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Comparison of the Effect of Two Rootstocks, *Citrus macrophylla* and *Citrus volkameriana*, on Water Productivity of Citrus "Orogrande" under Three Irrigation Doses

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***Abstract*—**This present work mainly concerns the improvement of citrus water productivity in the Souss Massa region. The objective is to evaluate the effect of deficit irrigation applied during the fruit growth stage on fruit size, quality and yield of the Orogrande variety grafted on *Citrus macrophylla* and *Citrus volkameriana*. Three irrigation regimes were adopted, a control D0 of 3.6 l/h and two doses D1 (58% D0 = 2.1 l/h) and D2 (236% D0 = 8.5 l/h). The experimental design was a randomized complete block while keeping the same spacing between drippers, the same duration of irrigation and the beginning of trials (fruit growth stage). Results showed that at the end of the cycle from October 1, 2020, to September 30, 2021, a total water supply of 732 mm and 785 mm using the D1 dose was provided to trees of Orogrande variety, respectively grafted on *Citrus macrophylla* and *Citrus volkameriana* rootstocks. *Citrus macrophylla* presented largest fruit size of 38 mm compared to *Citrus volkameriana* (33 mm) with a significant difference ($p = 0.007$). Total soluble sugar (8°Brix) and juice content level (40%) were higher with the application of the D1 dose on both rootstocks. Yield of 36 Tons was not affected by the deficit irrigation. Reduction of water supply by 18% increases agronomic productivity (6 MAD/m³) and economic productivity (3 MAD/m³).

***Keywords*—**Water productivity, Citrus, irrigation, fruit size, fruit quality, yield.

I. Introduction

THE Souss Massa region represents a horticultural area very famous in the production of citrus (600,000 tons) out of the 2.6 million tons produced nationally [1]. However, it is marked by a lack of rainfall and waves of very high temperatures that increase the need for water crops. These phenomena have led to the overexploitation of the water tables in this area, which have fallen by 30 to 75 m [2].

The use of efficient irrigation strategies that reduce water inputs without affecting the plant becomes a priority. Thus, the main objective of this study is to improve the agronomic productivity of water by reducing inputs without affecting the size and quality of fruits.

II. Materials and Methods

A. Study Area

Trials were conducted in the Souss Massa region, more precisely in Oulad Teima located in the province of Taroudant as represented on Fig. 1. It is bounded by three communes: to the North by the ISSEN commune, to the East by the Sidi Moussa Lhamri commune, to the Southeast by the El Bied and El Koudia communes and to the West by Ouled Dahou.

Trees aged 10 years were planted on areas of 5.81 ha and 2.10 ha respectively for those grafted on *Citrus macrophylla* and *Citrus volkamériana*.

The soils are sandy for the plot of Orogrande grafted on *Citrus macrophylla* and sandy-clay for the one grafted on *Citrus volkamériana*.

B. Climatic Conditions During Essay

The experiment took place from June 1, 2021, coinciding with the beginning of the fruit growth stage, to September 15, 2021, during the ripening phase of the fruit. This period was characterized by average temperatures ranging from 20 °C to 33 °C. Minimum temperatures were 11 °C during the months of June-July while maximum temperatures were around 38 °C in August (Fig. 2). However, heat waves also occurred for a few days during July and August with temperatures reaching 49 °C in the region of Oulad Teima. Relative humidity ranged from 40 to 89% with minimum humidity of 15% in August and maximum humidity of 89% in July.

Precipitation was almost absent during the period of the experiment which coincides with summer. Only a few light precipitations were noted, one during July with 0.8 mm and two during September with 0.6 mm and 0.2 mm respectively. Daily evapotranspiration was highly variable during the experimentations with ET0 ranging from 3 mm/d to 5.9 mm/d and an average of about 4 mm/d.

