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Comparative Assessment of Treated Wastewater and Freshwater Irrigation on Chlorophyll Content, Growth Performance, and Soil-Water Quality of Tomato (Solanum lycopersicum) and Periwinkle (Catharanthus roseus) in Muscat, Oman

Sazya Firdaus

Abstract: *The arid conditions of Oman and the ongoing depletion of groundwater have increased focus on treated wastewater (TWW) as an alternative irrigation source. This experiment involved comparing physiological, growth, soil, and water-quality of tomato (Solanum lycopersicum), a fruiting crop, and Madagascar periwinkle (Catharanthus roseus), a non-fruiting ornamental plant under TWW or freshwater (FW) irrigation. The controlled pot experiment in Muscat, Oman, took place between December 2025 and March 2026, and lasted four months. Plant growth (height), SPAD chlorophyll, reproductive biomass, soil pH, soil macronutrients (N, P, K) and TWW quality were checked. Statistical analysis with descriptive statistics, percentage difference, t-tests, one way ANOVA, and Pearson correlation analysis were utilized. The findings showed that Tomato-TWW possessed a statistically significant final SPAD value, which was 28.7 percentage points higher than Tomato-FW, and statistically significant general treatment group differences existed ($F = 6.776$, $p = 0.0018$). It is important to note that only Tomato-TWW yielded fruit (87 g yield) whereas Tomato-FW did not yield fruits. Periwinkle exhibited no significant or overall changes in chlorophyll and equal counts of flowers across treatments. The Periwinkle-TWW soil contained 136.7% more nitrogen than Periwinkle-FW, which is indicative of species-specific nutrient processes. One of the most important revelations was the dropping pH of TWW of 5.88 to 4.53, which is lower than the recommended pH of FAO of 6.5 to 8.4. Electrical conductivity (1519 to 1658 mu S/cm) and total dissolved solids (759-819 ppm) were moderately high and stable. The study demonstrates that TWW irrigation enhances chlorophyll content and*

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reproductive output in fruiting crops while raising concerns about water quality management.

Keywords: Treated wastewater irrigation; Chlorophyll content; Tomato; Periwinkle; Soil-water quality.

Introduction

The scarcity of freshwater and the high evapotranspiration rates are major limiting factors to agricultural practice in arid and semi-arid areas (Al-Rawahi et al., 2021). In Oman, especially in the Al Batinah region, smallholder farming still heavily relies on traditional irrigation methods falaj that continue to serve as the main source of water supply, but it is increasingly under pressure due to groundwater depletion, salinity intrusion, and climate variability (Ismaily et al., 2019). The area is incredibly dry, receiving less than 100 mm of precipitation annually.

