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THE EFFECT OF IRRIGATION DOSES ON THE PRODUCTIVITY OF *Citrus clementina variety* "*Fina Berkane*", A VARIETY OF CLEMENTINE PRODUCED IN TRIFFA PLAIN, NORTH EASTERN MOROCCO

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Water stress

Fina Berkane

Plain of Triffa

Yield

Fruit size

Fruit quality

ABSTRACT

Morocco is a Mediterranean country with an economy based on exporting agricultural products mainly to Europe. However, the ongoing climate change characterized by the frequency and the intensity of drought, along with the regularity of the rainfall is undeniably affecting the productivity of major agricultural products in Morocco. Citriculture is one of the key pillars of agricultural products in Moroccan conditions and the productivity of citriculture is tightly related to water management. To reduce this dependency under climatic change, a pilot study, over three years, has been launched to assess the effect of water stress on the production of clementine (*Citrus clementina* '*Berkane Clementine*'). This study was carried out on the clementine, variety "*Fina Berkane*" at the Triffa plain, Northeastern Morocco. This variety was grafted on Volkameria rootstock with a density of 3m x 6m. Experimental variety was planted during October 2012, in loam-clay soil equipped with a drip irrigation system. Four doses of water irrigation (60%, 80%, 100%, and the conventional irrigation dose⩾120%) were tested based on the real water demand of the studied plant. Throughout the three-year monitoring, the effect of used water amount on the various parameters including yield, fruit size, and fruit quality have been studied. Results of the study revealed that the treatment 100% ETc provided a high number of fruits, yield, and a good quality ratio. It was also well reported that adopting a dose of 80% ETc could save a significant amount of irrigation water (more than 40% ETc) compared to the conventional irrigation dose (⩾120% ETc) without significantly affecting either the yield or the desired caliber profile (marketable standard).

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1 Introduction

The citrus sector occupies a preeminent place in Moroccan agro and socio-economic development and constitutes one of the most important branches of the national economy (MAPM, 2016). The Triffa plain (Northeast region of the country) renowned for its famous clementine "*FinaBerkane*" variety (Anonymous, 2014), is a flagship product of the region, and undeniably one of the best varieties of Moroccan clementine orchards. "*Fina Berkane*" is well recognized for its organoleptic qualities, particularly in European markets (Anonymous, 2010).

In the plains of Triffa, the agricultural sector provides a gross annual income of nearly 6 M Dollars and creates more than two million jobs per year on farms and packaging stations, in addition to its foreign exchange contribution (Anonymous, 2020). However, in recent years, the area has experienced harsh climatic conditions marked with a low rainfall affecting the dams and reservoirs of the Moulouya hydraulic complex (Anonymous, 2017). The scarcity of irrigation water is one of the main factors causing the regression in productivity and the decline of operated citrus orchards (Disket et al., 2017). Currently, water resources for irrigation in the region are under pressure due to the increasing demand, frequency, and intensity of drought events due to climate change. Rational water management is therefore essential to minimize the pressure on these resources and improve the production quantity and quality.

Studies on the behavior of Clementine in the Triffa Plain concerning irrigation doses are very limited. In this context, this work investigates the effect of irrigation doses on the yield, size, and quality of the "*Fina Berkane*" variety grafted on the Volkameriana through a comparative study based on evapotranspiration data method (crop transpiration and soil evaporation) (FAO, 2021).

2 Materials and methods

2.1 The study site

This study was carried out during three consecutive agricultural seasons (2016-2017, 2017-2018, and 2018- 2019) on 9 years old Clementine "*Fina Berkane*" grafted on the Volkameriana rootstock. The study site is a private orchard called "*INAGRI*" with an area of 245 hectares, in the province of Berkane, northeast of Morocco (North 35 ° 00'05.7 "; West 2 ° 11'42.3"; altitude of 119m). The climate of the study area is Mediterranean, semi-arid, characterized by an average temperature between 17.1-20.5° C, and a very irregular rainfall ranged between 200 and 350 mm / year. The soil type is isohumic developed on a calcareous crust, rich in organic matter (ENAM, 2017).

