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Evaluation of Water Productivity and Yield of Citrus Reticulate Blanco under Different Soil Moisture Depletion Levels and Fertilizer Doses

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Abstract

Enhancement of water productivity and water use efficiency is possible through irrigation scheduling with optimum fertigation toward sustainable agriculture. The research was conducted on densely planted kinnow orchard under drip irrigation at Water Management Research Farm, Renala Khurd, Okara. Five years old plants were re-irrigated at 10% and 15% soil moisture depletion levels with four NPK fertilizer levels 100% (local), 75% (local), 50% (local), and 75% (imported) of the recommended dose. Kinnow plants showed significant ($p \leq 0.05$) results regarding canopy area, plant height, the average weight of fruits, and the number of fruits per plant. The maximum fruit yield (90.3 tons/ha) was observed at 10% soil moisture depletion level with 100% and 75% dose of the local recommended fertilizer, while the minimum yield (72.7 tons/ha) was observed at 10% soil moisture depletion level with 75% of the imported recommended fertilizer dose. It was also revealed that the maximum water productivity (12.4 Kg/m^3) was observed when irrigation was done at 10% soil moisture depletion level with 100% of the recommended dose of local fertilizer at par with (12.4 Kg/m^3) 10% soil moisture depletion level with 75% of the recommended dose of local fertilizer followed by (12.3 Kg/m^3) with 15% soil moisture depletion level with 75% of the recommended dose of imported fertilizer. The minimum water productivity (10.4 Kg/m^3) was at 15% soil moisture depletion level with 75% of the recommended dose of local fertilizer.

Keywords

Kinnow, water productivity, water depletion levels, fertilizer doses, yield

1. Introduction

Kinnow botanically called *Citrus Reticulate* Blanco is a type of mandarin and a member of *Rutaceae* family. It is the leading fruit of Pakistan with respect to area and production. The total area of citrus under cultivation in Pakistan is about 154,775 hectares with a total annual production of 2,599,689 MMT. Regarding provincial levels, Punjab has 143,582 hectares with an annual production of 2,526,898 MMT. Citrus is cultivated on 5691 ha in Sindh 33,555 tons of annual production. Khyber Pakhtunkhwa produced 29,236 MMT on 3722 hectares. The least production is found in Baluchistan with 10,000 MMT on 1,780 ha. During 2020-2021, Pakistan exported 3,710 thousand tons of kinnow to Afghanistan, Kuwait, Russian Federation, and UAE [1].

Different adaptation and management strategies are required to save water resources [2]. The extinction of fresh and quality water has an alarming situation for agricultural lands in arid zones of the world. Water depletion, water deficit, and scarcity is becoming severe in near future [3]. This has also emphasized producing more crops to feed such a big population by managing water resources [4-5]. Water use efficiency is of keen interest due to limited water resources and low rainfall [6].There is a need to develop a new technology that could help fully to utilize this precious input in an effective way [7].

In one previous study of the United States, five districts (Highlands, Polk, and Hillsborough) were chosen for water productivity research points in Florida. The district water management department conducted the project and find out the K_C value for the rescheduling. These models developed water-saving techniques according to regional climate [8].

Using a flume, the amount of water used for irrigation was calculated in flood and furrow irrigation in Kinnow orchard. The research showed that the number of fruits per tree was greatly increased using furrow, compared to a flood, the fruit output and juice percentage were higher fruit production using an irrigation method. TSS/Acidity Ratio, however and the various watering techniques had little impact on the percentage of peel and rag. In the system of irrigation in a furrow, A typical amount of water was used for 24 irrigations each year. Savings of 46% and water use efficiency of 4.58 kg m^{-3} compared to flood conditions average number of irrigations per irrigation system was 15 WUE was 2.34 kg m^{-3} alone and was annual. To increase the productivity, quality, and efficiency of water use by citrus growers, the furrow irrigation system is advised [9].

