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Impact of Drip Irrigation and Fertigation Levels on Vegetative growth of High-Density Guava (*Psidium guajava* L. cv. VNR Bhihi)

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A B S T R A C T

A two-season field study was conducted to evaluate the individual and interactive effects of four levels of drip irrigation (I_1 to I_4) and four levels of fertigation (F_1 to F_4) on the growth and canopy architecture of guava. The study measured Plant Height (m) and Plant Volume (m3) and analyzed the data using a factorial design with mean separation based on the Critical Difference (CD) at the 5% level of significance. Results indicated that both drip irrigation and fertigation levels significantly influenced both growth parameters ($P<0.05$). For both plant height and plant volume, the irrigation level I_2 consistently recorded the highest pooled mean values (1.80 m and 1.48 m^3, respectively), and was statistically superior to all other levels, demonstrating that an intermediate water supply was optimal. The highest irrigation level (I_4) resulted in the lowest pooled plant height (1.47 m) and volume (1.21 m3). Similarly, the lowest fertigation level, F_1, yielded the highest pooled means for plant height (1.69 m) and plant volume (1.40 m3), with F_4 resulting in the lowest values. While the interaction effect (I×F) on plant height was statistically non-significant, the interaction effect on Plant Volume was significant ($P=0.023$). The combination of I_2F_1 (optimal irrigation with the lowest fertigation) recorded the maximum pooled plant volume of 1.57 m^3. Conversely, the lowest plant volume (1.09 m3) was observed in the combination of the highest levels (I_4F_4). It is concluded that guava growth is highly sensitive to both water and nutrient levels, and excessive supply of either factor (I_4 or F_4) is detrimental to vegetative growth. The study recommends the use of an intermediate irrigation level (I_2) combined with a conservative fertigation level (F_1 or F_2) for maximizing the vegetative growth and canopy volume of guava.

Introduction

Guava (*Psidium guajava* L.) is a highly valued tropical fruit crop widely cultivated across the globe for its nutritional and economic importance. As a high-value orchard crop, achieving optimal vegetative growth and canopy development is crucial for maximizing photosynthetic efficiency, flowering potential, and ultimately, fruit yield. Plant growth parameters such as Plant Height and Plant Volume serve as key indicators of a tree's vigor and its capacity to bear fruit (1,2).

Crop production in arid and semi-arid regions is often constrained by both water availability and nutrient management (3). The adoption of modern, precise application techniques like drip irrigation and fertigation (the delivery of nutrients through the irrigation system) is essential for enhancing Water Use Efficiency (WUE) and Nutrient Use Efficiency (NUE) in orchards (5,6).

While drip irrigation ensures water is delivered directly to the root zone, different levels of water application (based on crop evapotranspiration, ETc) can significantly impact soil aeration, nutrient uptake, and physiological processes (4,7). Similarly, the concentration of soluble salts delivered through fertigation (e.g., as a percentage of the Recommended Dose of Fertilizer, RDF) must be carefully controlled, as excessive nutrient levels can lead to osmotic stress, restricting water absorption and, consequently, plant growth.

This study was thus designed as a factorial experiment to investigate the individual and interactive effects of four distinct levels of drip irrigation and four levels of fertigation on the vegetative growth of guava over two seasons.

The primary objective was to identify the optimal combination of water and nutrient supply that maximizes plant height and plant volume, thereby providing a robust basis for recommending precise irrigation and fertigation schedules to guava growers.

Materials and Methods

Experimental site and climate

The experimental site was located at College of Horticulture, Dr. Y.S.R Horticultural University, Venkataramannagudem, West Godavari district of Andhra Pradesh. The location falls under Agro-climatic zone-10, humid, east coast plain and hills (Krishna-Godavari zone) and is located at an altitude of 34 m (112 feet) above MSL receiving an average annual rainfall of 900 mm. The geographical situation of experimental site is 16^{o} 63’ 120” N latitude and 81^{o} 27’568” E longitude. It experiences hot humid summer and mild winter. The meteorological data of the past five years as recorded at Meteorological Observatory, Department of Agronomy, College of Horticulture were used for estimation of evapotranspiration and also in planning and execution of irrigation scheduling.

