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Effects of Different NaCl-Based Salinity Levels in Irrigation Water on Screen House Cucumber (Daewy F1)

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Article

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Abstract

The increasing scarcity of freshwater resources driven by climate change has compelled farmers in many parts of Nigeria to rely on alternative water sources such as groundwater and lower-course streams for dry-season irrigation. These sources frequently carry elevated salt concentrations that can suppress crop growth and reduce yield. This study evaluated the response of hybrid cucumber (Cucumis sativus L., variety Daewy F1) to five levels of irrigation water salinity under screen house conditions at the Federal University of Agriculture, Abeokuta. The experiment was arranged in a Completely Randomized Design (CRD) with five treatments and three replicates. Treatments consisted of irrigation water prepared at electrical conductivity (EC) levels of 0.00 dS/m (T1, non-saline control), 1.50 dS/m (T2), 2.50 dS/m (T3), 3.50 dS/m (T4), and 5.00 dS/m (T5), using sodium chloride (NaCl) as the salt source. Data were collected on microclimatic conditions, growth parameters (soil temperature, vine length, leaf area, leaf length, leaf breadth, and number of leaves), and yield characteristics (number of fruits, fruit length, fruit weight, and fruit diameter). Results showed that all growth and yield parameters declined progressively with increasing salinity. T2 (1.50 dS/m) produced results comparable to T1 across all yield parameters, while T3 (2.50 dS/m) produced a more than 50% reduction in fruit number relative to T1. T5 (5.00 dS/m) resulted in complete plant death by Week 7 with zero yield recorded. It is concluded that Daewy F1 cucumber can tolerate irrigation water salinity of up to 1.50 dS/m without significant production loss, while 2.50 dS/m represents the practical threshold beyond which economically significant losses occur under screen house conditions in Abeokuta.

Introduction

Climate change has led to a progressive decline in the availability of fresh surface water for agricultural use in sub-Saharan Africa and especially in Nigeria (FAO, 2017). Rainfed farming systems, which have historically supported smallholder farmers across the country, are becoming increasingly unreliable and unable to ensure year-round crop production (Adegbite & Olufemi, 2020). This has created a widening gap between the water demand of crops and the supply of high-quality freshwater suitable for irrigation.

To bridge this gap, farmers across Nigeria, particularly in southwestern Nigeria, have increasingly relied on alternative water sources including groundwater from boreholes, lower-course streams, shallow wells, and wastewater from urban and domestic activities (Ayers & Westcot, 1985). While these sources offer a practical solution, they carry a significant and often overlooked risk: elevated levels of dissolved salts that can impose considerable physiological stress on crops when applied repeatedly through irrigation. Salinity stress is one of the most significant abiotic constraints to global crop production, estimated to affect over 800 million hectares of agricultural land worldwide (FAO, 2011; Munns & Tester, 2008). When saline water is used for irrigation, accumulated salts in the root zone progressively lower soil water potential, triggering osmotic stress, ionic toxicity, reduced photosynthesis, and ultimately significant decline in growth and yield (Munns & Tester, 2008).

Cucumber (Cucumis sativus L.) is one of the most economically important vegetable crops in Nigeria, valued for its nutritional content and high commercial returns during the dry season (Eremie & Kini, 2020). The hybrid variety Daewy F1 is the dominant commercial cultivar in the Abeokuta area, preferred for its uniformity, high yield potential, and early maturity. However, cucumber is classified as moderately sensitive to salinity, with a threshold EC of approximately 2.5 dS/m beyond which significant yield reductions are expected (Maas & Hoffman, 1977). Despite this, the specific salinity tolerance of Daewy F1 under the agro-ecological conditions of Abeokuta has not been empirically established, creating a critical knowledge gap for farmers who increasingly rely on marginally saline water sources during the dry season.

The specific objectives of this study were to: (i) monitor the microclimatic conditions within the screen house during the growth period; (ii) determine the effects of different salinity levels on the growth parameters of Daewy F1 cucumber; and (iii) assess the yield and yield characteristics of Daewy F1 cucumber under different saline irrigation regimes.

Materials and Methods

The experiment was conducted in the screen house facility of FUNAAB, located behind the College of Environmental Resources Management (COLERM), at latitude 7°13'30"N to 7°19'00"N and longitude 3°20'15"E to 3°27'30"E, in Abeokuta, Ogun State, southwestern Nigeria. The area lies within the humid lowland rainforest region, characterised by a wet season from March to October and a dry season from November to February, with mean annual rainfall of approximately 1,113.1 mm distributed in a bimodal pattern. The geology of the campus is underlain by Pre-Cambrian basement complex rocks including biotite hornblende gneisses, quartzite, and quartz schist (Ufoegbune & Fabiyi, 2017). The screen house provided a protected growing environment that excluded rainfall, allowing irrigation salinity treatments to be maintained at their intended concentrations without dilution throughout the experimental period.

Topsoil was collected from the FADAMA area within the university premises, a low-lying seasonally waterlogged area with relatively high organic matter content and fine to medium texture. The soil was air-dried under shade, sieved to remove coarse material, and used to fill 15 plastic containers at 5 kg per container. Each container was perforated at the base to ensure adequate drainage and prevent waterlogging.

