Research Article

Optimization of Water Depletion Level and Nutrient Requirement in Drip-Irrigated High Dense Kinnow Orchard

Habib Ullah Habib[1], Malik Muhammad Akram[2], Mujahid Ali[1*], Tahir Mehmood[3], Muhammad Manzoor[4], Maqsood Ahmad[3], Hasseb Ahsan[1], Muhammad Mazhar Iqbal[3], Malik Abdul Rehman[5], Muhammad Mohsan[1] and Ahsan Mohyo ud Din[6]

[1]Water Management Research Farm, Renala Khurd 56150, Okara, Pakistan; [2]Directorate General, Agriculture Department (Water Management Wing), Government of the Punjab, Lahore 54000, Pakistan; [3]Water Management Training and Research Institute, Agriculture Department (Water Management Wing), Government of the Punjab, Lahore 54000, Pakistan; [4]Deputy Director Agriculture, On-Farm Water Management, Gujrat, Pakistan; [5]Citrus Research Institute, Sargodha, Pakistan; [6]Oilseed Research Institute, Faisalabad, Pakistan.

Abstract | Citrus can behave differently at different water depletion levels, which can be evaluated by various growth attributes. The study aimed to optimize water depletion level and nutrient requirement in drip-irrigated high dense kinnow orchard. To study such changes present study was performed with kinnow under different water depletion levels and fertilizer levels. The research was conducted on Water Management Research Farm, Renala Khurd, Okara. Kinnow was given two water depletion levels 10% and 15% along with four NPK fertilizer levels 100%, 75%, 50%, 75% of percent recommended dose of fertilizer) of NPK were studied by using soluble fertilizers. Fertigation was applied through drip irrigation according to the schedule derived through Crop Watt. Kinnow plants showed significant results regarding plant canopy, plant height, the average weight of fruits, the weight of large size fruits, the weight of medium size, the weight of small size fruits, number of fruits per plant, number of small fruits per plant, number of medium-size fruits per plant, and number of large size fruits per plant. The maximum number of medium-size fruits (15%) was observed at 15% water depletion level with a 50% NPK level. However, the minimum number of medium-size fruits (11%) were seen at 10% water depletion level with 75% of recommended NPK. The maximum number of large-size fruits (14%) was observed at 15% water depletion level with 75% and 100% NPK level at par with the number of fruits (14%) at 10% water depletion level with 50% NPK and 100% NPK of recommended fertilizer level. However, the minimum number of large-size fruits (9%) was seen at 10% water depletion level with 25% of recommended NPK. 10% and 15% water depletion levels and 75% and 100% of recommended NPK performed better than other treatments under consideration.

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***Correspondence** | Mujahid Ali, Water Management Research Farm, Renala Khurd 56150, Okara, Pakistan; **Email:** mujahidali2263@gmail.com
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1. Introduction

Kinnow (*Citrus reticulata* 'Blanco) belongs to the family *Rutaceae* and is ranked the first fruit in Pakistan regarding area and production while 5th in the world. The total area of citrus under cultivation in Pakistan is 181650 hectares with a total annual production of 2468671 tons. Punjab has 170370 hectares with an annual production of 2397306 tons. Sindh has 5536 hectares with a production of 31615 tons annually. KPK and Baluchistan have 4049 and 1695 hectares, respectively of citrus cultivation with 31330 and 8420 tons annually, respectively. Pakistan has exported 125 thousand tons of kinnow. The share of Kinnow, fresh in citrus exported is 353 thousand tons having 96% share of citrus (Nazir *et al*., 2022).

Different types of adaptation and management strategies are required for saving water resources (Iglesias and Garrote, 2015). The extinction of fresh and quality of water has alarming situation to agricultural lands in arid zones of the world. Water depletion, water deficit, and scarcity is becoming severe in near future (Abdelraouf and Abuarab, 2012). This has also emphasized producing more crops to feed such a big population by managing water resources (Bakry *et al*., 2012; Abdelraouf *et al*., 2013c). Water use efficiency is of keen interest due to limited water resources and low rainfall (Hozayn *et al*., 2013). There is a need to develop a new technology that can be help full to utilize this precious input in an effective way (Abdelraouf *et al*., 2013b).