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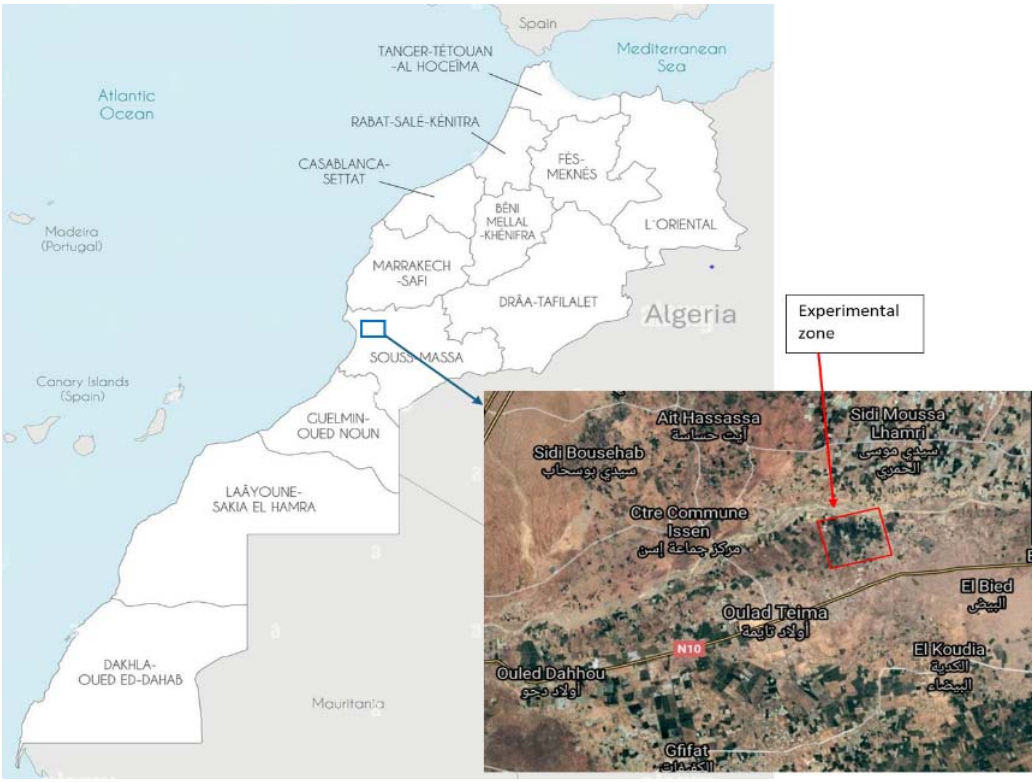

Fig. 1 Geographical location of the study area

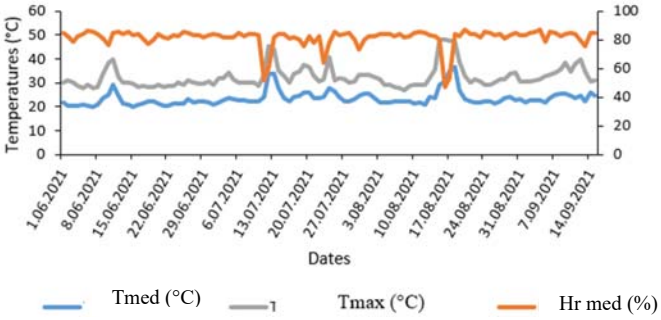

Fig. 2 Ambient temperature and humidity evolution during experimental period

C. Water Resources

The present area is composed of three basins: the Souss Basin (16,200 km²); the Massa Basin (6,280 km²), the Tamri-Tamghart Basin (2,600 km²) and the Tiznit Sidi Ifni plain (2,800 km²). The overall average surface water inflow is estimated at 668 Mm^3/year while groundwater has an average of 425 Mm^3/year [3]. On the outskirts of the center of Oulad Teïma, small streams are used for rainfall runoff during the winter. The most important stream runs near the Boukhreiss neighborhood northwest of the center. The water table is mainly fed by the inflow from the High Atlas. There are several water points in the area and subsequently a mobilization of groundwater for agricultural purposes and abundant.