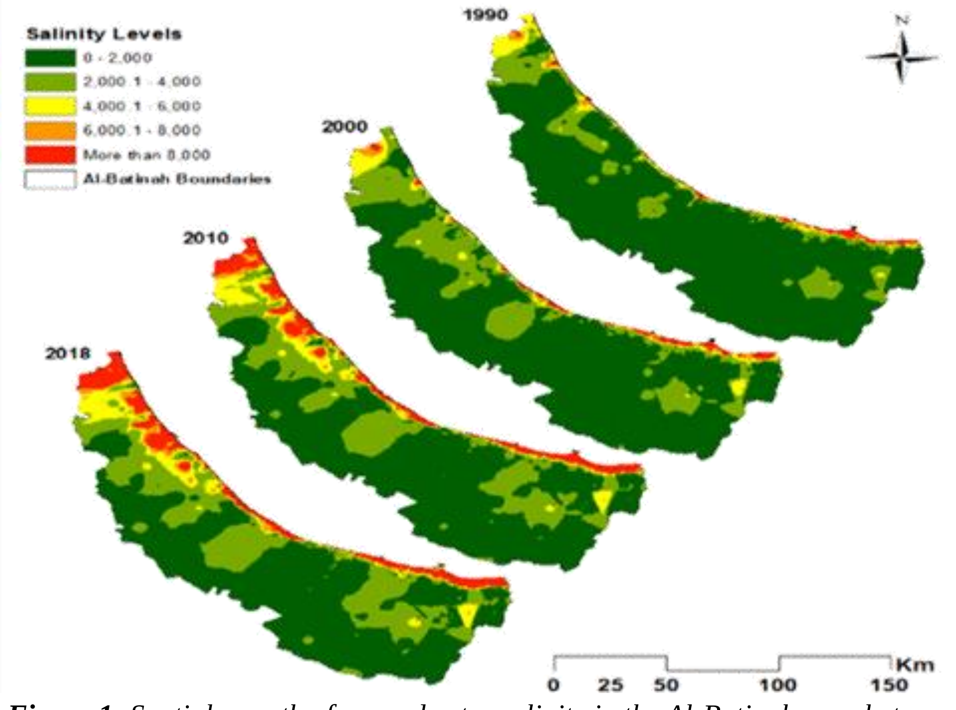


Figure 1: *Spatial growth of groundwater salinity in the Al-Batinah area between 1990 and 2018 (Abulibdeh et al., 2021)*

The freshwater scarcity has prompted the increasing attention to the use of treated wastewater (TWW) as an additional irrigation source. TWW has two advantages: it offers water security and offers necessary nutrients, such as nitrogen (N), phosphorus (P), and potassium (K), which can decrease the use of chemical fertilizers (Hussain et al., 2020). Nevertheless, there are still fears over the build-up of soil salinity, high electrical conductivity (EC), and modified soil pH as well as the possibility of heavy metal concentration (Qadir et al., 2010).

It is imperative to understand the short-term agronomic advantages and environmental hazards of TWW irrigation to design sustainable water management approaches in water-constrained environments. According to the previous research, TWW irrigation has the potential to positively stimulate physiological processes in plants, such as an increase in chlorophyll content and biomass accumulation (Muscarella et al., 2024; Christou et al., 2014). Yet, not many comparative studies investigate fruiting and non-fruiting plant species in the same TWW conditions in arid conditions like in Oman.

This paper fills these gaps by comparing physiological, growth, soil-water and water-quality behaviors of tomato (Solanum lycopersicum) and Madagascar periwinkle (Catharanthus roseus) watered with TWW and freshwater in Muscat, Oman.

Materials and Methods

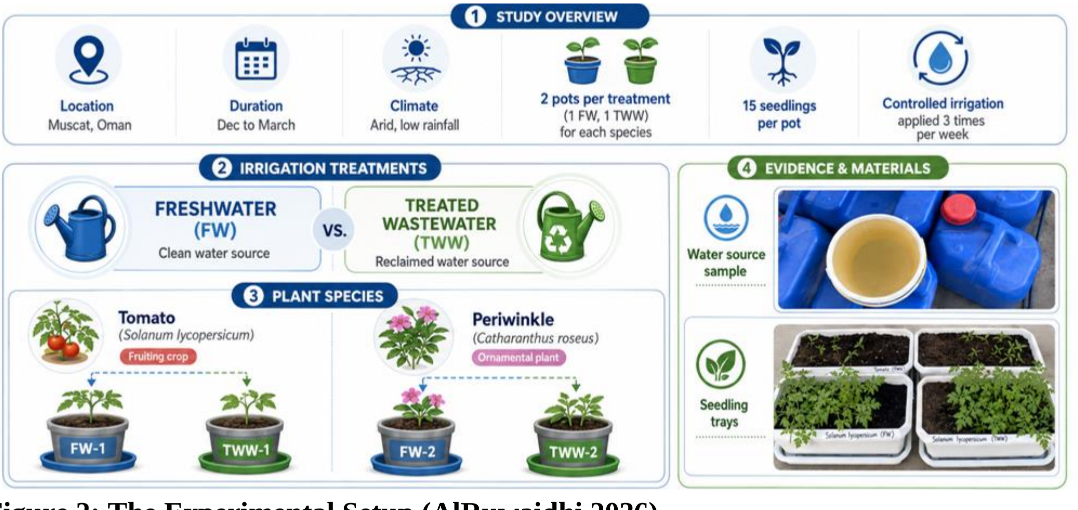


Figure 2: The Experimental Setup (AlRuwaidhi,2026)

2.1 Study Area and Experimental Design

The research was done in Muscat, Oman, a dry area with semi-tropical desert climate (Koppen: BWh). The design was a quantitative comparative experimental design comprised of a four-month controlled pot experiment between December 2025 and March 2026. There were four treatment pots, each holding 15 plant replicas (1) Tomato-Freshwater (FW), (2) Tomato-Treated Wastewater (TWW), (3) Periwinkle-FW and (4) Periwinkle-TWW resulting in 60 plant replicas in total. The independent variable was the type of irrigation-water (freshwater vs. treated wastewater). Dependent variables were chlorophyll content (SPAD), plant height, reproductive biomass, soil pH, soil macronutrients (N, P, K), soil moisture, soil temperature and irrigation-water quality parameters (pH, EC, TDS, S.G., ORP). The measurements were done every two months.