A study was performed during three sequential summer seasons, the impacts of deficit irrigation medicines applied on developing orange trees *Citrus sinensis* (L.) Osbeck. Two distinctive deficit irrigation systems providing 70 and half of harvest evapotranspiration (ET_c) were contrasted and the water system at the full pace of ET_c; the correlations were completed as far as plant physiological reaction, crop creation, quality, and nourishing status. The orange trees turned out to be less delicate to direct water limitations (when deficit irrigation was equivalent to 70% ET_c) allowing roughly 80 mm of water-saving (i.e., relating to an edge for water pressure vital of 60 MPa) per season with no critical effect on their water status and on agronomic exhibitions. Extreme water limitations (when deficit irrigation was equivalent to 1/4 half ET_c) diminished fruit weight and harvest creation consistently, with water-use proficiency esteems like those of moderate deficit irrigation (70% ET_c) [10].

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 by using mulch with drip irrigation [11].

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.

It has been proved that kinnow productivity depends on time and the nature of fertigation [12]. It is defined as the site-specific fertilizer contents application to citrus is vital to avoid soil and water pollution developed by the excessive use of fertilizer [13].

2. Methods

The research was conducted on kinnow plants having T-budded on rough lemon plants years old kinnow plants at Water Management Research Farm, Relana Khurd (WMRF) (30.8782 °N, 73.5954 °E) (Okara) Punjab Pakistan.

There were 432 kinnow plants with dense tree geometry (rectangular layout system) having a plant-to-plant distance of 2.3 m and a row-to-row distance 3.7 m on an area of 1 acre. Each experimental unit contained 18 plants. ET_o Value was computed by the mini-weather station (iMetos 3.3, release-3.0.4 / Dewberry) installed at WMRF Renala Khurd. The crop water requirement was measured by the following equation

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

ET_0= Evapotranspiration level which depends on the month and climatic location

K_C is a crop co-efficient, month, and stage of the plant. Soil moisture was measured by a soil moisture meter. Kinnow was given two water depletion levels 10% (having 54 plants on 482 m^2) and 15% (having 54 plants on 482 m^2) along with four NPK fertilizer levels 100%, 75%, 50%, 75% (Imported NPK) of percent recommended dose soluble fertilizers (Table 3.4). The local fertilizer was prepared by the Nuclear Institute of Agriculture and Biology (NIAB) Faisalabad-Pakistan. Total water application was the study was applied from March 2017 to February 2018 as shown in Table 3.2 and Table 3.3. Fertigation was applied through drip irrigation according to the schedule derived through Crop Watt according to the size of the canopy.

Keeping in view the maximum soil moisture depletion level of Kinnow is 50%. So, 10% and 15% were applied with various fertigation levels (Table 3.1). 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 diameter, canopy area, the number of fruits, plant height, average fruit per plant, fruit yield (tons/ha), and water productivity the results were drawn.

Considering moisture depletion levels and fertilizer doses, the layout of the experiment was established with two-factor factorials with three replications under a randomized complete block (RCBD) design. Analysis of variance (ANOVA) and multiple comparison tests (Tukey test) was done with Statistix (Version 10) with significance at $p \leq 0.05$.

3. Results

Bases of irrigation scheduling and total water applied with 10% and 15% MAD levels it was observed that there was a non-significant difference in WDL1 and WDL2 (Table 4.1).

Stem diameter (cm)

The maximum stem diameter (35.00 cm) was observed at 15% soil moisture depletion level + 100% dose of the local recommended fertilizer (W2F1), followed by at 10% soil moisture depletion level + 50% dose of local recommended fertilizer (W1F3) (34.92 cm), the minimum value (31.42 cm) was observed by 10% soil moisture depletion level + 75% dose of imported recommended fertilizer (W1F4) (Fig 3.1).

Table 3.1. Soil moisture depletion levels and doses of local and imported fertilizers used

Treatments	Treatments Description
W1F1	10% soil moisture depletion level with 100% of the recommended dose of local fertilizer
W2F2	10% soil moisture depletion level with 75% of the recommended dose of local fertilizer
W1F3	10% soil moisture depletion level with 50% of the recommended dose of local fertilizer
W1F4	10% soil moisture depletion level with 75% of the recommended dose of imported fertilizer
W2F1	15% soil moisture depletion level with 100% of the recommended dose of local fertilizer
W2F2	15% soil moisture depletion level with 75% of the recommended dose of local fertilizer
W2F3	15% soil moisture depletion level with 50% of the recommended dose of local fertilizer
W2F4	15% soil moisture depletion level with 75% of the recommended dose of imported fertilizer