2.2 Orchard management

2.2.1 Planting system

The study plot is approximately nine ha, planted in 2012, with a planting distance of 6 m between rows and 3 m within rows, which is equivalent to 556 trees per hectare.

2.2.2 Irrigation system

The orchard uses an irrigation system based on localized drips. Each planting line has two booms of 16mm in diameter each, fitted with integrated self-regulating Uni-ram drippers, uniformly distributed (0.75 m) on the boom and delivering 2.45 Liter per hour. Each tree receives about 9.8 L/h water ensured by four drippers. However, the surface affected by each dripper is 6m x 0.75m = 4.5 m^2. The hourly rainfall is the water supply capacity on the irrigation system. It is expressed in mm/hour and it depends on the adopted system developed by Boyer et al. (2013) as mentioned below:

Hourly rainfall (mm / h) = Dripper flow rate (L / hour) / device mesh (m2) = 0.54 mm / h

2.3 The objectives of the trial

This work is a part of the "Rational irrigation of citrus fruits in the sedimentary environment of eastern Morocco" project. The main objective of the study is to assess the real water needs of the clementine tree in the Triffa Plain and to study the behavior of this species in response to different irrigation regimes during three successive agricultural seasons i.e. 2016-2017, 2017-2018, and 2018- 2019. The trial involved 100 trees, following a completely random block experimental setup with three replicates per dose. The preliminary survey carried out among citrus farmers in the study area allows us to test four irrigation doses i.e. dose 1 (farmer dose): ⩾120% ETc, dose 2: 100% ETc, dose 3: 80% ETc, and dose 4: 60% ETc. The entire block was spread over 4 rows or 25 trees per irrigation dose.

2.4 Determination of the irrigation dose

The water requirements of citrus trees are determined by estimating the potential of evapotranspiration (ETc), which is established daily according to the method described in FAO's irrigation and drainage paper (No. 56) (Allen et al., 1998):

$$ETc\ (t) = Kc \times ETo\ (t)$$

Where;
t: time period; d (in days); ETo: reference of evapotranspiration (mm / d) calculated from the universal formula PENMAN-MONTEITH (Allen et al., 1998); Kc: coefficient of cultivation, which is the ratio between culture evapotranspiration (ETc) and potential evapotranspiration (ET0).

It incorporates the effects of the four main characteristics that distinguish culture from the reference culture which are crop height, soil surface resistance - vegetation, albedo, soil evaporation (Allen et al., 1998). Factors affecting the value of kc are characteristics of the crop, the dates of planting or sowing, the rate of its development and the duration of its vegetative cycle, and the climatic conditions.

To take into account, the surface of the ground covered by the foliage, the ETc equation becomes as follows:

$$ETc\ (t) = Kc \times ETo\ (t) \times Kr$$

With Kr is the reduction coefficient used to consider the soil covered by the tree (C.O.I, 1997), and it can be calculated by the following method:

$$Kr = 2 * Sc / 100$$

Where: $Sc = \pi * D2 * N / 400$, D is the average of the canopy diameters (m) and N is the planting density (tree/ha). In this study, the Kr values are represented in Table 1.

Table 1 Calculation of the Kr for the current study

Kr test	
D	2.48 m
N	555.55 trees
$Sc = \pi * D2 * N/400$	26.82 m^2
$Kr = 2 * Sc / 100$	0.54 m^2

The ET_0 is the reference of evapotranspiration, precipitation, and other climatic parameters, which are determined from the climatic data recorded by the PROAGOR domain weather station located in Laatamna - Berkane.

2.5 Observations

2.5.1 Yield and number of fruits

Harvesting of citrus fruit from Triffa plain carried out between mid-Octobers and early November. During this period of each season, the yield of each tree was determined in weight (kg) and the number of fruits.