In one previous study of the United States, five districts (Highlands, Polk, and Hillsborough) were chosen as research points in Florida for water productivity. The district water management department conducted the project and find out KCs value for the rescheduling. These models developed water-saving techniques according to regional climate (Romero *et al*., 2009). García-Tejero *et al*. (2012) revealed that the fruit growth and flowering stages were the most sensitive periods in relation to irrigation water deficit and yield loss.

Irrigation management and soil water balance according to climate change is imperative to sustain quality production in citrus (Martínez-Ferri *et al*., 2013). Dry spells and high temperatures during the fruit-drop season become a cause of substantial fruit drops and diminished yield. The dry season and high temperatures cause a lot of fruit splitting and wrinkling and lessen yield. On the off chance that unusual dry spells and high temperatures happen frequently, measures for avoidance of these issues ought to be taken. Mulch development has been expanded to deliver excellent Satsuma mandarins by forestalling the retention of over the top water by roots. RDI (shortfall water system), which depends on decreasing water application during phases of harvest advancement when yield and fruit quality have a low affectability to water pressure and giving ordinary water system during the remainder of the period to keep up fruit quality at sufficient levels, has been tried on citrus (Sato, 2015).

Shahabian *et al*. (2012) described the impacts of deficit and partial root-zone drying in navel orange trees having silty clay loam soil. 50% and 75% deficit and partial root-zone drying full was compared with water conventional or full irrigation. Results showed that deficit irrigation decreased fruit yield by up to 30% compared with full irrigation. While fruit yield was maintained in case of partial root zoon drying. No adverse consequence was observed in fruit quality in the wake of applying deficit irrigation and partial root zoon drying. Water use productivity of root zoon drying in trees increased to almost double that of full irrigation. So, partial root zoon drying was found a satisfactory deficiency water system.

Stagno *et al*. (2015) studied during three sequential summer seasons, the impacts of deficit irrigation applied in sweet orange trees. Two deficit irrigation systems providing 70 and half of the harvest evapotranspiration were compared with the full pace of evapotranspiration; the correlations were completed as far as plant physiological reaction, crop creation, quality, and nourishing status. 70% deficit irrigation saved 80 mm of water-saving per season with no effect on growth and yield of oranges. However, extreme drought (DI 1/4 half ETc) decreased fruit weight and water productivity.

Physical and morphological attributes of plant roots are major factors for water absorption and irrigation scheduling with deficit irrigation and transpiration ratio. A very effective way to regulate irrigation water is using mulch with drip irrigation (Wang *et al*., 2021).

The natural and monetary manageability of horticultural frameworks needs to confront the overall diminishing pattern of water assets through the selection of procedures pointed toward improving water-use effectiveness. Pakistan has citrus cultivation mostly in a semi-arid climate where rain and precipitation are unequal and uncertain due to climate change. So, it is imperative to ascertain the maximum allowable depletion levels with fertigation and its impacts on kinnow yield and quality. So, the aim of the study was to optimize water depletion levels and nutrient requirements in drip-irrigated kinnow dense orchards.

2. Materials and Methods

The research was conducted on five years of old kinnow mandrin plants at Water Management Research Farm, Relana Khurd (30.8782° N, 73.5954° E) (Okara) Punjab Pakistan. Data of climate and weather was recorded daily.

There were 432 kinnow plants with dense tree geometry (rectangular layout system) having plant to plant distance 2.3 m and row to row distance 3.7 m on an area of 1 acre. Each experimental unit contained 18 plants. The irrigation schedule was established by Crop-Watt (Model 8.0) with the following principle of crop water requirement given below:

$$Crop\ Water\ Requirement\ (CWR) = ET0\ X\ KC$$

ET_0= Evapotranspiration level which depends on the month and climatic location; KC is a constant factor that depends on the crop, month, and stage of the plant (Table 4).

