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INVESTIGATING THE IMPACT OF FIELD CAPACITY AND AERATION METHODS ON PLANT GROWTH: A LINEAR MODEL ANALYSIS

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Abstract:
The implementation of effective irrigation and aeration techniques is vital in enhancing plant growth and striving towards optimal crop yields. This study examines the effects of varying field capacities (FC) and two distinct aeration methods on plant growth (Africa-spinach - Amaranth cruentus). The experiment aimed to investigate the effects of different field capacity levels (100% FC, 75% FC, 65% FC, and 55% FC) and aeration methods (air injected into irrigated soil and air injected into irrigation water) on plant growth. Several growth parameters, including Shoot fresh weight, number of leaves at various weeks after planting, and plant height, were measured to assess development. Linear regression model was employed to quantify the relationships between these factors and their impact on plant growth. Field capacity and water use efficiency significantly increase Shoot fresh weight, while the aeration methods show marginal effects. The study finds that field capacity and water use efficiency are key factors influencing Shoot fresh weight, while aeration methods have a less significant impact on growth. Correlation matrix reveals that SFW water use efficiency is strongly positively correlated with Shoot fresh weight, indicating its crucial role in optimizing plant growth, while other variables show weaker correlations, underscoring the complexity of factors influencing growth.

Keywords: *Plant, Growth, Irrigation, Techniques, Aeration, Weight, Regression, Model*

Introduction / Background Study

Field capacity (FC) and aeration methods are critical factors in agricultural irrigation, impacting plant growth and yield (Halli et al. 2021). Field capacity, the amount of water soil can retain after excess drainage, directly influences plant health by ensuring adequate moisture levels for root uptake. Optimal FC levels support robust growth, whereas deviations can lead to water stress or over-saturation, affecting plant performance (Chacon et al. 2020). Aeration methods, including air injection into soil or irrigation water, play a crucial role in improving soil oxygen levels and water distribution (Parameshwarareddy and Dhage 2022). Xiao et al. (2022) observed that aeration, achieved by bubbling air into irrigation water, enhances soil oxygen levels and. that adding 15% air bubbles significantly increased the oxygen diffusion rate in the soil, leading to improved crop growth, particularly during flowering and fruiting, with a yield increase of over 9%. Enhanced aeration can prevent waterlogging, promote better root respiration, and facilitate more efficient water use (Jin et al. 2023). While the effects of aeration methods can vary, their ability to optimize soil conditions contributes to improved plant growth and higher yields (Du et al. 2020; Li et al. 2020; Qian et al. 2022). Overall, managing FC and employing effective aeration techniques are essential for maximizing agricultural productivity and ensuring sustainable crop cultivation. Rigoni et al. (2022) presents an analytical solution using the method of manufactured solutions (MMS) for Thorpe's grain mass aeration model, comparing several numerical approximations including finite difference methods (FDM) with various spatial schemes (Roberts and Weiss, Leith, UDS, CDS, and UDS-C) and temporal formulations (explicit, implicit, and Crank-Nicolson). Error analysis showed that the Leith method achieved superior accuracy with minimal CPU time compared to the widely used UDS-Explicit method, recommending it as the optimal approach for solving the model. Aytac et al. (2024) optimized the physical parameters of high-aeration capacity, high-head gated conduits for low-energy-cost pond aeration by developing a prototype that maximizes aeration performance, with key influencing factors including flow rate, gate opening, hydrostatic level, and jet plunge angle, resulting in over three times the unit volume of water being circulated with an energy cost of 0.10 kWh/m³ air, demonstrating superior energy efficiency compared to alternatives. Baram et al. (2022) observed that long-term drip irrigation with nanobubbles oxygenated treated wastewater (ONB-TWW) enhances oxygen availability in both well-aerated and poorly aerated soils, significantly improving lettuce yield, reducing membrane leakage and osmotic potential in plant tissues, and enhancing root viability and leaf chlorophyll content, despite supplying only 1% of the daily oxygen required, indicating its potential as a viable method to mitigate soil hypoxia and boost plant growth. Further research is needed to clarify the mechanisms by which ONB-TWW promotes plant health. Soil aeration, crucial for soil fertility, is impacted by slow drainage, excessive water input, or soil sealing, with shallow groundwater exacerbating the issue by reducing drainage and increasing soil water content. Ben-Noah et al. (2021) observed that poor aeration notably hindered tree growth and