2.5.2 Fruit size

The size of the fruit is considered among the most important parameters that determine the value of the fruit in the international market. Governments, producers, traders, importers, exporters, and other international organizations use the UNECE FFV-14 standard for the marketing and commercial quality control of citrus fruits (Anonymous, 2017a). Its purpose is to define the qualities that citrus fruits must exhibit after conditioning and packaging (Anonymous, 2017a). Commercially, sizes 1, 2, and 3 have the highest economic value (Table 2), followed by size 4, while sizes 5 and 6 represent the least market value (Anonymous, 2021).

Table 2 Scale of citrus fruit sizes according to the UNECE standard FFV-14(UNECE Standard FFV-14, 2017a)

	Standards	Diameters (in mm)
Satsuma, Clementine and other varieties of mandarins and their hybrids	1-XXX	78 & Plus
	1-XX	67-78
	1 or 1-X	63-74
	2	58-69
	3	54-64
	4	50-60
	5	46-56
	6	43-52
	7	41-48
	8	39-46
	9	37-44
	10	35-42

Fruit size was determined after harvest using a digital caliper. Fifty fruits per irrigation dose were taken at random to see the effect of the applied irrigation regime on the final fruit size.

2.5.3 Organoleptic qualities of the fruits

Fruit quality is an important factor in assessing the nutritional value and market value of citrus fruits, whether for fresh consumption or processing into juice. The qualitative characteristics of the fruits include the juice content (%), the acidity (g/l), and the sugar rate (rate of soluble extract TSS) (° Brix). They were determined at harvest with samples of at least 12 fruits per tree tested according to the procedures described by González Sicilia (1951).

2.6 Data analysis

The data collected on the yield parameters and the quality parameters were subjected to analysis of variance (ANOVA), followed by the analysis of means to show significant differences using S-N-K post-hoc test at 0.05 threshold value (Gomez & Gomez, 1984).

3 Results and Discussion

3.1 The effect of irrigation doses on yield and number of fruits

Regarding the number of fruits, the results revealed non-significant differences between the irrigation doses in the first two seasons (2016-2017 and 2017-2018). While significant differences between various tested doses ($P < 0.05$) were detected in the third season (2018/2019) (figure 1). For 60% Etc dose, the maximum number of harvested fruits per tree in three successive agricultural seasons i.e. 2016-2019 was 696, 809, and 494 respectively. While during the first season (2016/2017), the doses⩾120% ETc, 100% ETc,

and 80% Etc resulted in a low number of fruits per tree with an average of 599, 650, and 550 respectively. The high number of fruits at the 60% ETc dose could be due to moderate water stress which favors the flowering rate and consequently the number of hanging fruits.

From the analysis of results presented in figure 2, it is clear that the yield of "*FinaBerkane*" is slightly affected by the irrigation doses. The applied irrigation doses did not show any significant effect on the yield of Clementine during the last two seasons (2017/2018 and 2018/2019). The stressful dose (60% ETc) recorded the lowest yield for both seasons with respective averages of 53.5 and 39.7 kg per tree.

In the first season (2016-2017), the trees responded differently to different irrigation doses applied. These responses were significant for 60% Etc dose with a production not exceeding 39.3 kg/tree. While the doses ⩾120% ETc, 100% ETc, and 80% Etc produced 51.4, 51.6, and 49.9 kg/tree respectively. Hendre et al. (2020) reported similar results, of reduced yield and fruit load following the application of water stress, for sweet oranges. Other studies carried out by Cheng et al. (2021) on cotton and Goramnagar et al. (2018) on the acid Lime also indicated a significant increase in yield when increasing irrigation doses.