2.2 Data Collection and Instrumentation

A SPAD Chlorophyll Meter was used to measure chlorophyll content. The height of plants was measured by using a measuring tape. Soil parameters (pH, nitrogen, phosphorus, potassium, temperature, moisture) were measured directly in pots by a soil NPK and pH meter. A portable water-quality tester was used to measure the quality of treated wastewater (pH, EC, TDS, salts, S.G., ORP). End of experiment harvest data (fruit/flower count and total biomass) were measured (March 2025). All the analyses were conducted in Microsoft Excel (descriptive statistics, t-tests, ANOVA, Pearson correlation).

Table 1 Instruments used in the experiment

	
SPAD Chlorophyll Meter	Portable Water-Quality Tester
	
Soil NPK and pH Meter	Digital Balance Device

Results & Discussion

3.1 Chlorophyll Content Response

The responses of the species to the TWW irrigation were species-specific as indicated by SPAD chlorophyll readings. The mean final SPAD of tomato-TWW was found to be 45.74 or 28.7 per cent higher than Tomato-FW (35.53). There was a statistically significant difference in one-way ANOVA in all the four treatment groups ($F = 6.776$, $p = 0.0018$) and this showed that there was a significant difference in the chlorophyll content. Periwinkle was found to have little chlorophyll response with only 7.0% of the total increase when compared to FW. This species-specific variation is interesting: fruits crops proved to have a higher reaction to chlorophyll to nutrient-enriched TWW, whereas non-fruiting decorative species exhibited minimal physiological differentiation.

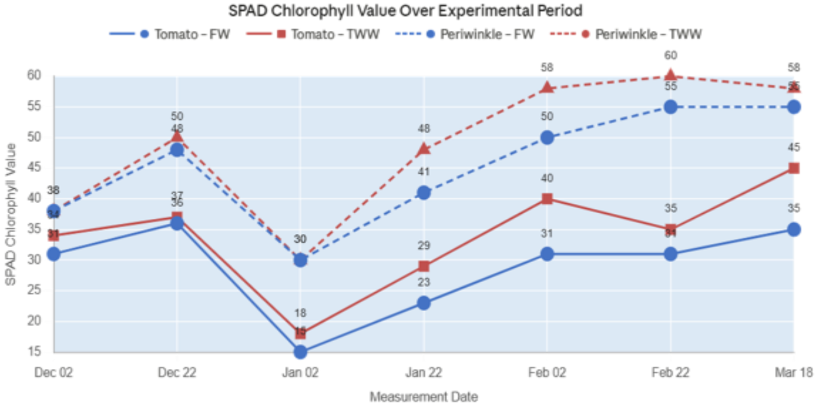


Figure 3: *Chlorophyll (SPAD) Readings Over Time for All Four Treatment Groups*

3.2 Growth Performance and Reproductive Output

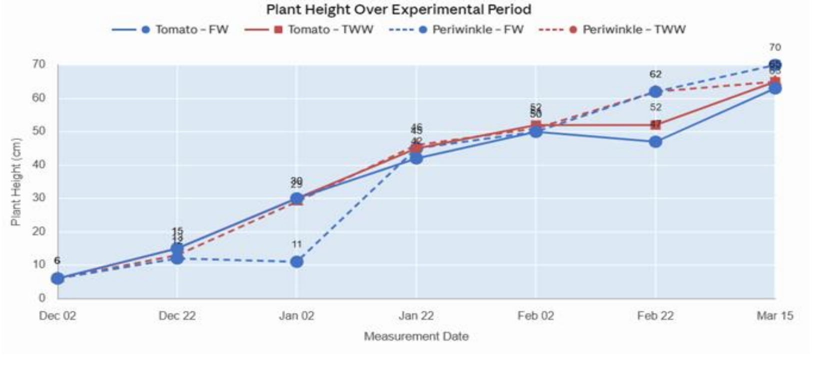
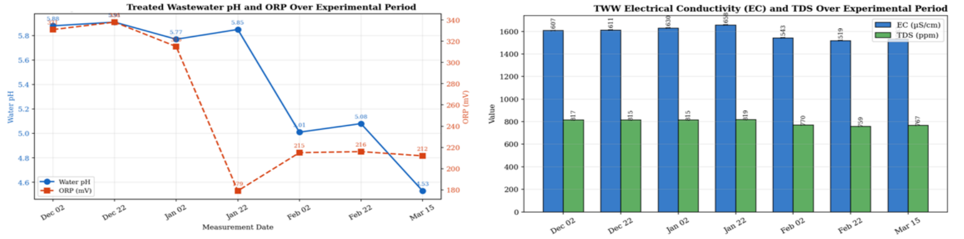