The plant material was Daewy F1 hybrid cucumber (Cucumis sativus L.), seeds for which were obtained from a reputable agro-input supplier. Direct seeding was adopted, consistent with the methodology recommended by Makinde et al. (2009) for cucurbit production in the FUNAAB screen house environment. Three seeds were sown per pot and later thinned to two seedlings per pot after germination, retaining the two most vigorous plants. Plants were staked using twine ropes tied vertically to overhead support structures to prevent vines from trailing on the ground and to facilitate accurate vine length measurement. Manual weeding was carried out as needed throughout the experiment.

Five irrigation water salinity levels were prepared using commercially available sodium chloride (NaCl). Salinity concentrations were determined using the conversion: TDS (g/L) = EC (dS/m) x 0.55, as recommended by Rhoades et al. (1992). The required NaCl mass was dissolved in tap water and the EC of each solution was verified using a conductivity meter before application. The five treatments are presented in Table 1.

Table 1
Irrigation Water Salinity Treatment Levels

Treatment	Salinity Category	EC (dS/m)	NaCl Concentration (g/L)
T1	Non-saline (Control)	0.00	0.00
T2	Slightly Saline (Low)	1.50	0.83
T3	Slightly Saline (High)	2.50	1.38
T4	Moderately Saline (Low)	3.50	1.98
T5	Moderately Saline (High)	5.00	2.75

Source: Adapted from Rhoades et al. (1992)

The experiment was laid out in a Completely Randomized Design (CRD) with five treatments and three replicates each, giving a total of 15 experimental units. The CRD was considered appropriate because the screen house environment provided relatively uniform conditions of light, temperature, and humidity across the experimental area. Each pot was assigned to a treatment group by random allocation.

Irrigation was carried out every two days throughout the experimental period, applying 400 ml of the respective treatment solution to each pot at every irrigation event. Separate watering containers were used for each treatment to prevent cross-contamination. The fixed irrigation volume and interval across all pots ensured that observed differences in plant performance could be attributed to salinity concentration rather than to differences in water quantity.

Microclimatic parameters including air temperature and relative humidity (recorded using a digital thermo-hygrometer), light intensity (measured using a lux meter at canopy level), and soil temperature (measured at a depth of 10 cm using a soil thermometer) were recorded weekly. Growth parameters were also measured weekly: vine length was measured from the soil surface to the growing tip using a flexible measuring tape; leaf area was estimated non-destructively using the formula LA = Leaf Length x Leaf Breadth x 0.75, as recommended by Pandey and Singh (2011) for cucurbit species; and the number of fully expanded leaves per plant was counted. Yield parameters measured at commercial maturity included number of fruits per pot, fruit length (ruler), fruit weight (electronic weighing scale), and fruit diameter (Vernier caliper).

Data were subjected to analysis of variance (ANOVA) and where significant treatment effects were found, means were separated using the Least Significant Difference (LSD) test at a 5% level of

probability. All statistical analyses were carried out using standard statistical software.

Results and Discussion

Microclimatic Conditions

Room temperature within the screen house ranged from 29.0 degrees Celsius in Week 9 to a peak of 37.6 degrees Celsius in Week 4, while relative humidity ranged from 39.0% in Week 4 to 76.0% in Week 9. The inverse relationship between temperature and humidity across the measurement weeks was consistent with established atmospheric relationships. Light intensity ranged from 1,386 lux in Week 9 to 2,857 lux in Week 4. All recorded light intensity values remained within the range sufficient for photosynthesis and normal vegetative development in cucumber (Shamshiri et al., 2018). The microclimatic conditions were uniform across all treatment pots and are therefore not expected to have confounded the treatment effects observed in growth and yield. The microclimatic trend is presented in Fig. 1.

Soil Temperature

Soil temperature at a depth of 10 cm showed no significant differences among treatments in Weeks 1 to 3, as salt concentrations do not immediately alter the thermal properties of the soil. From Week 5 onwards, however, soil temperature increased progressively with increasing salinity level and salinity significantly ($p < 0.05$) influenced soil temperature from Week 4 after planting. By Week 10, T5 recorded a mean soil temperature of 30.03 degrees Celsius compared to 23.70 degrees Celsius for T1, a difference of 6.33 degrees Celsius. T2, T3, and T4 recorded Week 10 means of 25.07, 27.40, and 28.70 degrees Celsius respectively. This pattern is consistent with the observations of Rhoades et al. (1992), who noted that repeated saline irrigation alters soil heat capacity and reduces moisture retention, leading to higher root zone temperatures. The rising soil temperature under higher salinity treatments from Week 5 onwards also reflects the declining transpiration from salt-stressed plants, which reduces the evaporative cooling effect in the root zone (Munns & Tester, 2008). The trend of soil temperature across treatment levels is presented in Fig. 2.