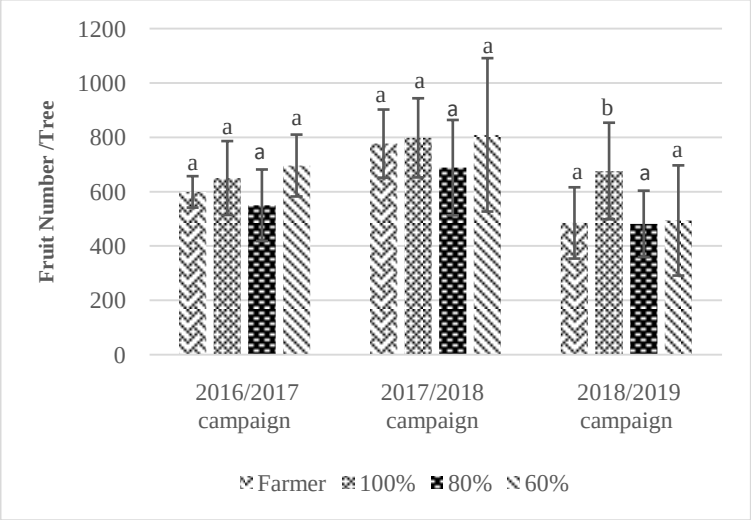

Figure 1 Effect of irrigation doses on the number of fruits per tree
(**values followed by the same letter are not significantly different according to the S-N-K test at 5%)

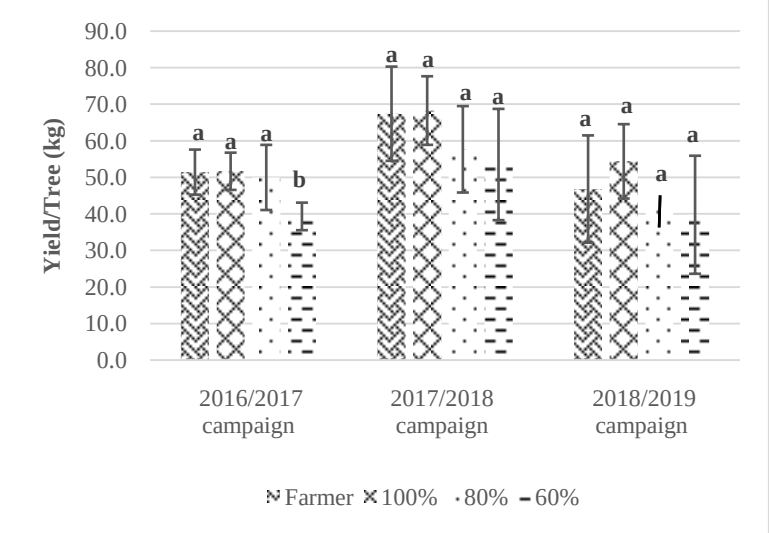

Figure 2 Effect of irrigation doses on yield per tree in kg
(** values followed by the same letter are not significantly different according to the S-N-K test at 5%).

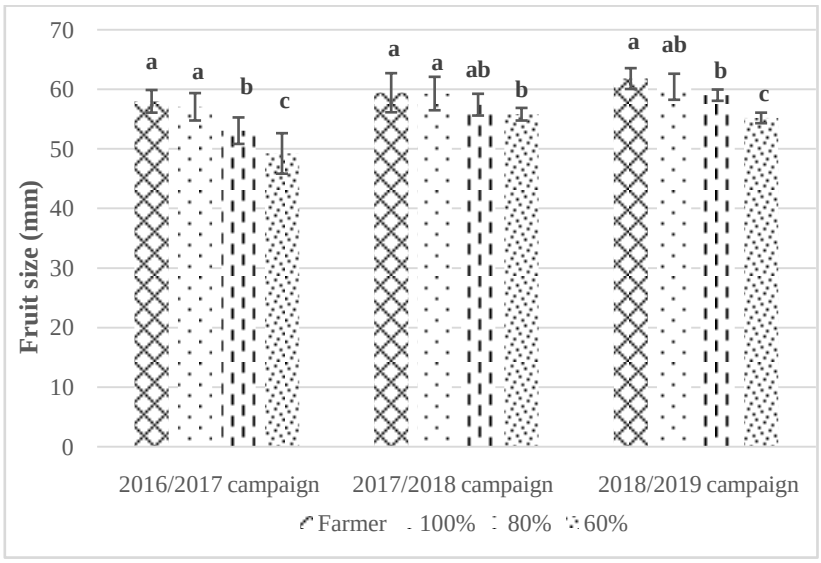

Figure 3 Effect of irrigation doses on final fruit size
(** values followed by the same letter are not significantly different according to S-N-K test at 5%).