Soil moisture was measured by a soil moisture meter. Kinnow was given two water depletion levels (WDL) 10% and 15% along with four NPK fertilizer levels 100%, 75%, 50%, 75% of percent recommended dose of fertilizer as per Ayub Research Centre of NPK were studied by using soluble fertilizers (Table 1). Fertigation was applied through drip irrigation according to the schedule derived through Crop Watt Model (Table 2) according to the size of the canopy (Table 3).

The maximum Allowable Depletion (MAD) of Kinnow is 50% (Panigrahi *et al*., 2014). Further, 10% and 15% were applied which means water was applied to plants in the respective blocks when 10 and 15% moisture was depleted from the field capacity of the soil, respectively. The amount of water was applied up to its field capacity and according to the size of the canopy. Based on data recorded for stem girth, canopy diameter, number of small, medium, and large fruits per plant, and size of small, medium, and large fruits, the results were drawn.

Table 1: Experimental treatments of water depletion levels and fertilizer doses.

Sr. No	Treatments	Treatment detail
1	D1F1	10% water depletion level + 100% NPK
2	D1F2	10% water depletion level + 75% NPK
3	D1F3	10% water depletion level + 50% NPK
4	D1F4	10% water depletion level + 25% NPK
5	D2F1	15% water depletion level + 100% NPK
6	D2F2	15% water depletion level + 75% NPK
7	D2F3	15% water depletion level + 50% NPK
8	D2F4	15% water depletion level + 25% NPK

Table 2: Recommended 1rrigation schedule of drip-irrigated high dense orchard for loamy soils.

Months	Irrigation (m^3/day/484 plant)
January	2.9
February	4.6
March	7.5
April	9.8
May	12.3
June	13.6
July	11.1
August	10.3
September	9.4
October	6.5
November	3.6
December	2.7

1: Kinnow plant population 484; 2: Mostly 12 lph (liter per hours) dripper of red color are used along with blue dripper of 8 lph; 3: Plant to plant distance 8ft and line to line distance 12ft; 4: Kinnow garden was almost 6-year-old; 5: 3 drippers per plant; 6: Area 1 acre/ 4047 m^2/ 43560 ft^2.

2.1 Design and statistical analysis

The layout was under two-factor factorials (water depletion levels vs NPK levels) under a randomized complete block (RCBD) design. To reduce potential error each treatment was replicated thrice. Analysis of variance (ANOVA) and multiple comparison tests (Tukey Honestly Significant Difference test) was computed using Statistix (Version 8.1). Differences among treatments were considered significant at $p \leq 0.05$ after statistical analysis.

Links Researchers

Table 3: Fertigation schedule of drip irrigated high dense orchard.

Recommendation	Removed by whole plant (Kg/ton)			Kg/acre		
	N	P2O5	K2O	N	P2O5	K2O
	0.60	0.45	0.45	292	219	219
Total nutrients to be supplied (Kg/ac)				292	219	219
Nutrients available from the soil (Kg/ac)				--	--	--
Nutrients given through basal dose (Kg/ac)				--	--	--
Total nutrients available before fertigation (Kg/ac)				--	--	--
Remaining nutrient quantity required (Kg/ac)				292	219	219

3. Results and Discussion

3.1 Stem diameter (cm)

Maximum stem girth (35 cm) was found at 15% water depletion with 100% NPK levels at par (34.92 cm) with 10% water depletion level with 50% NPK level. Whereas minimum stem girth (31.41 cm) was seen at 10% water depletion level with 25% NPK level was observed when water depletion levels and different fertilizer levels were applied in drip-irrigated high dense kinnow orchard (Figure 1).