Vine Length

Salinity significantly ($p < 0.05$) reduced vine length from two weeks after planting. T1 and T2 performed similarly in the early weeks, suggesting that 1.5 dS/m salinity did not immediately impose osmotic stress on elongation growth. T3, T4, and T5 recorded noticeably shorter vines from the beginning, with the gap widening progressively. In T5, vine length increased briefly from 5.00 cm at Week 1 to 15.00 cm at Week 5, after which growth was completely arrested through Weeks 6 to 10, indicating plant death under 5.0 dS/m irrigation water. By Week 10, T1 recorded the longest vines at 235.07 cm, followed by T2 at 195.00 cm, T3 at 140.00 cm, T4 at 80.97 cm, and T5 at 15.00 cm. The percentage reductions in final

vine length relative to T1 were 17.0% for T2, 40.5% for T3, 65.6% for T4, and 93.6% for T5. These results agree with Naseri et al. (2017), who reported significant and progressive reductions in cucumber vine length as irrigation water salinity increased beyond 2.5 dS/m, and with Navarro et al. (2010), who documented complete arrest of shoot growth at salinity levels above 4.0 dS/m. The trend of vine length across treatment levels and weeks is presented in Fig. 3.

Leaf Area

Leaf area showed significant treatment differences from Week 1. All treatments increased in leaf area through the mid-experimental period before declining in later weeks as plants directed resources toward fruiting. T1 peaked at 125.39 cm2 at Week 7, T2 at 98.84 cm2, T3 at 70.50 cm2, and T4 at 47.83 cm2. T5 peaked at only 13.52 cm2 at Week 3 before declining sharply to zero by Week 7. At Week 10, leaf area values were 90.63, 78.42, 54.25, 34.15, and 0.00 cm2 for T1 through T5 respectively, with percentage reductions of 13.5%, 40.1%, 62.3%, and 100% for T2, T3, T4, and T5 relative to T1. These findings are consistent with Chaves et al. (2016), who identified leaf area reduction as one of the earliest and most reliable indicators of salinity stress in cucurbit crops. The trend of leaf area across treatment levels and weeks is presented in Fig. 4.

Leaf Length and Leaf Breadth

Both leaf length and leaf breadth declined progressively with increasing salinity throughout the experiment. T1 and T2 performed similarly in early weeks for both parameters, confirming that 1.5 dS/m salinity did not cause measurable leaf expansion impairment during the seedling phase. By Week 10, leaf length was 10.03, 9.50, 8.00, 6.50, and 0.00 cm for T1 through T5 respectively, with percentage reductions of 5.3%, 20.2%, 35.2%, and 100% relative to T1. Leaf breadth at Week 10 was 12.03, 11.00, 9.03, 7.00, and 0.00 cm respectively, with percentage reductions of 8.6%, 24.9%, 41.8%, and 100% relative to T1. The greater relative reduction in leaf breadth compared to leaf length across the moderate salinity treatments is consistent with Pandey and Singh (2011), who noted that lateral leaf expansion tends to be more sensitive to osmotic stress. These patterns align with Munns and Tester (2008), who explained that leaf elongation is among the first growth processes suppressed under salt stress because cell expansion depends entirely on the plant maintaining adequate turgor pressure. The trends of leaf length and leaf breadth across treatment levels are presented in Fig. 5.

Number of Leaves

The number of leaves produced per plant decreased consistently with increasing salinity throughout the ten weeks. T1, T2, T3, and T4 each peaked at Week 8 at 40.00, 32.00, 24.00, and 16.33 leaves respectively, before declining slightly to Week 10. T5 reached only 5.00 leaves at Week 3 before declining to zero by Week 7. At Week 10, leaf numbers were 32.33, 26.00, 18.00, 9.67, and 0.00 for T1 through T5 respectively, with percentage reductions of 19.6%, 44.3%, 70.1%, and 100% relative to T1. These results

are consistent with Navarro et al. (2010), who documented accelerated leaf loss in cucumber at salinity levels above 3.0 dS/m, and with Zhu (2001), who identified toxic salt ion accumulation in older leaves as the primary mechanism of premature leaf abscission under prolonged salt stress. The trend of leaf number across treatment levels and weeks is presented in Fig. 6.

Yield and Yield Characteristics

All four yield parameters declined progressively with increasing salinity, and T5 produced no fruits. For number of fruits per plant, T1 and T2 were statistically similar (5.00 and 4.33 fruits respectively), indicating that 1.5 dS/m salinity does not significantly reduce fruit set. At T3 (2.5 dS/m), fruit number fell to 2.33, a reduction of more than 50% relative to T1, representing a commercially significant loss. T4 produced only 1.00 fruit per plant.

Fruit length followed the same pattern, with T1 at 16.50 cm, T2 at 15.00 cm, T3 at 12.50 cm, T4 at 9.03 cm, and T5 at 0.00 cm. Fruit weight declined from 180.00 g at T1 to 160.00, 120.00, 75.03, and 0.00 g at T2 through T5 respectively. The more than 100-gram difference in fruit weight between T1 and T4 would be immediately perceptible to buyers in the fresh produce market. Fruit diameter was 3.80, 3.50, 3.00, 2.40, and 0.00 cm for T1 through T5 respectively. Fruits from T4 would appear visibly narrower and lighter than those from T1 or T2, undermining their commercial competitiveness.

