water salinity on the growth of eggplant ($\bar{x}$±sd)

Salinity Level	Stem diameter (Cm)	Height increment (Cm)	Leaf count (Pcs)
0	1.03±0.06	50.98±4.22	23.93±2.19
0.5	1.05±0.03	56.23±4.30	21.73±2.66
1.0	0.99±0.03	49.25±8.61	22.87±2.14
1.5	0.94±0.04	47.25±3.62	25.07±3.35
2.0	0.96±0.05	45.78±1.74	23.47±2.69

a b

Figure 1. Experimental plants irrigated with water of varying salinity levels at (a) the early stage and (b) the maturity stage, after final harvesting.

In general, the results in growth parameters (stem diameter, plant height, and leaf counts) manifest that the eggplants used are relatively salt-tolerant plants. Some eggplant varieties are known to be moderately salt-tolerant (Suarez et al., 2021; Bsoul et al., 2016), meaning that they can grow in soils with a certain level of salinity. Therefore, the range of salinity levels applied in our experiment may not have been high enough to cause a significant difference in growth.

The duration of exposure to salt may also play a role in the effect on growth. Short-term exposure to salt may not have a significant impact on the growth of plants, especially because they are given access to fresh water between periods of exposure. In the experiment, the application of different salinity treatments to the experimental crops was done at a seven-day interval for 56 days. Between these intervals, the crops were irrigated with fresh water, which helped to dilute any accumulated salts in the soil (Zeng et al., 2014). This process of freshwater irrigation helps to prevent salt buildup in the soil, which can negatively affect plant growth and yield.

Additionally, the eggplants were planted in an open area, which exposed them to rainfall. Rainwater can also contribute to the leaching of salts from the soil (Li et al., 2018; Biswas & Biswas, 2014) by washing away excess salts that have accumulated in the soil. This further reduces the risk of salt buildup and helps to maintain a healthy soil environment for the eggplants. The results of the soil analysis presented in Table 2 provide validation for the observed trends in the experiment. Despite the application of different levels of salts to the experimental crops, the salinity of the soil remained relatively constant across all treatments.

Yield Parameters

Table 4 shows the average weight of each fruit and the count of fruits harvested per plant. It was revealed that the different salinity levels of irrigation water significantly affected the number of fruits developed per plant.

It was observed that the fruits of eggplant became smaller as the salinity of the irrigation water increased. The findings of Al-Zubaidi (2018) validate this result. However, after conducting a statistical analysis, no significant difference ($p>0.05$) was found between the fruit weight across the different levels of salinity. The present study suggests that while there was a trend towards smaller fruit sizes with saltier irrigation water, moderate levels of salinity (up to 2% salinity seawater) are unlikely to have a significant negative effect on eggplant fruit size

Table 4. The effects of irrigation water salinity on the yield of eggplant ($\bar{x}$±sd)

Salinity Level (%)	Weight of fruits (g)	Fruit count (pcs)
0	66.02±7.20	3.13 ± 0.38^{ab}
0.5	61.69±3.66	3.83 ± 0.71^{a}
1.0	48.93±9.62	2.17 ± 0.80^{bc}
1.5	57.11±8.84	2.17 ± 0.31^{bc}
2.0	46.96±2.38	1.97 ± 0.51^{c}

Means in a column carrying the same letter are not significantly different (p>0.05).

The results also indicate that the number of fruits harvested was significantly affected (p<0.05) by the different treatments applied. The parameter decreased consistently as the salinity level increased, and there was a significant difference in mean fruit yield between the treatments. The eggplants treated with 2% salinity produced significantly fewer fruits compared to those treated with 0% salinity and 0.5% salinity. Furthermore, eggplants exposed to 0.5% salinity level had the highest (p<0.05) number of fruits developed (3.83 fruits/plant), with a significantly higher fruit yield compared to those subjected to higher salinity levels. This effect is similar (p>0.05) to plants exposed to zero salinity. Further, this effect is higher than the 2.3 fruits/plant reported by Parkash and Singh (2020) but slightly lower than the 4.42 fruits/plant reported by Damasceno et al. (2022).

The finding on the number of fruits harvested suggests that treatment B was effective in mitigating the negative effects of salinity on fruit yield, but it did not surpass the productivity of plants grown in a salinity-free environment. Overall, findings on this parameter propose that salinity level significantly impacts the fruit production of eggplants and that treatments with lower salinity levels may be more effective in promoting higher yields.

The present result also aligns with recent research findings by Sanwal et al. (2022) and Damasceno et al. (2022), which indicate that the level of salinity in the soil or irrigation water significantly affects crop yield. Specifically, a low level of salinity can increase crop yield, but as the level of salinity increases beyond a certain threshold, crop yield decreases. This phenomenon is related to the hormetic effects of salt on plant growth and development (Brito et al., 2018). At low levels of salinity, the presence of some salts can improve soil structure, facilitate nutrient uptake, and enhance plant growth (Mattson, 2008). However, as the salt concentration increases, it can cause ion toxicity, osmotic stress (Arif et al., 2020), and water stress (Lima et al., 2015), which can lead to reduced photosynthesis, decreased cell expansion, and ultimately lower crop yield. The same phenomenon was not only observed in this study but also noted in previous research conducted by Fogliatto (2019) and Bai et al. (2014)

The positive response of eggplant to a 0.5% salinity level can also be attributed to the additional nutrients provided by the irrigation water applied. The results shown in table 1 prove that seawater contains macro and microelements that are necessary for the fruit development of plants (especially potassium). With the indications that a 0.5% salinity level is still within the range of tolerance for eggplant, the plant could still absorb enough water and nutrients from the soil to produce a good yield.

CONCLUSION

In conclusion, the results of this experiment suggest that the application of seawater diluted with freshwater can be a viable option for irrigating eggplants without negatively impacting their growth and yield. The findings indicate that seawater concentrations of up to 0.5% applied at a seven-day interval can improve eggplant yield without significantly affecting plant growth. This study highlights the potential benefits of using seawater for irrigation in regions where freshwater resources are limited or scarce. However, it is important to note that the effectiveness of seawater irrigation will depend on several factors, including the specific crop being grown, the soil type, and the specific salts present in the water. Further research is needed to explore the potential benefits and limitations of using seawater for irrigation, as well as to identify the optimal seawater concentrations and application frequencies for different crops and soil types. Nevertheless, the findings of this study provide valuable insights into the potential of seawater as an alternative irrigation source and can help inform future efforts to promote sustainable agriculture in water-scarce regions.

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