Figure 4: *Plant Height Over Time*



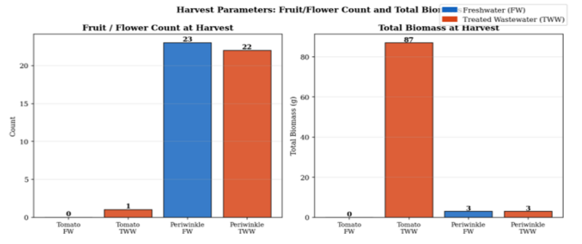


Figure 5: *Harvest Parameters: Fruit/Flower Count and Total Biomass at End of Experiment (March 2025)*

Plant height measurements showed minimal differences. Tomato-TWW was 66 cm compared to 62 cm with Tomato-FW (6.5% growth). One-way ANOVA was non-significant ($F = 0.272$, $p = 0.845$). Reproductive output was the most impressive observation: Tomato-TWW gave one fruit (87 g), whereas Tomato-FW gave no fruit and zero biomass. This dramatic difference suggests that enhanced chlorophyll content and photosynthetic capacity in Tomato-TWW provided sufficient photosynthate to support fruit development. Periwinkle had insignificant reproductive variation at equal numbers of flowers and equal biomass (3 g each), showing that non-fruiting ornamental plants need not be proportionally sensitive to nutrient supply.

3.3 Soil Chemistry and Water Quality

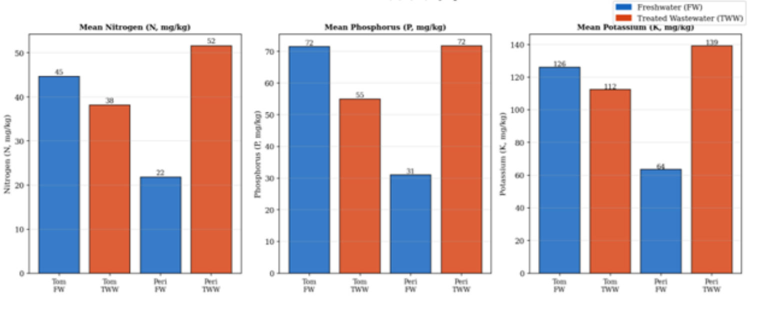


Figure 6: *Mean Soil Macronutrients (N, P, K) by Species and Treatment Group*

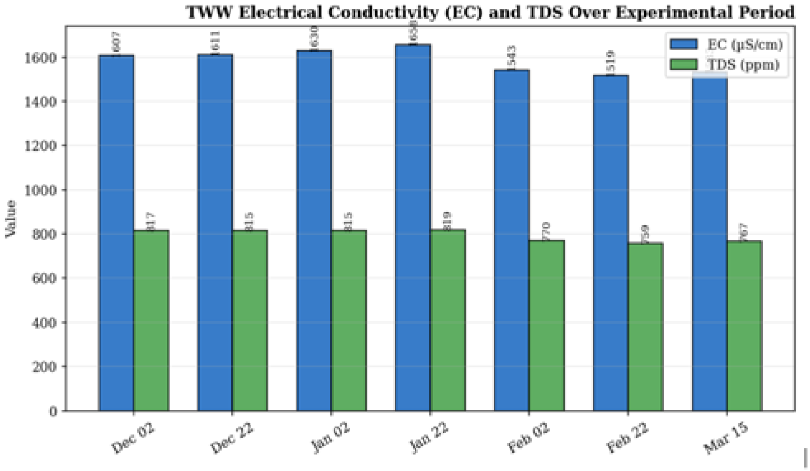


Figure 7: *TWW Water pH and Oxidation-Reduction Potential (ORP)*

Figure 8: TWW Electrical Conductivity (EC, µS/cm) and Total Dissolved Solids (TDS, ppm)