Table 3.2. 1rrigation schedule of drip-irrigated high dense orchard for loamy soils for 54 plants (482 m^2)

Months	Water Applied (m^3) WDL1	Water Applied (m^3) WDL2
March	32.88	29.42
April	32.31	32.15
May	42.44	43.58
June	37.23	34.77
July	34.35	38.00
August	29.90	30.46
September	24.74	18.02
October	15.82	17.25
November	11.96	11.93
December	7.89	11.72
January	7.75	5.77
February	11.91	11.67

Table 3.3. Summary of Irrigation applied and rainwater

Water Application	WDL_1	WDL_2
Area	482 m^2	482 m^2
No. of Plants in this area	54	54
Irrigation Applied	289.2 m^3	284.7 m^3
Rainwater	61.7 m^3	61.7 m^3
Total Water Applied	350.9 m^3	346.4 m^3

Table 3.4. Fertigation schedule of drip-irrigated high-dense orchard

	WDL1		
Local Fertilizer	Urea (g)	MAP (g)	SOP (g)
F1 (100%)	42521	17167	32857
F2 (75%)	31890	12875	24643
F3 (50%)	21260	8583	16429
	Imported Fertilizer		
F4 (75%)	NPK (g)	SOP (g)	Urea (g)
	42290	10510	16324
	WDL2		
Local Fertilizer	Urea (g)	MAP (g)	SOP (g)
F1 (100%)	41871	16989	30999
F2 (75%)	28179	11641	22392
F3 (50%)	20936	8494	15500
	Imported Fertilizer		
F4 (75%)	NPK (g)	SOP (g)	Urea (g)
	39675	9374	13851

Table 4.1. Mean comparison of moisture depletion levels (WD) for attributes studied

Attributes							
Stem Girth		Canopy Area		No. of Fruits		Plant Height	
WD1	33.3 A	WD1	5.7 A	WD1	561 A	WD1	276 A
WD2	33.9 A	WD2	5.6 A	WD2	543 A	WD2	273 A
HSD value	1.5	HSD value	0.70	HSD value	49.2	HSD value	16.5

Attributes					
Fruit weight per plant		Fruit Yield		Water Productivity	
WD1	75.2 A	WD1	83.9 A	WD1	11.5 A
WD2	72.9 A	WD2	81.6 A	WD2	11.4 A
HSD value	7.61	HSD value	8.48	HSD value	1.17

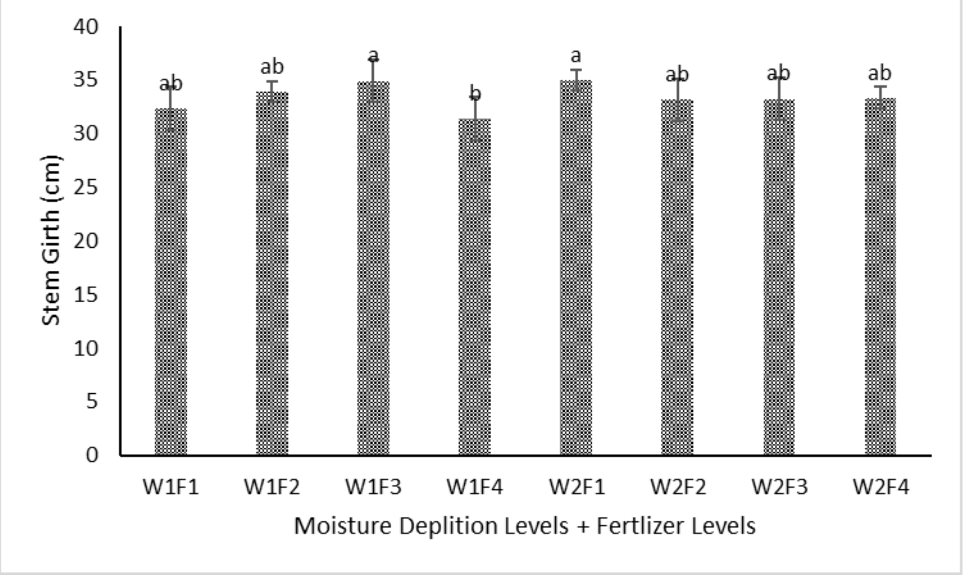

Fig 3.1. Stem girth of kinnow as affected by moisture depletion levels and NPK doses.