The overall picture from the yield data confirms that T2 (1.5 dS/m) is the most forgiving salinity level for Daewy F1, producing results marginally below the non-saline control. T3 (2.5 dS/m) marks the point at which losses become economically significant across all yield dimensions, and T4 (3.5 dS/m) represents near-total commercial yield failure. These findings are consistent with Navarro et al. (2010), who reported that fruit set and fruit development in cucumber are among the most salinity-sensitive stages of the crop's life cycle, and with Munns and Tester (2008), who explained that the combined osmotic and ionic effects of salt stress reduce both the number and size of fruits by limiting water uptake, nutrient supply, and photosynthetic output during the reproductive phase. The 53.3% reduction in fruit number observed at T3 (2.5 dS/m) is notably larger than the incremental 13% per dS/m reduction predicted by Maas and Hoffman (1977), suggesting that Daewy F1 may be more sensitive to salinity at the threshold level than the general species classification implies. The effects of salinity on yield and yield characteristics are presented in Fig. 7.

Conclusion

This study evaluated the response of Daewy F1 hybrid cucumber to five levels of irrigation water salinity (0.00 to 5.00 dS/m) under screen house conditions in Abeokuta, Nigeria. All growth and yield parameters declined progressively with increasing salinity. Irrigation at 1.5 dS/m (T2) did not cause significant losses in growth or yield relative to the non-saline control, establishing this level as the practical safe limit for this variety under the conditions tested. Salinity at 2.5 dS/m (T3) caused economically significant yield reductions across all measured yield dimensions, while 3.5 dS/m (T4) severely

compromised production. Irrigation at 5.0 dS/m (T5) was entirely incompatible with viable Daewy F1 cucumber production, resulting in complete plant death by Week 7 of the experiment.

Farmers in Abeokuta and similar areas who use borehole or stream water for dry-season irrigation should monitor their water quality and ensure that the EC of their irrigation supply does not exceed 1.5 dS/m. Where salinity levels approach or exceed 2.5 dS/m, blending saline water with cleaner freshwater before application is recommended as a low-cost practical measure. Further research on the salinity responses of other commercial cucumber hybrid varieties under open-field conditions in southwestern Nigeria is recommended to broaden the evidence base for farmer advisory guidelines.

Declarations

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Author Contribution

P.B.A. wrote the main manuscript text, prepared all figures, conducted the experiment, and collected the raw data. A.A.M. performed the data analysis and supervised the study. All authors reviewed the manuscript.

Data Availability

The datasets generated and analysed during the current study are not publicly available but are available from the corresponding author on reasonable request and is attached as an additional file in this submission.

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Figures

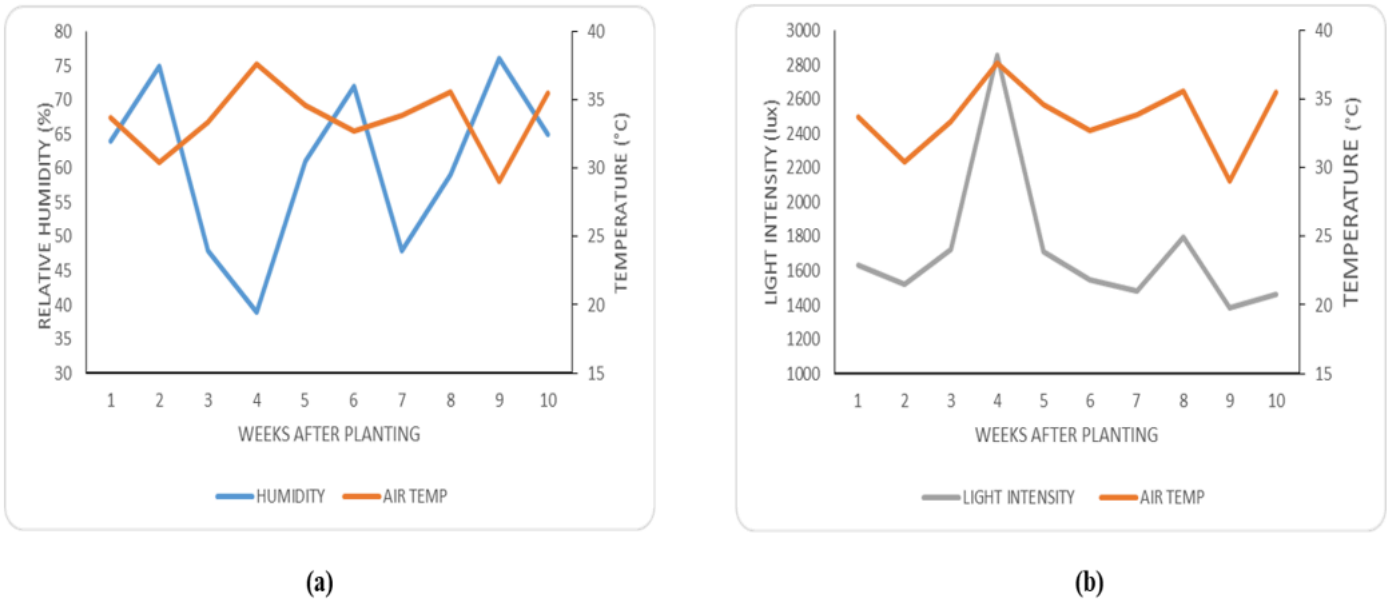


Figure 1

Microclimatic conditions within the screen house: (a) room temperature and relative humidity; (b) room temperature and light intensity