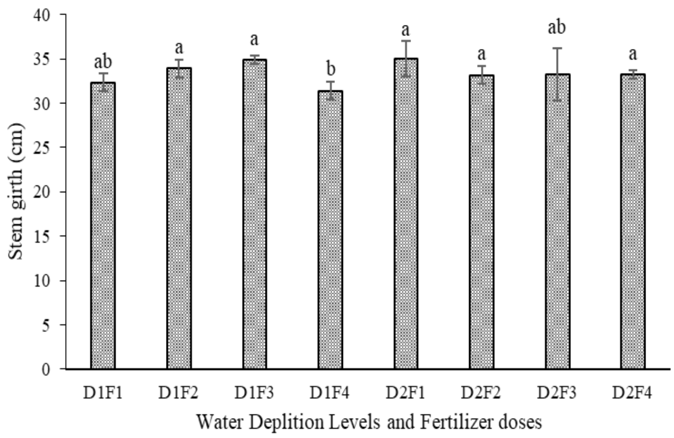

Figure 1: Effect of various water depletion levels and fertilizer doses on stem girth of kinnow.

3.2 Plant height (cm)

Results depicted a significant ($p \leq 0.05$) response of plant height regarding different fertilizer levels and selected water depletion levels. It was observed that maximum plant height (286. cm) was found at 10% water depletion level with 75% NPK level at part (286 cm) at 10% water depletion level with 50% recommended NPK, while minimum plant height (251 cm) was seen at 10% water depletion level with 25% recommended fertilizer dose (Figure 2).

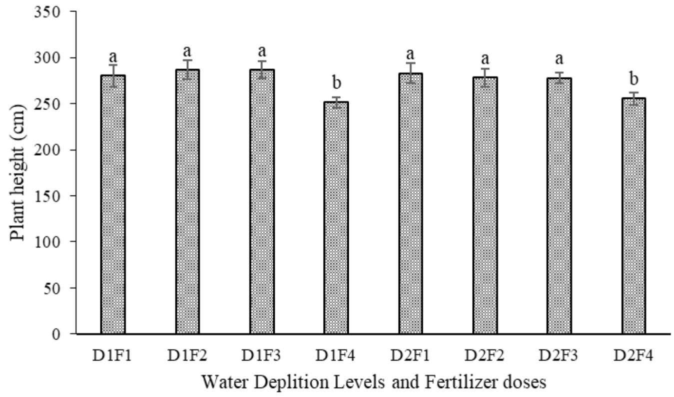

Figure 2: Effect of various water depletion levels and fertilizer doses on plant height of kinnow.

3.3 Number of fruits per plant

A remarkable difference ($p \leq 0.05$) in the number of fruits was found regarding different fertilizer levels and selected water depletion levels. The maximum number of fruits (610) at 10% water depletion level with 75% of recommended NPK, while a minimum number of fruits (490) were found at 15% water depletion level with 75% of recommended NPK (Figure 3).

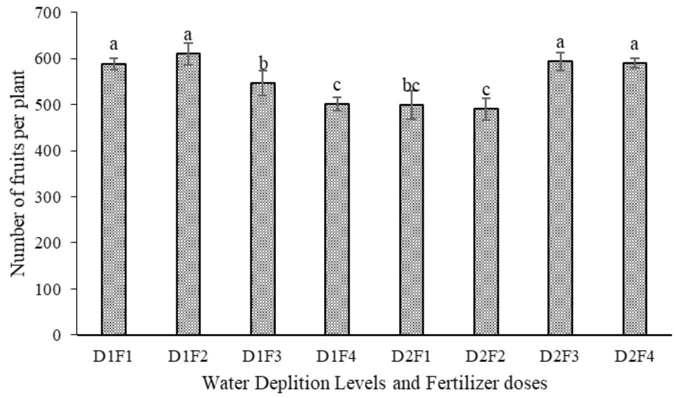

Figure 3: Effect of various water depletion levels and fertilizer doses on number of fruits of kinnow.

3.4 Average fruit weight (Kg/tree)

Average fruit weight showed a noticeable response ($p \leq 0.05$) regarding different fertilizer levels and selected water depletion levels. Maximum average fruit weight (81 Kg) was observed at 10% and 15% water depletion levels with 100% and 75% recommended NPK level, respectively. However, the minimum average fruit weight (65 Kg) was seen at a 10% water depletion level with 25% of recommended NPK (Figure 4).