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yield, with soil texture significantly affecting yield due to its influence on water retention. Faloye et al. (2020) calibrated and validated the AquaCrop model using field data to predict maize growth, canopy cover, and yield in soils treated with biochar and inorganic fertilizer, demonstrating good predictive accuracy and showing enhanced crop productivity, especially in treatments combining biochar and fertilizer. Suleiman (2022) evaluates the effectiveness of aeration in treating shea butter wastewater, which contains harmful tannins with pollutants and concluded that increased aeration reduced concentrations of pollutants. Ojeikere and Okonji (2020) observed that extended water aeration can significantly enhance spawning success and could be a cost-effective solution for hatcheries in developing countries. Oyewusi (2023) used effluent treated with peroxide-oxidation from cassava processing to irrigate Amaranthus plants and noted that 75% treated effluent showed improved growth and higher bioaccumulation of iron, potassium, and nitrogen compared to the control. Zhu et al. (2020) noted that aerated irrigation (AI) effectively mitigates rhizosphere hypoxia caused by subsurface drip irrigation (SDI), leading to improved soil aeration, enhanced plant growth, and increased fruit yield in tomatoes. AI also boosts irrigation water use efficiency (IWUE) and fruit quality, including higher levels of lycopene, Vitamin C, and soluble sugars giving optimal results with irrigation levels of 0.6 and 1.0, and dripper depths of 25 cm, with AI treatments proving superior in both plant performance and fruit quality compared to standard SDI. Xiao et al. (2022) used logistic model to described crop elongation across treatments, with aeration boosting both elongation rates and fruit yield giving optimal yield of 324.63 g/plant with the highest nitrogen, irrigation, and aeration levels. This study aims to evaluate the effects of different levels of FC and aeration methods on plant growth indicators - air injected into irrigated soil and air injected into irrigation water—under four FC levels: 100% FC, 75% FC, 65% FC, and 55% FC. The objective is to determine how these variables influence Shoot fresh weight, number of leaves, plant height, and water use efficiency.

Methodology

The experiment was conducted to investigate the effects of field capacity and aeration methods on plant growth. Four levels of field capacity were tested: 100% FC (F0), 75% FC (F1), 65% FC (F2), and 55% FC (F3). To explore the impact of aeration, two methods were employed: air was either injected into the irrigated soil or into the irrigation water. Several growth parameters were measured throughout the experiment to assess plant development. These parameters included Shoot fresh weight (measured in grams), the number of leaves at 4, 5, 6, and 7 weeks after planting (WAP), and plant height at the same intervals. Additionally, water use efficiency, denoted as WUE, was also recorded to evaluate the efficiency of water utilization in relation to the applied aeration methods. To analyze the effects of the field capacity levels and aeration methods on these growth parameters of Africa-spinach (*Amaranth cruentus*), a linear regression model was employed using R programming language (Lambert et al. 2020; Burnett et al. 2021). The model aimed at quantifyig the relationships existing between the observed variables and their influence and impact on the outcomes of plant growth. In the study, the regression model is expressed as:

Shoot fresh weight (g) =β0 + β1(Air injected irrigated soil) +
β2(Air injected irrigation water) +β3 (FieldCapacity) +
β4 (No of leaves at 4WAP) +β5 (No Air injected irrigation water) +
β6 (No of leaves at 5WAP) +β7 (No of leaves at 6WAP) +
β8 (No of leaves at 7WAP) +β9 (Plant heightat4W APcm) +
β10 (Plant height 5WAP cm) +β11 (Plant height 6WAP cm) +
β12 (Plant height 7WAP cm) +β13 (SFW water use efficiency) + ϵ

where: β0 is the intercept, β1 to β13 are the coefficients for each predictor. ϵ is the error term