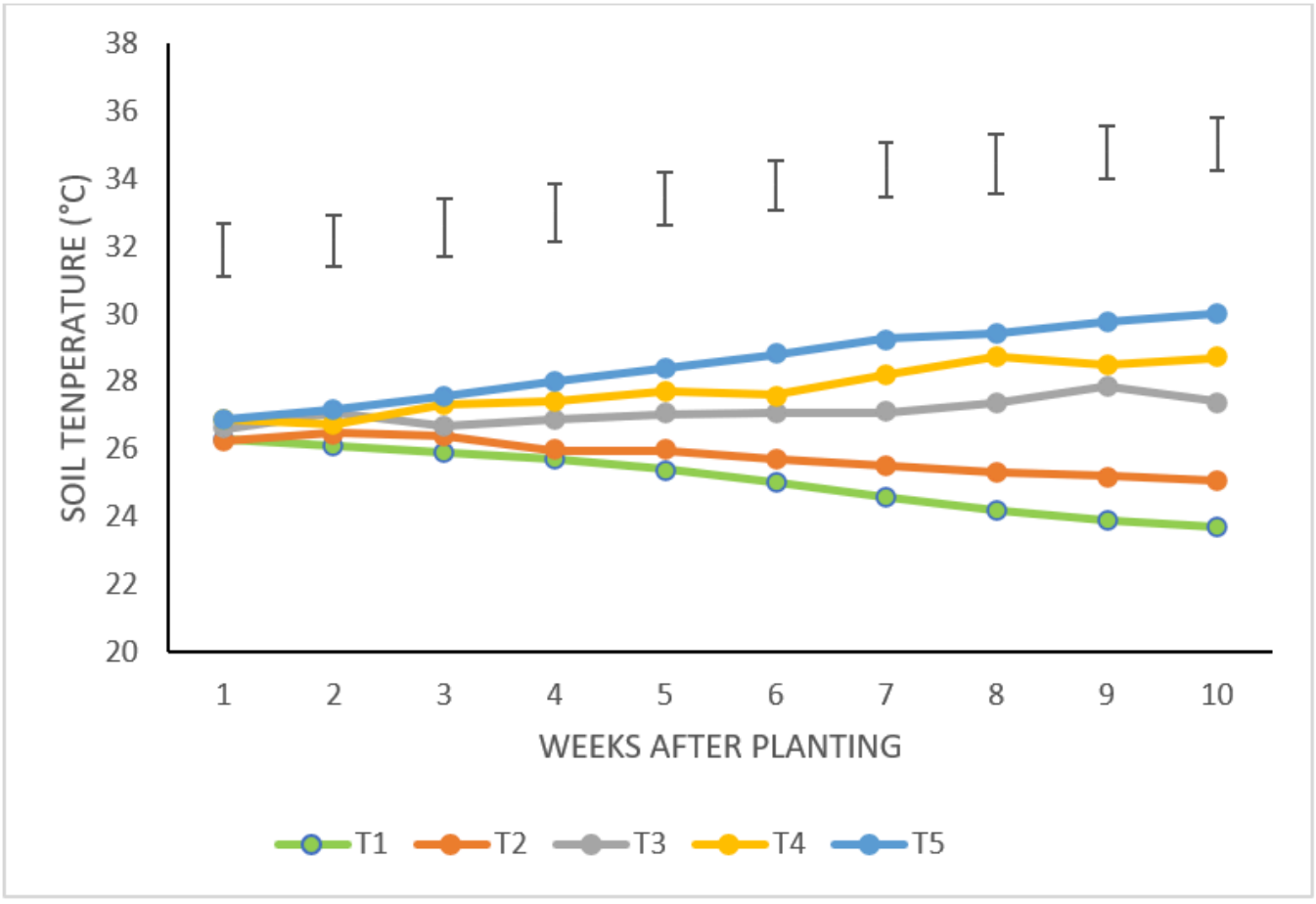


Figure 2

Trend of Soil Temperature Under Different Water Salinity

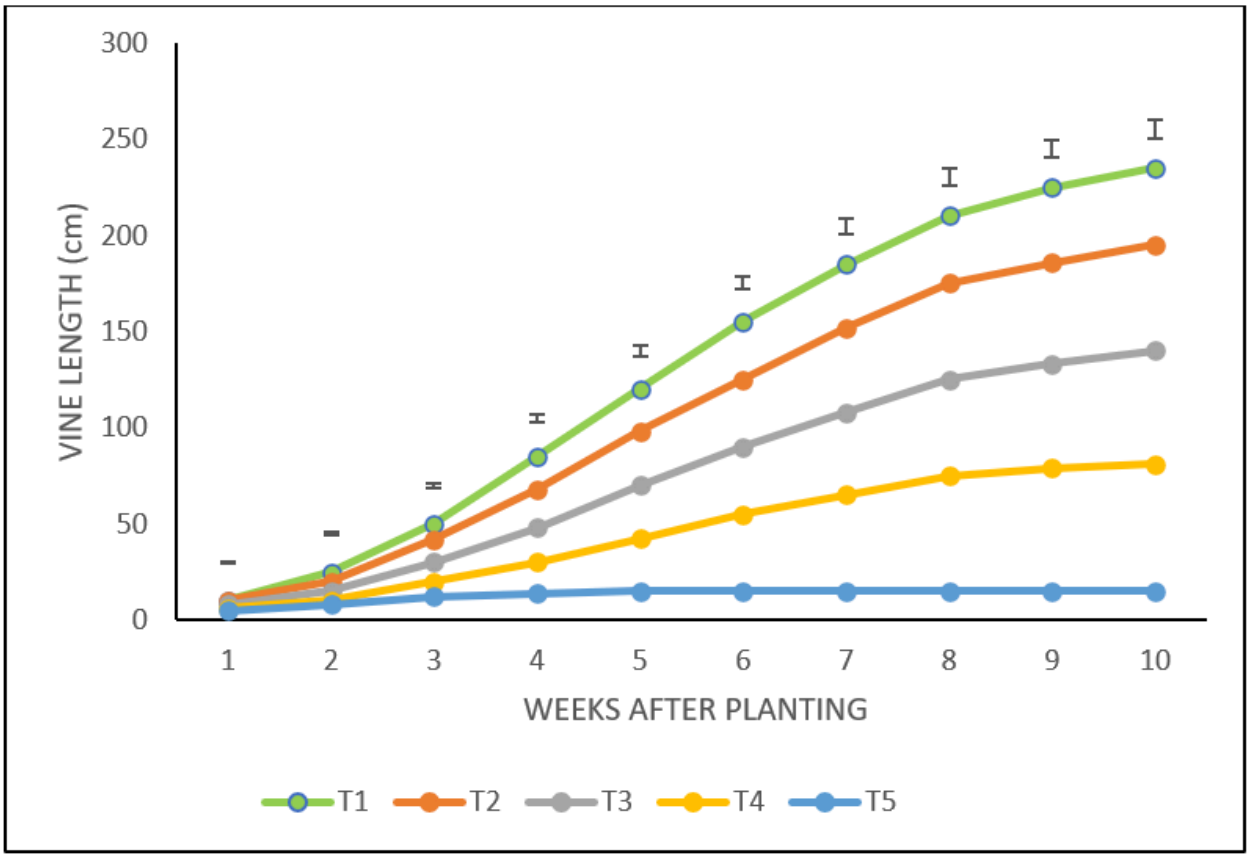


Figure 3