3.5 Weight of large-size fruits (Kg/tree)

A remarkable difference ($p \leq 0.05$) in the weight of large-size fruits was found regarding different fertilizer levels and selected water depletion levels.

The maximum weight of large size fruits (43 Kg) was observed at 10% water depletion level with 100% NPK level at par (41.22 Kg) with 15% water depletion level with 100% NPK. However, the minimum weight of large-size fruits (27 Kg) was seen at a 10% water depletion level with 25% of recommended NPK (Figure 5).

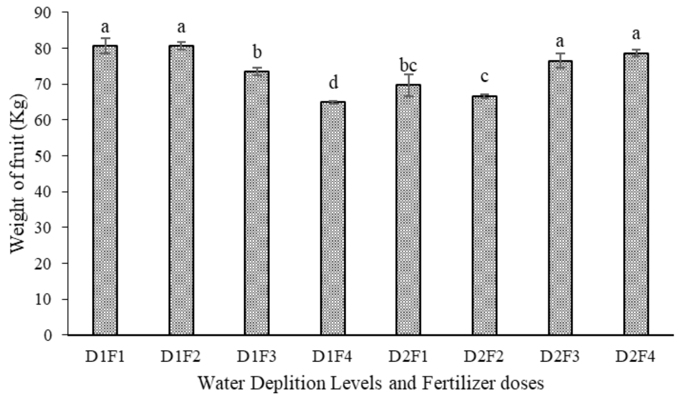

Figure 4: Effect of various water depletion levels and fertilizer doses on the overall weight of fruits of kinnow.

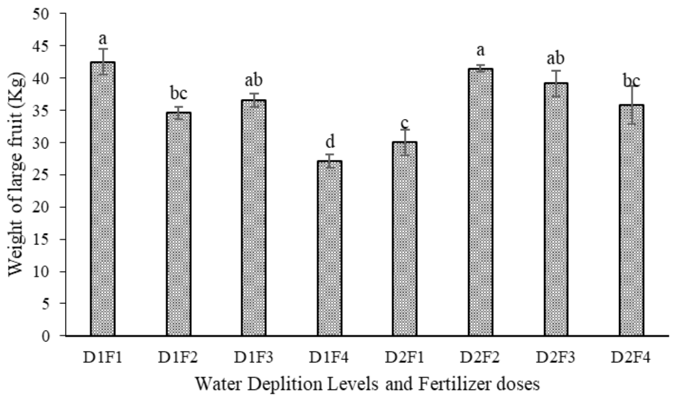

Figure 5: Effect of various water depletion levels and fertilizer doses on the weight of large-sized fruits of kinnow.

3.6 Weight of medium size fruits (Kg/tree)

The weight of medium size fruits revealed a noticeable response ($p \leq 0.05$) regarding different fertilizer levels and selected water depletion levels. The maximum average weight of medium size (38 Kg) was observed at 10% water depletion level with 75% NPK level, respectively. However, the minimum weight of medium-size fruit (30 Kg) was seen at a 10% water depletion level with 50% of recommended NPK (Figure 6).

3.7 Weight of small size fruits (kg/tree)

The maximum average weight of small size fruits (11.58 Kg) was observed at a 15% water depletion level with a 25% NPK level, respectively. However, the minimum weight of small-size fruits (4.83 Kg) was seen at a 15% water depletion level with 50% of recommended NPK (Figure 7).