Results and Discussion

The regression analysis in the study reveals various factors impacting ad affecting shoot fresh weight in the study as presented in Table 1. The model's intercept is -23.4059 (p = 0.2838), indicating the baseline level of shoot fresh weight when all predictor variables are zero. Notably, air injected into irrigated soil and air injected into irrigation water have coefficients of 7.3596 (p = 0.1414) and 9.8205 (p = 0.0851), respectively, suggesting a positive, though not statistically significant, effect on shoot fresh weight. Field capacity significantly influences shoot fresh weight with a coefficient of 0.2712 (p = 0.0117). However, the number of leaves at various weeks after planting (WAP) and plant height at different stages show mixed and largely insignificant effects, except for plant height at 7 WAP (coefficient = 0.5581, p = 0.0780). The variable for water use efficiency at constant aeration shows a significant positive impact, with a coefficient of 24.2177 (p = 0.0242). These results indicate that while factors like field capacity and water use efficiency play a significant role, others like aeration methods have marginal effects on shoot fresh weight.

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Table 1: Regression analysis

Variable	Estimate	t value	Pr(>|t|)
Intercept	-23.41	-1.09	0.28
Air injected irrigated soil	7.36	1.51	0.14
Air injected irrigation water	9.82	1.77	0.09
Field Capacity	0.27	2.66	0.01
No of leaves at 4WAP	1.42	0.59	0.56
No Air injected irrigation water	0.50	0.09	0.93
No of leaves at 5WAP	-1.67	-1.29	0.21
No of leaves at 6WAP	-1.87	-1.19	0.24
No of leaves at 7WAP	1.02	0.78	0.44
Plant height 4WAP (cm)	1.29	0.85	0.40
Plant height 5WAP (cm)	0.46	0.47	0.64
Plant height 6WAP (cm)	-0.28	-0.65	0.52
Plant height 7WAP (cm)	0.56	1.82	0.08
SFW water use efficiency	24.22	2.36	0.02

The linear regression model indicates that field capacity and water use efficiency at constant aeration significantly impact Shoot fresh weight as shown in model Equation 1 having adjusted R-squared of 95.50 %.

$$
\begin{aligned}
\text{Shoot fresh weight (g)} = {} & -23.41 + 7.36(\text{Air injected irrigated soil}) + \\
& 9.82(\text{Air injected irrigation water}) + 0.27(\text{Field Capacity}) + \\
& 1.42(\text{No of leaves 4WAP}) + 0.5(\text{No Air injected irrigation water}) - \\
& 1.67(\text{No of leaves 5WAP}) - 1.87(\text{No of leaves 6WAP}) + \\
& 1.02(\text{No of leaves 7WAP}) + 1.29(\text{Plant height 4WAP (cm)}) + \\
& 0.46(\text{Plant height 5WAP (cm)}) - 0.28(\text{Plant height 6WAP (cm)}) + \\
& 0.56(\text{Plant height 7WAP (cm)}) + 24.22(\text{SFW water use efficiency}) \qquad (1)
\end{aligned}
$$