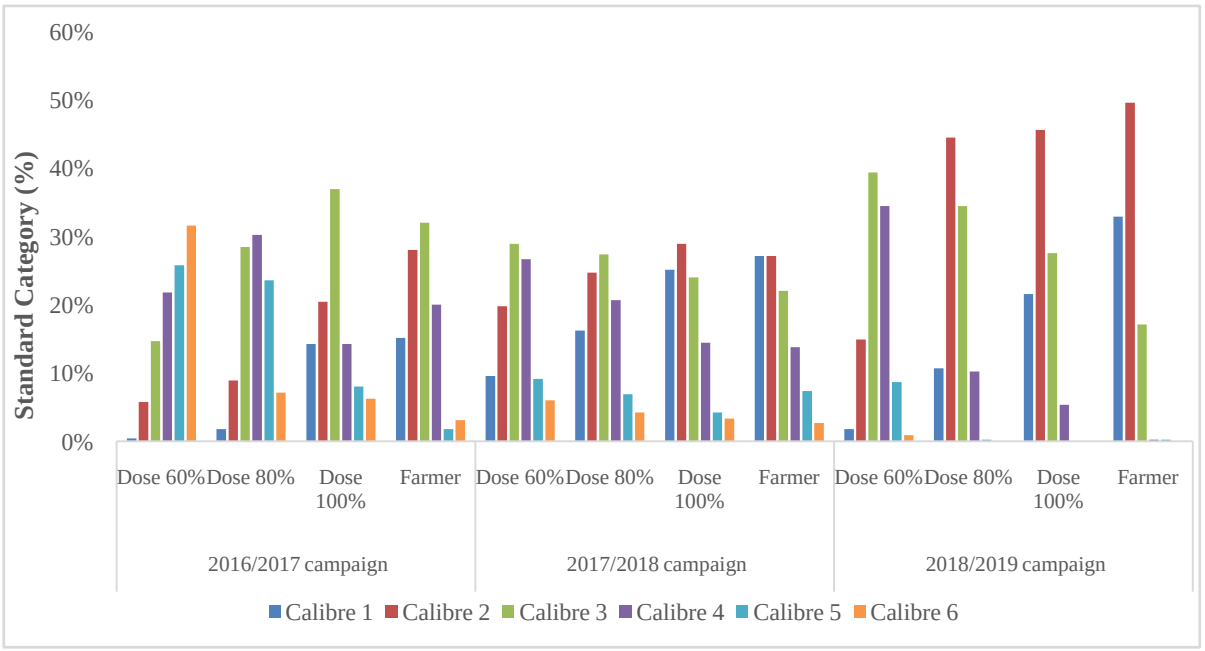

Figure 4 Effect of irrigation doses on different standard (caliber) categories of citrus fruits

3.2 The effect of irrigation doses on fruit size

The increase in average fruit size was significantly affected by irrigation doses (Figure 3). This effect was more pronounced during the first season (2016-2017), probably due to the low fruit load per tree. Generally, the fruit sizes were positively correlated with the irrigation doses. The high doses (100% ETc and⩾120% ETc) provided the highest fruit sizes, and the low doses (80 and 60% ETc) recorded the lowest fruit sizes respectively.