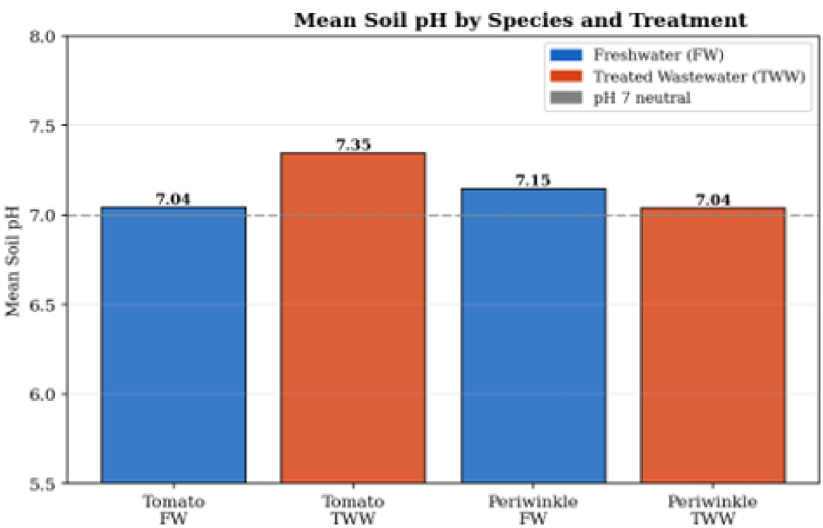


Figure 8: *Mean Soil pH by Species and Treatment Group*

Macronutrient responses of soil showed distinct trends. In Periwinkle pots, TWW irrigation dramatically increased soil nitrogen (51.67 mg/kg vs. 21.83 mg/kg, +136.7%), phosphorus (+131.7%), and potassium (+119.4%). Tomato-TWW soils, on the contrary, demonstrated lower mean N, P, K values which implies active nutrient consumption. A critical concern was declining TWW pH from 5.88 (Dec 2024) to 4.53 (Mar 2025), below FAO recommended range (6.5–8.4). EC (1,519–1,658 µS/cm) and TDS (759–819 ppm) remained stable but elevated. Soil pH remained neutral (7.04–7.35) with no significant differences ($t = -0.660$, $p = 0.516$).

Conclusions and Suggestions

4.1 Conclusions

This controlled pot experiment illustrates that TWW irrigation has tangible short term agronomic advantages to fruiting crops in arid settings. TWW increased chlorophyll level in tomato by 28.7% (end SPAD: 45.74 compared to 35.53). Overall ANOVA showed statistically significant differences ($F = 6.776$, $p = 0.0018$). The dual water-and-nutrient advantage was shown as Tomato-TWW yielded fruit (87 g) whereas Tomato-FW did not. There was little physiological response of the non-fruiting species (7.0% chlorophyll, similar flowers) suggesting a species-specific use of nutrients. Nutrient demand is different in periwinkle (soil accumulation of macronutrient +136.7% N) and tomato (soil depletion of nutrient).

4.2 Suggestions

Use TWW irrigation on fruit crops to optimize agronomic value. Install pH controls; when pH is below 6.0, make lime amendments prior to irrigation. Institute routine soil testing procedures on accumulation of effects of pH, salinity and heavy metals across several seasons. Encourage water-soil management that integrates TWW reuse and organic amendments with soil remediation. Apply satellite based measurements (NDVI) to schedule irrigation and long-term land-use planning in TWW programs.

Limitations & Future Scope

Limitations: Study limited to single 4-month season; long-term cumulative effects unassessed. Single-pot design limits statistical power. Soil measurements limited to 20 cm depth. Heavy metals, microbial contamination, and soil biology not analyzed. Results specific to Silal STP source.

Future Work: Extend to multi-year field trials with plot-level replication. Incorporate heavy-metal analysis at multiple soil depths. Test microbiological contamination in produce. Evaluate pH buffering capacity under repeated acidic irrigation. Extend to date palm, lemon, and leafy vegetables.

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