Field capacity has an estimated coefficient of 0.27 with a p-value of 0.0117, suggesting a statistically significant positive effect on Shoot fresh weight, corroborating the findings reported by Zhu et al. (2020). Similarly, water use efficiency at constant aeration has an estimated coefficient of 24.22 with a p-value of 0.0242, also indicating a significant positive influence. In contrast, the effects of aeration methods are less clear. Air injected into irrigated soil shows an estimated coefficient of 7.36 with a p-value of 0.1414, while air injected into irrigation water has an estimated coefficient of 9.82 with a p-value of 0.0851. These p-values suggest that while these aeration methods have some effect on Shoot fresh weight, their influence is not statistically significant at the 0.05 level but may be considered marginally significant. Other variables such as the number of leaves at different weeks after planting (WAP) and plant height at various stages did not show statistically significant effects on Shoot fresh weight, with p-values ranging from 0.0780 to 0.9316. The correlation matrix reveals several key relationships among the variables studied as shown in Table 2. Air injected irrigated soil shows a perfect positive correlation with itself (1.00) and a weak negative correlation with air injected irrigation water (-0.33), SFW water use efficiency (-0.02), and Shoot fresh weight (g) (-0.07). This suggests that air injection into soil does not significantly correlate with Shoot fresh weight or water use efficiency. Air injected irrigation water also has a perfect positive correlation with itself (1.00) and shows weak to moderate correlations with other variables, including a moderate positive correlation with SFW water use efficiency (0.42) and Shoot fresh weight (g) (0.49). This indicates that injecting air into irrigation water may have a more noticeable impact on Shoot fresh weight and water use efficiency compared to injecting air into soil. Field Capacity shows no correlation with air injection methods (0.00) and a weak positive correlation with Shoot fresh weight (g) (0.16). Interestingly, it has a weak negative correlation with SFW water use efficiency (-0.52), suggesting that higher field capacity may not necessarily lead to higher water use efficiency. SFW water use efficiency has a moderate positive correlation with Shoot fresh weight (g) (0.74), indicating that improved water use efficiency is associated with increased Shoot fresh weight. This correlation is the strongest observed in the matrix, highlighting the importance of water use efficiency in plant growth (Zhu et al., 2020).

Table 2: Correlation Matrix

	Air injected irrigated soil	Air injected irrigation water	Field Capacity	SFW water use efficiency	Shoot fresh weight (g)
Air injected irrigated soil	1				
Air injected irrigation water	-0.33	1			
Field Capacity	0	0	1		
SFW water use efficiency	-0.02	0.42	-0.52	1	
Shoot fresh weight (g)	-0.07	0.49	0.16	0.74	1

The findings indicate that SFW water use efficiency has the most substantial positive correlation with Shoot fresh weight (g), suggesting that efficient water use is crucial for optimizing Shoot fresh weight. The relatively weaker correlations of other variables highlight the complexity of factors affecting plant growth and the need for further investigation into these relationships. Figure 1 showed the predictor effect plots depict the impact of various treatments on the shoot fresh weight of plants, measured in grams. The three plots illustrate the relationships between air-injected irrigated soil, air-injected irrigation water, field capacity, and shoot fresh weight.