Trend of Vine Length Under Different Water Salinity

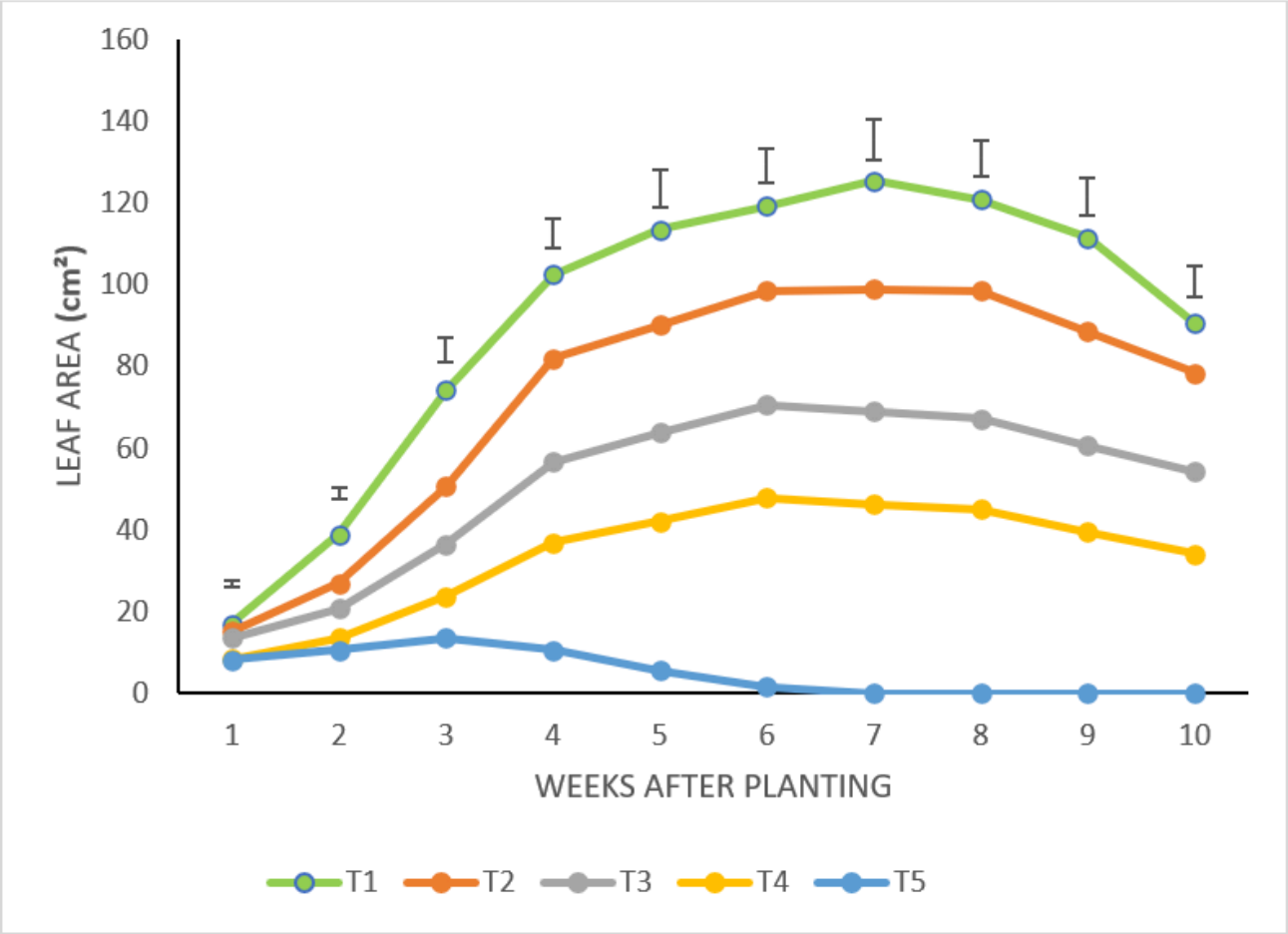


Figure 4

Trend of Leaf Area Under Different Water Salinity