Plant height (cm)

The maximum plant height (286.8 cm) was expressed by at 10% soil moisture depletion level + 50% dose of the local recommended (W1F3), followed by (285.6 cm) at 10% soil moisture depletion level + 75% dose of the local recommended fertilizer (W1F2), and the minimum plant height (251.3 cm) was at 10% soil moisture depletion level + 75% dose of the local recommended fertilizer (W1F4) (Fig 3.2).

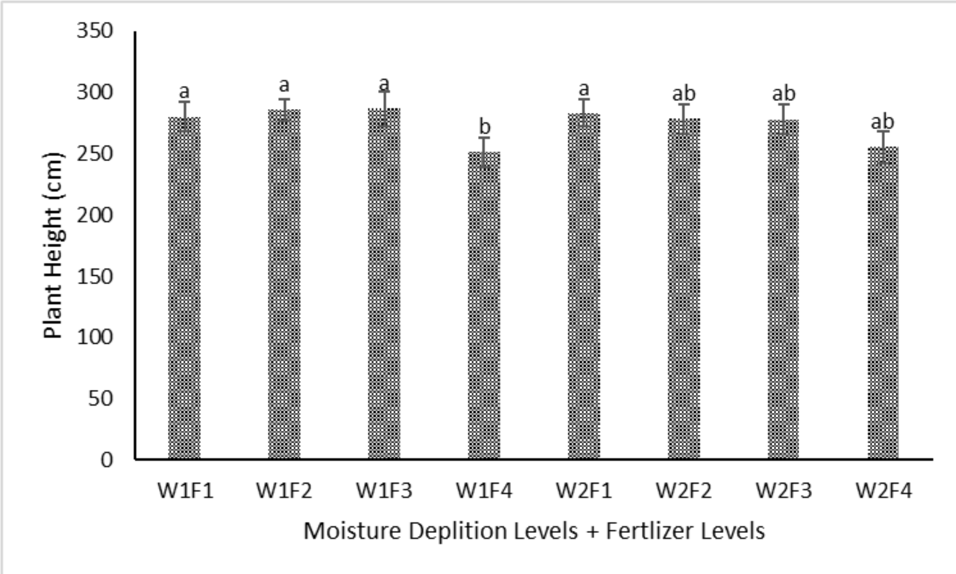

Fig 3.2. Plant height of kinnow as affected by moisture depletion levels and NPK doses.

Canopy Area (m^2)

The maximum canopy area (6.12 m^2) was observed by 15% soil moisture depletion level + 75% dose of the local recommended fertilizer (W_2F_2), followed by (5.84 m^2) 10% soil moisture depletion level + 50% dose of local recommended fertilizer (W_1F_3), while the minimum (5.10 m^2)was seen at 10% soil moisture depletion level + 75% dose of local recommended fertilizer (W_1F_4) (Fig 3.3).

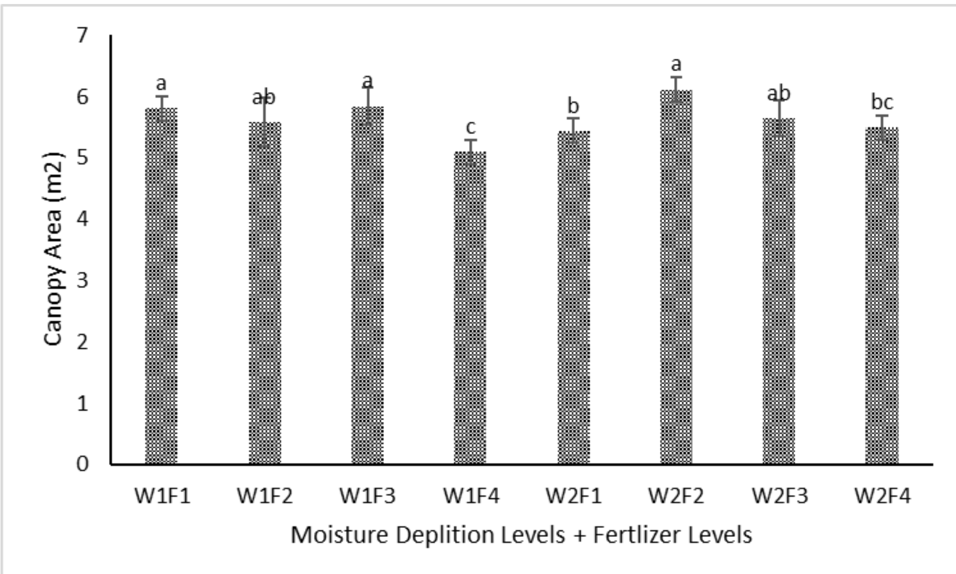

Fig 3.3. Canopy area of kinnow as affected by moisture depletion levels and NPK doses.