Treatment Application

The experiment was laid out in a Factorial Randomized Block Design (FRBD) with sixteen treatments and each replicated thrice during 2020-21. The treatments were imposed on uniform two years old VNR Bhihi variety guava plants.

Five plants were maintained in each treatment of the experimental plot. There were four levels of irrigation namely (I_1) at 120 % of ET, (I_2) at 100 % of ET, (I_3) at 80 % of ET and (I_4) at 60 % of ET. There were four levels of fertigation namely F_1 125% of recommended dose of fertilizer (300,200,200 g of NPK/ plant/ year), F_2 100% of recommended dose of fertilizer (240,160,160 g of NPK/ plant/ year), F_3 80% of recommended dose of fertilizer (180,120,120 g of NPK/ plant/ year) and F_4 60% of recommended dose of fertilizer (120,80,80 g of NPK/ plant/ year).

The irrigation was applied to guava plants as per treatments. The drip irrigation was scheduled as suggested by Mane *et al.,* (2006). The drip irrigation

was supplied at an alternate day interval. The daily USDA class A open pan evaporation readings for five years were obtained from meteorological observatory, Department of Agronomy, College of Horticulture, Venkataramannagudem. Estimation of ET was done by applying average of five years (2015 to 2020) meteorological data of the study site. For rainy days, irrigation requirement was calculated after subtracting corresponding effective rainfall from ET.

Treatment wise requirement of fertilizer was calculated based on recommended dose of fertilizer suggested by Technical Bulletin, CISH, Lucknow. Nitrogen was applied in 6 equal splits at bi-monthly intervals (At February, April, June, August, October and December months) during the experimental period. Treatment wise phosphate and Potassium were applied in two equal splits in the months of June and October as per the treatment. SSP was applied as soil application and MOP was applied through fertigation. Nitrogen was applied as urea, phosphorus as single super phosphate and potassium as muriate of potash. The plants were prunned twice in a year in the months of February and September.

The drip irrigation system was set up with main (75 mm) and sub-mains (50 mm) made up of high density polyethylene and laterals (12 mm) made up to low density polyethylene. The spacing between two adjacent laterals was 2.8 m. Two (8 lph discharge) emitters were used per plant for application. Water soluble fertilizers were injected in drip system through injection pump.

Observations recorded

The data on plant height (m), plant spread from north-south and east-west (m) and girth of primary branches (cm) were recorded using meter scale and vernier caliper. Canopy volume was calculated as the method described by the Samaddar and Chakrabarti (1988) and expressed in (m^3). Fruit diameter, polar and equatorial was taken with the help of Vernier caliper. Average fruit weight was recorded with the help of an electronic balance. Mature fruits were harvested periodically from each treatment separately and the weight was recorded with the help of electronic balance and expressed in kilogram.

Statistical analysis

Data were statistically analyzed using Factorial RBD and treatment means were compared using LSD at 5% significance ($p < 0.05$).

Results and Discussion

This study investigated the effect of four levels of Drip Irrigation (I_1 to I_4) and four levels of Fertigation (F_1 to F_4) and their interaction on the growth parameters of guava: Plant Height (m) and Plant Volume (m^3) over two seasons (Season-1 and Season-2), along with their Pooled mean.

The experiment was analyzed using a factorial design (implied RBD or similar) with Critical Difference (CD) at 5% used for mean comparison.

Plant Height (m)

Discussion (Plant Height - Irrigation)

The effect of drip irrigation levels on guava plant height was highly significant across both seasons and the pooled data ($P<0.0001$).

- Optimal Level: The maximum plant height was consistently recorded under treatment I_2 (1.59 m in Season-1, 2.01 m in Season-2, and 1.80 m pooled).
- Statistical Superiority: Based on the pooled mean (CD at 5% = 0.070 m), I_2 (1.80 m) was significantly superior to all other irrigation levels.
- Suboptimal Levels: I_3 (1.68 m) was the next best treatment, followed by I_1 (1.62 m). The lowest height was recorded by the highest irrigation level, I_4 (1.47 m pooled), suggesting that excessive water supply at I_4 may have led to soil saturation, reduced aeration, and inhibited growth. The mean differences are: $I_2>I_3>I_1>I_4$.