D. Objectives of the Study

Citrus production in the Souss-Massa region is very important with an area of 40,000 ha i.e. 31% of the national area devoted to citrus production. However, the region is faced with a notable lack of water that affects the water tables and most basins. The level of groundwater is between 30 and 75 m, with water reserves in deficit of 260 Mm^3 and the basins fill only 33% of their capacity [4]. In addition, citrus is a very demanding crop in terms of water, especially in the Souss region, with needs that can reach 1,200 mm/year [5] due to high temperatures and the presence of chergui (dry and hot wind) at certain times of the year. The control of irrigation of citrus fruits then becomes essential for a sustainable agriculture.

The main objective of this study is to compare the effect of three irrigation rates in order to improve the water productivity of citrus. In parallel, this work allows:

- To see the effect of applying reduced irrigation rates on fruit size and quality
- To compare the effect of rootstocks on fruit size and yield
- To choose the irrigation rate for each rootstock variety combination
- To reduce irrigation costs

E. Methodology

A randomized complete block design with four replications was used to conduct the experiment.

The treatments (irrigation doses) were drippers with a flow rate of 3.6 l/h for the D0 control, 2.1 l/h for the D1 dose and 8.5 l/h for the D2 dose, which were installed without changing the spacing between drippers (0.9 m) and starting the trials at the beginning of the fruit growth stage.

The main parameters monitored were fruit size by measuring the equatorial diameter of 24 fruits/treatment at a weekly

frequency, monitoring of sugar and juice content by taking samples of 10 fruits/treatment each week and by taking measurements using a refractometer for Brix and juice extraction using a press. The yield was estimated by counting 600 fruits/treatment at each block on 15/09/2021 and determined the expected yield on 15/10/2021 using the average weight of 600 fruits, the average weight and size of 100 fruits and the evolution of fruit size in mm/week for each irrigation rate.

III. Results and Discussion

A. Water Inputs

From October 1st to September 30th, a total water inputs of 9030 m³ and 9627 m³/ha were provided using the control dose respectively with the *Citrus macrophylla* and *C. volkameriana* rootstocks (Fig. 3).

Inputs were lower with the D1 dose where the cumulative inputs were 7316 m³ and 7851 m³ on the same rootstocks.

The extra dose D2 presented the highest inputs exceeding the citrus water requirements.