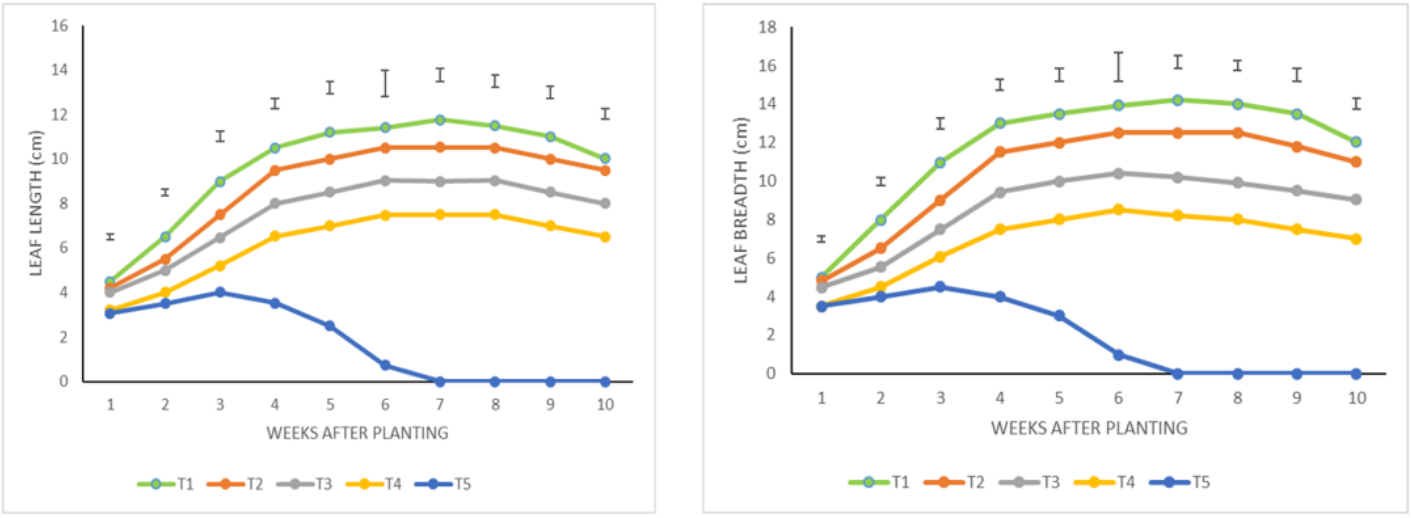


Figure 5

Trend Under Different Salinity on: (a) leaf length; (b) leaf breadth

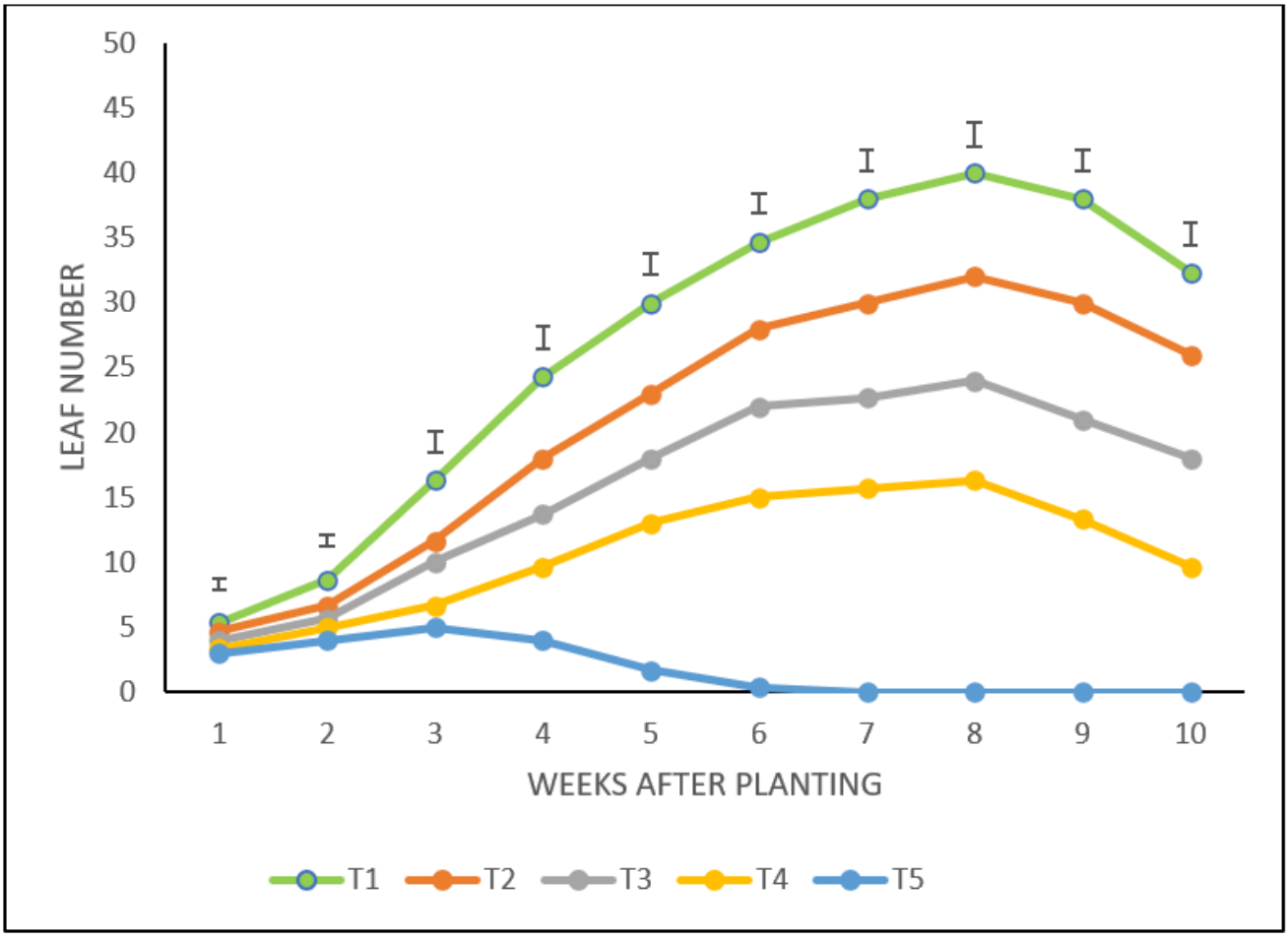


Figure 6