Discussion (Plant Height - Fertigation)

The effect of fertigation levels was significant in Season-1 (P=0.042), highly significant in Season-2 (P<0.0001), and significant in the pooled data (P=0.036).

- Best Performance: The maximum plant height was achieved with the lowest fertigation level, F_1 (1.69 m pooled).
- Inverse Relationship: There was a general trend of decreasing plant height as the fertigation level increased from F_1 to F_4. F_4 recorded the lowest pooled height of 1.60 m.
- Statistical Grouping (Pooled): F_1 (1.69 m) was significantly superior to F_3 (1.61 m) and F_4 (1.60 m) (since $1.69-1.61=0.08>0.070$), but was statistically at par with F_2 (1.67 m). This indicates that the lower rates of fertigation (F_1 and F_2) were more conducive to optimal vertical growth.

Discussion (Plant Height - Interaction)

The interaction effect of irrigation and fertigation on plant height was statistically Non-Significant (NS) for all seasons and the pooled data, although the P-values (0.050, 0.056, 0.051) are very close to the 5% significance threshold.

- Trend: Despite being non-significant, the highest mean pooled height (1.84 m) was recorded by I_2F_1 (1.84 m), confirming that the combination of the optimal irrigation level (I_2) and the best performing fertigation level (F_1) was numerically the most effective treatment.

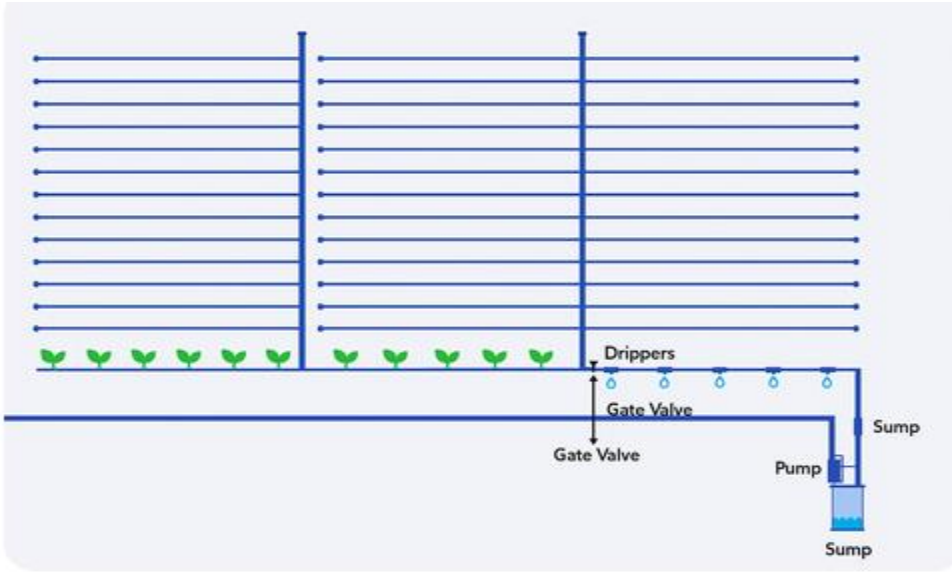
Plant Volume (m^3)

Discussion (Plant Volume - Irrigation)

The effect of drip irrigation on plant volume was highly significant across all seasons (P<0.0001).

- Optimal Level: Consistent with plant height, the maximum plant volume was achieved under treatment I_2 (1.48 m^3 pooled).
- Statistical Order: Applying the pooled CD at 5% (0.057 m^3), I_2 (1.48 m^3) was significantly superior to all other irrigation levels. I_3 (1.38 m^3) and I_1 (1.34 m^3) were statistically at par (difference is $0.04<0.057$). The lowest volume was recorded by I_4 (1.21 m^3 pooled).
- Interpretation: The results indicate that I_2 (intermediate irrigation level) provides the optimal water regime for overall canopy development, leading to maximum volume, while I_4 (excess irrigation) restricts growth.