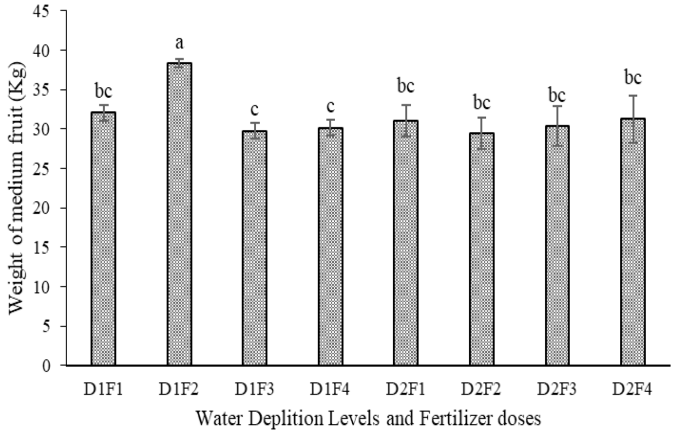

Figure 6: Effect of various water depletion levels and fertilizer doses on the weight of medium-sized fruits of kinnow.

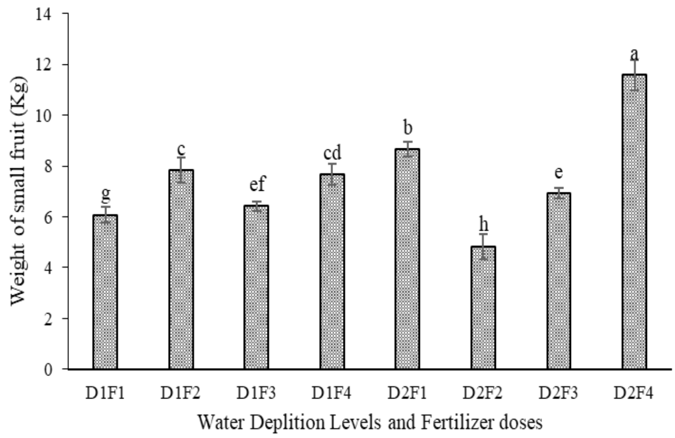

Figure 7: Effect of various water depletion levels and fertilizer doses on the weight of small-sized fruits of kinnow.

3.8 Number of large size fruits per plant

The number of large-size fruits revealed significant responses regarding different fertilizer levels and selected water depletion levels. A maximum (14.1%) number of large-size fruits (245) was observed at 15% water depletion level with 75% NPK level (D2F2) at par with the number of fruits (241) at 10% water depletion level with 100% NPK (D1F1), with 15% water depletion level with 75% recommended level (D2F2) and 10% water depletion level and 75% NPK (D1F2) (Table 5). However, the minimum (8.8%) number of large-size fruits (153) was seen at a 10% water depletion level with 25% of recommended NPK (D1F4) (Figure 8).

Table 4: Recommended fertigation schedule according to months/days according to plant growth.

Plant phase	Fertigation days	Months	Fertilizer per Kg per zone per day		
			Nutraful urea	NP	WS-SOP (Solupotash)
Vegetative growth	15	1-15 February	0.33	3.28	1.11
Flowering stage I	13	16-28 February	0.33	3.28	1.11
Flowering stage II	31	March	0.66	6.55	1.11
Pea size fruit development I	30	April	0.66	6.55	2.22
Pea size fruit development II	31	May	0.33	3.28	2.22
Fruit development stage-I	30	June	0.33	3.28	2.22
Fruit development stage-II	31	July	0.33	3.28	2.22
New sprout + Fruit development stage	31	August	0.66	6.55	2.22
Fruit development stage-IV	30	September	0.33	3.28	1.11
Dormant stage	123	Oct-January	0.00	0.00	0.00

Table 5: Effect of various water depletion levels and fertilizer doses on number of large, medium, and small size fruits.