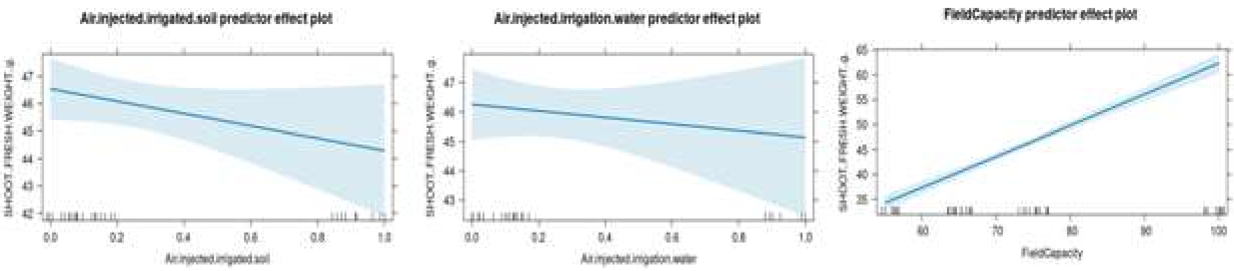

Figure 1: Predictor effect plots

The "Air injected irrigated soil predictor effect plot" shows a slightly negative relationship between the use of air-injected irrigated soil and shoot fresh weight. As the proportion of air-injected irrigated soil increases from 0 to 1, the shoot fresh weight decreases slightly from approximately 46.5 grams to 45 grams. The confidence interval around the regression line indicates some uncertainty in this relationship, especially at higher levels of air injection. The "Air injected irrigation water predictor effect plot" similarly indicates a negative relationship between air-injected irrigation water and shoot fresh weight. With increased use of air-injected irrigation water, shoot fresh weight declines from around 46.5 grams to about 43 grams. The confidence interval widens at higher levels of air injection, suggesting increased variability and uncertainty in the effect of air-injected water on shoot weight. The "FieldCapacity predictor effect plot" shows a positive relationship between field capacity and shoot fresh weight. As field capacity increases from 60 to 100, shoot fresh weight rises significantly from about 35 grams to 60 grams. This positive trend suggests that higher soil moisture retention, indicated by increased field capacity, positively influences plant growth. The narrow confidence interval across the range of field capacity values suggests a consistent and statistically significant effect. The findings indicate that field capacity and water use efficiency are significant predictors of Shoot fresh weight, suggesting that optimizing these factors can enhance plant growth. The aeration methods showed some influence on Shoot fresh weight within the parameters of this study, aligning with the observations reported by Xiao et al. (2022). This suggests that while aeration methods are important, their impact may be less pronounced compared to field capacity and water use efficiency.

Conclusion

This study has examine the role of advertising in motivating consumer brand preference for beverages with special reference to This study explored the effects of field capacity and aeration methods on plant growth, focusing on shoot fresh weight (SFW) as the primary outcome. Four levels of field capacity (100%, 75%, 65%, and 55%) and two aeration methods (air injected into irrigated soil or irrigation water) were tested. The linear regression model revealed that field capacity and water use efficiency at constant aeration are significant predictors of SFW. Field capacity demonstrated a statistically significant positive effect on SFW with a coefficient of 0.27 ($p = 0.0117$), while water use efficiency showed a significant positive influence with a coefficient of 24.22 ($p = 0.0242$), confirming report by previous study (Zhu et al., 2020). Aeration methods, however, did not show a statistically significant effect on SFW at the 0.05 level. Air injected into irrigated soil and air injected into irrigation water had coefficients of

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7.36 (p = 0.1414) and 9.82 (p = 0.0851), respectively, suggesting only marginal significance. Additionally, variables such as the number of leaves at various weeks after planting and plant height did not significantly affect SFW. The correlation matrix highlights that water use efficiency has the strongest positive correlation with SFW, emphasizing its critical role in optimizing plant growth. The weaker correlations of other variables suggest that while field capacity and water use efficiency are crucial, aeration methods' impact may be less significant. The findings indicate that focusing on optimizing field capacity and water use efficiency can enhance plant growth more effectively than modifying aeration methods alone.

References

Aytac, A.; Kelestemur, G. T. & Tuna, M. C. (2024). *An effective aeration system for high performance pond aeration at low energy cost*, Aquaculture International : 1-18.

Baram, S.; Weinstein, M.; Evans, J. F.; Berezkin, A.; Sade, Y.; Ben-Hur, M.; Bernstein, N. & Mamane, H. (2022). *Drip irrigation with nanobubble oxygenated treated wastewater improves soil aeration*, Scientia Horticulturae 291 : 110550.

Ben-Noah, I.; Nitsan, I.; Cohen, B.; Kaplan, G. & Friedman, S. P. (2021). *Soil aeration using air injection in a citrus orchard with shallow groundwater*, Agricultural Water Management 245 : 106664.

Burnett, A. C.; Anderson, J.; Davidson, K. J.; Ely, K. S.; Lamour, J.; Li, Q.; Morrison, B. D.; Yang, D.; Rogers, A. & Serbin, S. P. (2021). *A best-practice guide to predicting plant traits from leaf-level hyperspectral data using partial least squares regression*, Journal of Experimental Botany 72 : 6175-6189.