For the commercial fruit size, the results showed that this parameter is improved by increasing the irrigation dose (Figure 4). The evaluation of fruits size percentage under various irrigation treatments indicated that the best marketable fruit sizes (cal.1, cal.2, and cal.3) were observed for 100% ETc, ⩾120% ETc, and 80% ETc doses respectively. While the stressful dose (60% ETc) was dominated by small calibers (cal. 4, cal. 5, and cal. 6), which have a low marketable value for export. Similarly, Mota et al. (2018) recorded that Chestnut fruit size was improved with

Table 3 Effect of irrigation doses on different parameters of fruit qualities

Seasons	Dose	Juice (%)	TSS (Brix °)	Acidity (g/l)
2016/2017	⩾120% ETc	61.80^{a} ± 4.39	11.20^{b} ± 0.72	6.33^{a} ± 0.99
	100% ETc	56.16^{b} ± 2.19	11.74^{a} ± 1.36	5.53^{b} ± 1.48
	80% ETc	51.74^{c} ± 6.20	11.87^{a} ± 1.73	5.13^{c} ± 0.98
	60% ETc	50.00^{c} ± 0.59	12.18^{a} ± 1.60	5.15^{c} ± 3.21
2017/2018	⩾120% ETc	40.81^{a} ± 4.26	10.57^{b} ± 0.83	2.82^{a} ± 0.67
	100% ETc	40.54^{a} ± 2.50	11.15^{b} ± 0.50	2.77^{a} ± 0.51
	80% ETc	39.24^{a} ± 3.44	11.46^{ab} ± 0.87	3.7^{b} ± 0.77
	60% ETc	37.36^{a} ± 2.32	12.05^{a} ± 0.61	3.71^{b} ± 0.65
2018/2019	⩾120% ETc	36.3^{ab} ± 2.61	10.53^{a} ± 0.87	7.75^{a} ± 2.32
	100% ETc	38.6^{a} ± 3.25	10.07^{a} ± 0.40	8.91^{a} ± 2.08
	80% ETc	35.16^{b} ± 1.81	10.91^{a} ± 0.64	7.77^{a} ± 2.76
	60% ETc	34.13^{b} ± 2.78	10.84^{a} ± 0.73	7.03^{a} ± 2.50

**values following by similar letters are not significant according to the S-N-K test at 5%.

increasing irrigation doses. Other studies on Kinnow Mandarin (Vijaya et al., 2017), Mosambi Sweet Orange (Ghosh & Pal, 2016), and Valencia orange (El-Sayed & Ennab, 2013) also suggested that the size of the final fruit is proportional to the irrigation doses.

3.3 Effect of irrigation doses on fruit quality parameters

According to the results presented in table 3, the "*Fina Berkane*" variety expressed different responses to different irrigation treatments. The response was positive for the juice content, and the highest values were reported for the highest doses viz., ⩾120% ETc, and 100% ETc. These results are in line with the findings of Panigrahi & Srivastava (2017) in citrus. The high juice contents dilute the sugar concentrations (TSS) in the fruits. However, the high values in sugar level (TSS) with a lower acidity of the juice were observed for the stressful doses (60% ETc and 80% ETc). This high TSS ratio with low acidity is explained by a large conversion of acids to sugars in the bags of dehydrated juice (Huang et al, 2000). These results are in agreement with the findings of Mota et al. (2018), Panigrahi et al. (2012), and Beniken et al. (2008).

Conclusion

Over 70% of the world's fresh water is used for irrigation. Finding an efficient irrigation model becomes an urgent need within the context of climate change. In Morocco, irrigation is one of the most important technical issues facing citrus growers. Therefore, this work intended to investigate the effect of reduced irrigation water on the fruit yield, size, and quality of the "*Fina Berkane*" variety during three agricultural seasons in the open field. Results of the current study revealed a significant effect of irrigation does on the fruit yield and quality. The best irrigation treatment (100% ETc) provides a high yield, a good caliber profile, and the desired quality ratio. This study demonstrated that 80% Etc allows a 20% reduction in the irrigation dose without affecting the yield, fruit quality, and desired size of citrus fruits. Results of the study recommend and urge the citrus farmers to adopt 80% ETc dose to significantly reduce water demand for irrigation and ultimately increase the operated citrus orchards in the Triffa plain.

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Conflict of interest

The authors declare no conflict of interest

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