Number of Fruits

The highest value for the number of fruits (610) was observed at 15% soil moisture depletion level + 75% dose of the local recommended fertilizer (W_1F_2), followed (590) by 15% soil moisture depletion level + 75% dose of the imported recommended fertilizer (W_2F_4), while the minimum number of fruits (490) was observed at 15% soil moisture depletion level + 75% dose of the local recommended fertilizer (W_2F_2) (Fig 3.4).

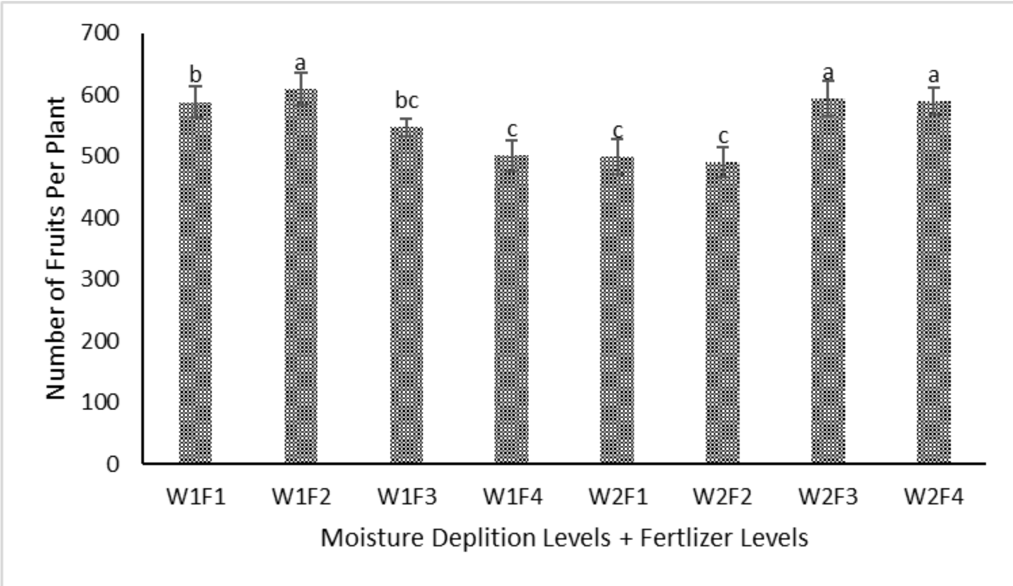

Fig 3.4. Number of fruits per plant of kinnow as affected by moisture depletion levels and NPK doses.

Average Fruit Weight Per Plant

The maximum average fruit weight (80.7 Kg) was observed at 10% soil moisture depletion level + 100% and 75% dose of the local recommended fertilizer, while the minimum fruit weight (64.9 Kg) was at 10% soil moisture depletion level + 75% dose of the imported recommended fertilizer (W_1F_4) (Fig 3.5).