Trend of Leaf Number Under Different Water Salinity

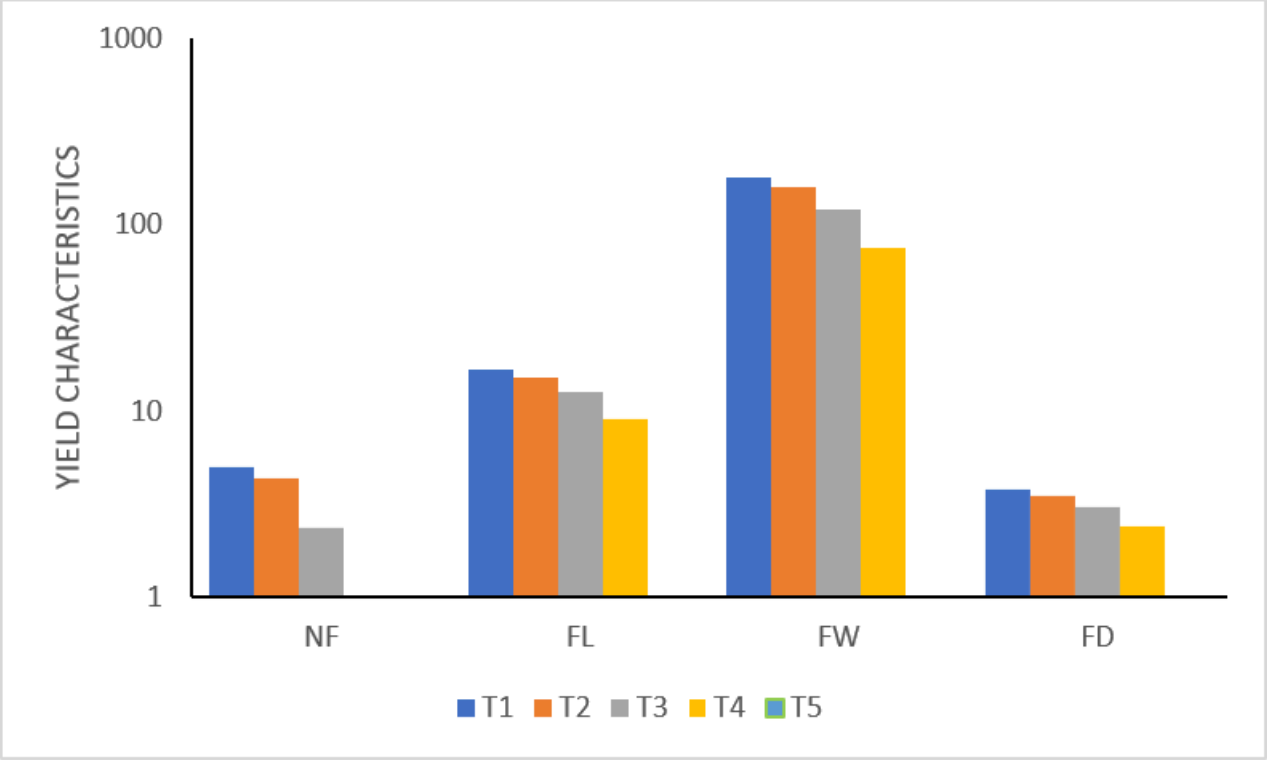


Figure 7

Trend of Yield and Yield Characteristics Under Different Water Salinity