Sr. No	Treatment detail	Large size fruits (%)	Medium size fruits (%)	Small size fruits (%)
1	10% water depletion level + 100% NPK	13.8	12.8	10.51
2	10% water depletion level + 75% NPK	13.9	13.2	14.22
3	10% water depletion level + 50% NPK	12.8	11.0	11.26
4	10% water depletion level + 25% NPK	8.8	12.2	12.42
5	15% water depletion level + 100% NPK	10.3	12.0	11.93
6	15% water depletion level + 75% NPK	14.1	14.5	8.37
7	15% water depletion level + 50% NPK	13.8	12.2	11.75
8	15% water depletion level + 25% NPK	12.6	12.1	19.55

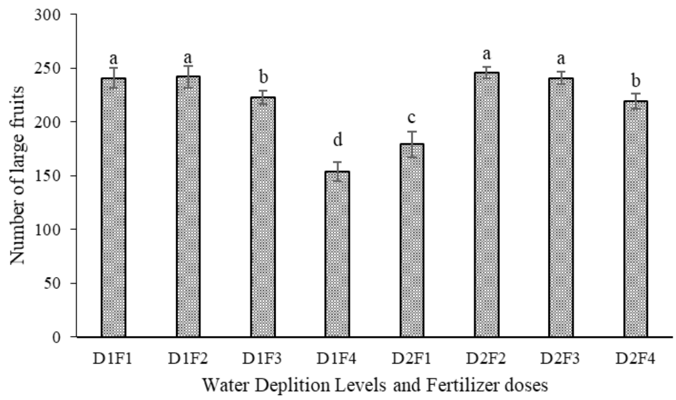

Figure 8: Effect of various water depletion levels and fertilizer doses on the number of large-sized fruits of kinnow.

3.9 Number of medium size fruits per plant

A significant response ($p \leq 0.05$) of a number of medium-size fruits regarding water depletion levels and different fertilizer levels in drip-irrigated kinnow dense orchard was observed. The maximum (14.5%) number of medium-size fruits (300) was observed at a 15% water depletion level with 75% NPK level (D2F2), respectively. However, the minimum (11%) number of medium-size fruits (228) was seen at a 10% water depletion level with 50% (D1F3) of recommended NPK (Figure 9).

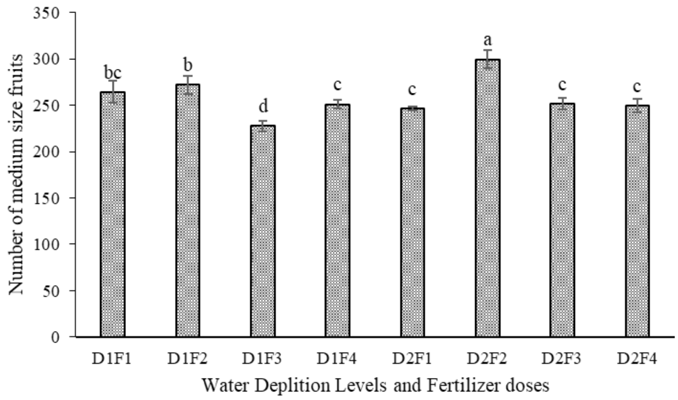

Figure 9: Effect of various water depletion levels and fertilizer doses on the number of medium-sized fruits of kinnow.

3.10 Number of small size fruits per plant

A significant response ($p \leq 0.05$) of the number of small size fruits regarding water depletion levels and different fertilizer levels in drip-irrigated kinnow dense orchard was seen. The maximum (19.6%) number of small-size fruits (120) was observed at a 15% water depletion level with 25% NPK level (D2F4), respectively. However, the minimum (8.4%) number of medium-size fruits (52) was seen at 15% water depletion level with 75% of recommended NPK (D2F2) (Figure 10).

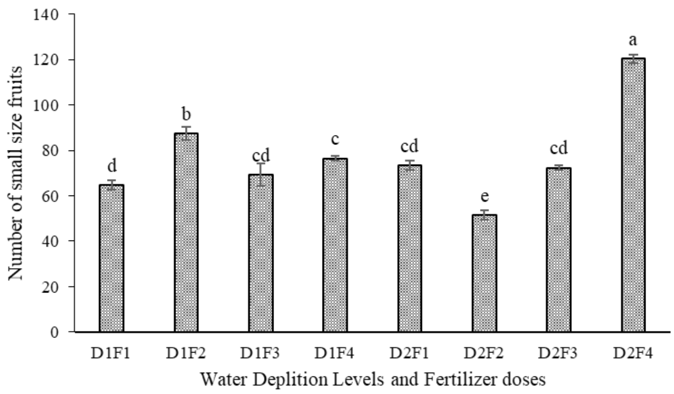

Figure 10: Effect of various water depletion levels and fertilizer doses on the number of small-sized fruits of kinnow.