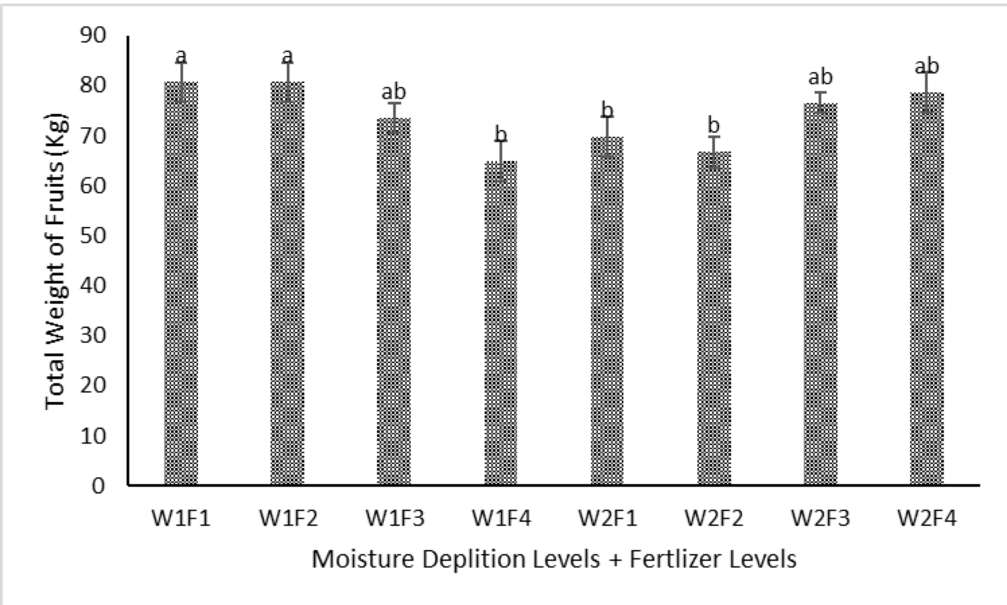

Fig 3.5. Total weight of fruits per plant of kinnow as affected by moisture depletion levels and NPK doses.

Fruit Yield

A significant response ($p \leq 0.05$) was there with respect to fruit yield regarding different fertilizer levels and selected soil moisture depletion levels. The maximum fruit yield (90.3 tons/ha) was observed when at 10% soil moisture depletion level + 100% and 75% doses of the local recommended fertilizer followed at 15% soil moisture depletion level + 75% dose of the imported recommended fertilizer (W_2F_4) (88.1 tons/ha). The minimum (72.7 tons/ha) was 10% soil moisture depletion level + 75% dose of the imported recommended fertilizer (W_1F_4) (Fig 3.6).

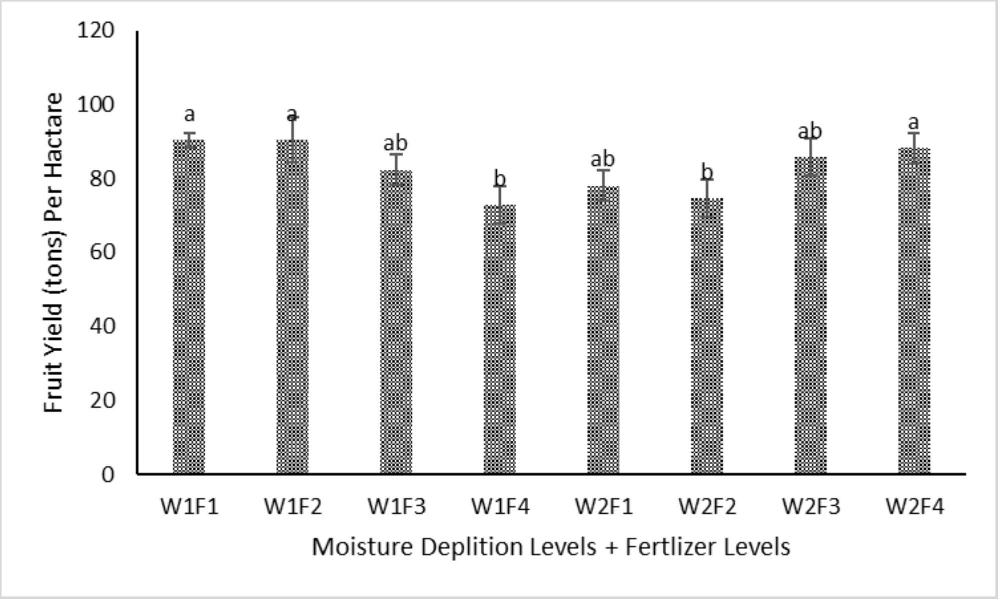

Fig 3.6. Fruit yield of kinnow as affected by moisture depletion levels and NPK doses.

Water Productivity

Data concerning water productivity revealed a significant response ($p \leq 0.05$) regarding different fertilizer levels at both selected soil moisture depletion levels. The maximum water productivity (12.4 Kg/m^3) was observed at 10% soil moisture depletion level with 100% and 75% of the recommended dose of local fertilizer followed by (12.3 Kg/m^3) at 15% soil moisture depletion level with 75% dose of imported fertilizer. The minimum water productivity (10.4 Kg/m^3) was at 15% soil moisture depletion level + 75% dose of local fertilizer (Fig 3.7).