Chacon, A. I.; Baer, A.; Wheeler, J. K. & Pittermann, J. (2020). *Two coastal Pacific evergreens, Arbutus menziesii, Pursh. And Quercus agrifolia, Née show little water stress during California's exceptional drought*, PLoS One 15 : e0230868.

Du, Y.-D.; Zhang, Q.; Cui, B.-J.; Sun, J.; Wang, Z.; Ma, L.-H. & Niu, W.-Q. (2020). *Aerated irrigation improves tomato yield and nitrogen use efficiency while reducing nitrogen application rate*, Agricultural Water Management 235 : 106152.

Faloye, O. T.; Ajayi, A. E.; Alatise, M. O.; Ewulo, B. S. & Horn, R. (2020). *Maize growth and yield modelling using aquacrop under deficit irrigation with sole and combined application of biochar and inorganic fertiliser*, Journal of Soil Science and Plant Nutrition 20 : 2440-2453.

Halli, H. M.; Angadi, S.; Kumar, A.; Govindasamy, P.; Madar, R.; El-Ansary, D. O.; Rashwan, M. A.; Abdelmohsen, S. A. M.; Abdelbacki, A. M. M. & Mahmoud, E. A. (2021). *Influence of planting and irrigation levels as physical methods on maize root morphological traits, grain yield and water productivity in semi-arid region*, Agronomy 11 : 294.

Jin, C.; Lei, H.; Chen, J.; Xiao, Z.; Leghari, S. J.; Yuan, T. & Pan, H. (2023). *Effect of soil aeration and root morphology on yield under aerated irrigation*, Agronomy 13 : 369.

Lambert, I., Paysant-Le Roux, C., Colella, S., & Martin-Magniette, M. L. (2020). DiCoExpress: a tool to process multifactorial RNAseq experiments from quality controls to co- expression analysis through differential analysis based on contrasts inside GLM models. *Plant Methods*, *16*, 1-10.

Li, Y.; Niu, W.; Cao, X.; Zhang, M.; Wang, J. & Zhang, Z. (2020). *Growth response of greenhouse-produced muskmelon and tomato to sub-surface drip irrigation and soil aeration management factors*, BMC plant biology 20 : 1-15.

Ojeikere, B. A. & Okonji, V. A. (2020). *Effects of varied hours of aeration on the spawning success of African catfish (Clarias gariepinus)*, (dissertation)

Oyewusi, T. F. (2023). *Olayinka Akinola Omotosho1, Jimmy Akinfemi Osunbitan2 Gbolabo Abidemi Ogunwande*, Indian Journal of Engineering 20 : e2ije1002.

Parameshwarareddy, R. & Dhage, S. S. (2022). *Oxygation to Unlock Yield Potential of Crops: A Review*, Agricultural Reviews 43 : 122-126.

Qian, Z.; Zhuang, S.; Gao, J.; Tang, L.; Harindintwali, J. D. & Wang, F. (2022). *Aeration increases soil bacterial diversity and nutrient transformation under mulching-induced hypoxic conditions*, Science of the Total Environment 817 : 153017.

Rigoni, D.; Pinto, M. A. V. & Kwiatkowski Jr, J. E. (2022). *Verification and error analysis for the simulation of the grain mass aeration process using the method of manufactured solutions*, Biosystems Engineering 223 : 149-160.

Suleiman, H. D. (2022). *Development of Aerated Pits for Shea Butter Wastewater Treatmen* (Doctoral dissertation).

Xiao, Z. Y., Lei, H. J., Zhang, Z. H., Zhang, Q. A., Jin, C. C., & Sun, K. P. (2022). Modelling growth and yield of aerated pepper by the logistic model.

Zhu, Y.; Cai, H.; Song, L.; Wang, X.; Shang, Z. & Sun, Y. (2020). *Aerated irrigation of different irrigation levels and subsurface dripper depths affects fruit yield, quality and water use efficiency of greenhouse tomato*, Sustainability 12 : 2703

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