Fig.1 Layout of drip irrigated experimental plot



Effect of Drip Irrigation Levels (I)

Irrigation Level	Season-1 Mean (m)	Season-2 Mean (m)	Pooled Mean (m)
I_1	1.43	1.81	1.62
I_2	1.59	2.01	1.8
I_3	1.48	1.87	1.68
I_4	1.3	1.63	1.47
CD at 5%	0.065	0.083	0.07
P-Value	0	0	0

Effect of Fertigation Levels (F)

Fertigation Level	Season-1 Mean (m)	Season-2 Mean (m)	Pooled Mean (m)
F_1	1.5	1.89	1.69
F_2	1.47	1.86	1.67
F_3	1.42	1.8	1.61
F_4	1.41	1.78	1.6
CD at 5%	0.065	0.083	0.07
P-Value	0.042	0	0.036

Interaction Effect (I×F)

Parameter	Season-1	Season-2	Pooled
CD at 5%	NS	NS	NS
P-Value	0.05	0.056	0.051

Effect of Drip Irrigation Levels (I)

Irrigation Level	Season-1 Mean (m3)	Season-2 Mean (m3)	Pooled Mean (m3)
I_1	0.78	1.9	1.34
I_2	0.86	2.1	1.48
I_3	0.81	1.96	1.38
I_4	0.7	1.72	1.21
CD at 5%	0.033	0.082	0.057
P-Value	0	0	0

Effect of Fertigation Levels (F)

Fertigation Level	Season-1 Mean (m^3)	Season-2 Mean (m^3)	Pooled Mean (m^3)
F1	0.82	1.98	1.4
F2	0.8	1.95	1.37
F3	0.78	1.89	1.33
F4	0.75	1.86	1.31
CD at 5%	0.033	0.082	0.057
P-Value	0.004	0.025	0.014

Interaction Effect (I×F)

Interaction Treatment	Pooled Mean (m^3)
I_2F_1	1.57
I_2F_2	1.52
CD at 5%	0.114
P-Value (Pooled)	0.023

Discussion (Plant Volume - Fertigation)

The effect of fertigation levels on plant volume was significant for all seasons and the pooled data ($P<0.05$).

- Best Performance: Similar to plant height, the maximum plant volume was recorded under the lowest fertigation level, F_1 (1.40 m^3 pooled).
- Statistical Grouping (Pooled): F_1 (1.40 m^3) was significantly superior to F_3 (1.33 m^3) and F_4 (1.31 m^3) (since $1.40-1.33=0.07>0.057$), but statistically at par with F_2 (1.37 m3).
- Trend: Increasing the fertilizer concentration beyond F_2 appeared to be detrimental to overall canopy growth, possibly due to increased osmotic stress or nutrient imbalance caused by excessive salt concentration in the rhizosphere under drip conditions.

Discussion (Plant Volume - Interaction)

The interaction effect between irrigation and fertigation on plant volume was significant for Season-1, Season-2, and the Pooled data ($P<0.05$). This indicates that the effect of fertigation on plant volume depends significantly on the level of irrigation applied.

- Optimal Combination: The significantly highest plant volume was recorded by the combination I_2F_1 (1.57 m3 pooled), which involved the optimum irrigation level (I_2) and the lowest fertigation level (F1).
- Statistical Superiority: I_2F_1 (1.57 m^3) was statistically at par with I_2F_2 (1.52 m3) (difference of $0.05<0.114$). Both were significantly superior to the remaining treatments.
- Least Combination: The lowest pooled volume (1.09 m^3) was recorded by I_4F_4, the combination of the highest irrigation and highest fertigation levels, reinforcing the detrimental effect of high water and high nutrient concentrations on guava plant growth.

In conclusion, the growth parameters of guava (Plant Height and Plant Volume) were most effectively promoted by the intermediate irrigation level I_2 and the lowest fertigation level F_1. The I_2F_1 combination consistently yielded the highest numerical and statistically significant results for plant volume, confirming a synergistic effect where an optimal water supply (I_2) is best complemented by a conservative nutrient supply (F_1). Excessive water (I_4) and excessive fertilizer (F_4) were found to be limiting factors for plant growth.

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