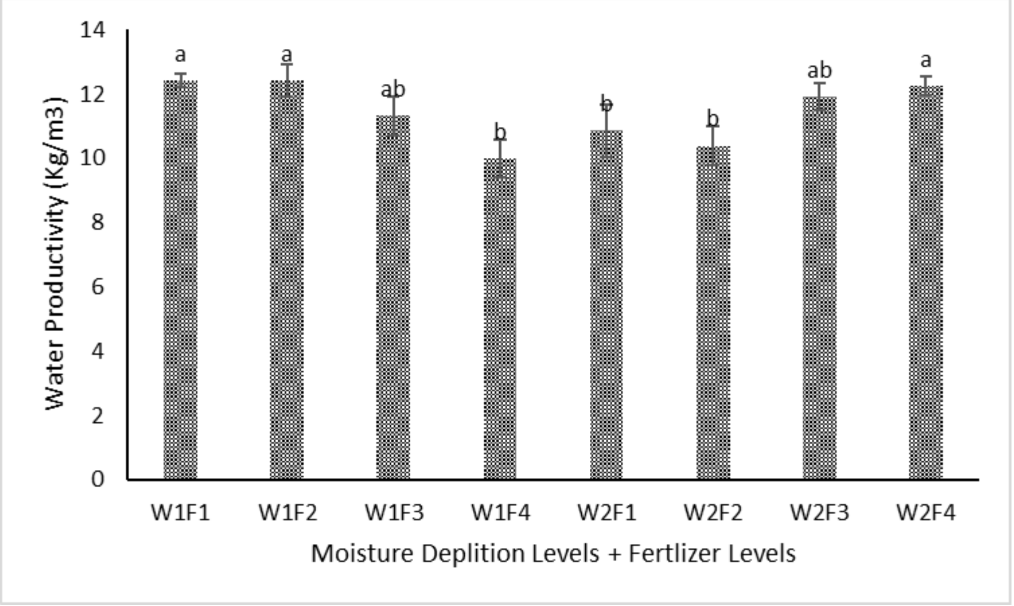

Fig 3.7. Water productivity of kinnow as affected by moisture depletion levels and NPK doses.

4. Discussion

Drip irrigation or micro irrigation improves the water and nutrient use efficiency as drippers are dropping water close to the root zone in citrus plants. Drip and sprinkler fertigation enhanced the yield and quality of citrus fruits compared to the broadcasting of fertilizers [14]. The present results showed that there was a non-significant difference between irrigation applied at 10% soil moisture depletion and 15% soil moisture depletion which might be due to the smaller limits (10% and 15%) selected in the experiment as the maximum allowable depletion level of kinnow is about 50%. A previous study described the irrigation scheduling of kinnow orchards to maximize yield which is in line with the present results regarding the higher number of fruits [15]. A previous study showed that more water depletion leads to low yield and its related attributes which might be affected due to some oxidative stress [16]. It was proved that minerals in crop plants and yield did not decline due to gentle water decreases. A moderate water limitation could be applied in orange plantations since it saved water and improved fruit quality by increasing total soluble solids (TSS) and titratable acidity (TA), while fruit development was slowed [10].

Drip fertigation in Japan used for satsuma mandrin was found much more effective as an integrated objective cultivation technique [17]. It was revealed that water productivity was higher in drip irrigation (in three days application) as compared to hydrogel (with 90 g application) [18]. The maximum fruit yield with better quality was recorded under plants treated with regulated drip irrigation (RDI) at 100% ETc at early and 50% ETc in the final fruit growth period. Conversely higher acidity and lower total soluble solids with the fruits in regulated drip irrigation 0-100-0 treatment compared to other treatments [19].

5. Conclusion

The maximum fruit yield was observed at 10% soil moisture depletion level with 100% and 75% doses of recommended local NPK. The maximum water productivity was observed at 10% soil moisture depletion level + 100% and 75% of the recommended dose of local fertilizer. As local fertilizer prepared by NIAB is more economical as compared with imported fertilizer, therefore, it could be used instead of imported fertilizers.

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