During the current study, it was observed that the number of large-size fruits (economical yield) was higher at the lowest water depletion level at the recommended dose of fertilizer which means more economical yield. Water stress up to 50% of ETC at the onset of the reproductive stage flowering stage would impose a yield loss of up to 20% (García-Tejero *et al*., 2012). More water depletion would lead to dryness. Furthermore, transpiration patterns have a close relationship to drying soil. Soil drying triggers a gradual closure of stomata and a reduction in transpiration rate (Sinclair *et al*., 2005; Comstock, 2002). This ultimately leads to low yield. In general, as the soil dries under constant environmental conditions, the transpiration rate remains constant. However, it will decline linearly, after threshold soil-water content is reached (Sinclair and Muchow, 2001). 10% and 15% WDL significantly influenced the fruit weight which might be due to the fact that photosynthetic activity is altered owing to water regulations stomatal opening and closing are affected (Xie *et al*., 2012)

The present result revealed that the number of small-size fruits was higher at higher water depletion levels. These findings are according to Hussain *et al*. (2018) which mean more water depletion leads to low yield and its related attributes which might be affected due to some oxidative stress, who also demonstrated that citrus trees are affected by different abiotic stresses including drought which decreases its yield. In this study, six different citrus rootstocks were subjected to drought stress (24 days) and leaf relative water content (LRWC), chlorophyll a and b, antioxidant capacity (AC), total phenolic content, and proline content (PRO) were measured. Hydrogen peroxide (H_2O_2), lipid peroxidation (MDA), total soluble proteins (TSP), and enzymatic antioxidant activities, such as superoxidase dismutase (SOD), catalase (CAT), and peroxidase (POD), were measured in leaves and roots of the rootstocks.

Stagno *et al*. (2015) stated that crop mineral sustenance characteristics and yield decline were brought about by low water stress. A moderate water limitation could be applied in orange plantations since it saved water and improved fruit quality by expanding total solvent solids and titratable acidity, while the fruit development was postponed. However, water management is imperative for the proper growth and quality of citrus fruits (Johnson *et al*., 2013), so results described 10 to 15% WDL were gently affecting growth and yield.

Conclusions and Recommendations

On an overall basis, to improve water use efficiency 10% WDL and 15% WDL with 75% and 100% recommended NPK performed better than other treatments under consideration. Further, it is economical to adopt a 75% recommended dose with 15% water depletion from field capacity under drip irrigated kinnow orchard. So, it is recommended that water should be applied when the maximum allowable depletion level from field capacity reaches 15% for kinnow under a drip-irrigated system. While a 15% water depletion level having 25% recommended fertilizer results in poor yield as the number of small size fruits was higher in this treatment. It is recommended that the study should be continued for the next years to get useful information through this experiment.

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Novelty Statement

This this the first study encompasses the bearable water depletion range and optimum NPK levels in high dense kinnow orchards under drip irrigation in Pakistan.

Author's Contribution

Habib Ullah Habib and Muhammad Manzoor conducted the research, Mujahid Ali drafted the research article, Malik Muhammad Akram guided about treatment plan, Maqsood Ahmad collected and analyzed the research data, Muhammad Mazhar Iqbal and Tahir Mehmood reviewed the research article, Haseeb Ahsan executed the safe conduction of water depletion levels by soil moisture measuring gadgets, Malik Abdul Rehman controlled diseases and insect-pest during the experiment, Muhammad Mohsan, Ahsan Mohyo ud Din reviewed the manuscript.

Conflict of interest

The authors have declared no conflict of interest.

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