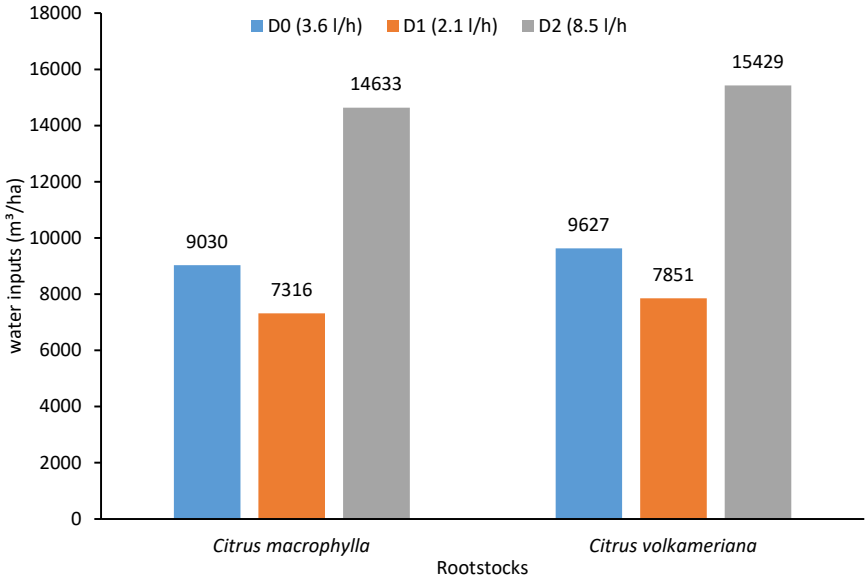

Fig. 3 Total water inputs during production cycle

B. Effect of Deficit Irrigation on Fruit Size

Table I shows that fruit size of Orogrande variety was not influenced by the use of the three irrigation doses, which had no significant effect on either the *Citrus macrophylla* rootstock ($p = 0.440 > 0.05$) or the *Citrus volkameriana* rootstock ($p = 0.418 > 0.05$) using Gupta comparison.

The deficit irrigation dose D1 (2.1 l/h) resulted in fruits with a higher average size than those treated with the control D0 (3.6 l/h) but smaller than those treated with D2 (8.5 l/h) in both rootstocks.

The water stress applied during the period of fruit growth resulted in a decrease of fruit size and slower growth over time but without significant effect. This affirmation has been reported by several authors such as [6]-[8].

TABLE I
Average Fruit Size Based on Irrigation Rates and Rootstocks

Treatments	*C. macrophylla*	*C. volkaméria*na
D0 (3,6 l/h)	38 a	32,8 a
D1 (2,1 l/h)	38,5 a	33,2 a
D2(8,5 l/h)	39,2 a	33,4 a

In contrast to irrigation rates, rootstocks showed a very highly significant effect ($p = 0.000$) on fruit size. The rootstock *Citrus macrophylla* gave the highest average fruit size of 38.6 mm compared to 33 mm for *Citrus volkameriana* (33.1 mm). *Citrus macrophylla* has the ability to confer higher fruit size compared to other rootstocks. This claim is also reported by [9].

C. Effect of Deficit Irrigation on Fruit Quality

Table II shows that the application of three different irrigation doses in Orogrande variety grafted on *Citrus macrophylla* had no significant effect either on the sugar content of fruits ($p = 0.05$) or on juice content ($p = 0.569$). However, the highest sugar content (8°brix) was obtained with the D1 dose (2.1 l/h) while the D2 excess dose (8.5 l/h) gave the highest juice content (42.6%).

On the other hand, in the rootstock *Citrus volkameriana*, the difference between the three irrigation doses was highly significant ($p = 0.001$). D0 (3.6 l/h) and D1 (2.1 l/h) doses gave the highest sugar contents of 7.8 °Brix and 8.5 °Brix. A significant difference was not noted ($p = 0.769$) on the juice content of the fruits while it was higher with D1.

Rootstocks did not influence the sugar content of 7.7 °Brix and the juice content (40.9%).

Deficit irrigation improves fruit quality by increasing the sugar content of the fruit due to a more concentrated solution of nutrients reaching the fruit as reported by different authors such as [10].

TABLE II
AVERAGE SUGAR AND JUICE CONTENT OF OROGRANDE'S FRUITS GRAFTED ON *C. MACROPHYLLA* AND *C. VOLKAMERIANA*

Treatments	*C. macrophylla*		*C. volkaméria*na	
	Sugar content (°Brix)	Juice content (%)	Sugar content (°Brix)	Juice content (%)
D0 (3,6 l/h)	7.7 a	40 a	7.8 a	41.4 a
D1 (2,1 l/h)	8 a	40 a	8.5 a	41.5 a
D2(8,5 l/h)	7.3 a	42.6 a	6.9 b	39.9 a

The most stressed trees give the fruits with the highest juice contents, which is also consistent with the work of [7].

D.Yield and Productivity of Orogrande Variety

The estimated yield was not significantly influenced by the three irrigation rates in the rootstock of *Citrus macrophylla* ($p = 0.957$) and *Citrus volkameriana* ($p = 0.415$).

Real agronomic productivity was calculated using water inputs as suggested by the International Water Management Institute [11] and not the potential agronomic productivity which refers to the crop evapotranspiration (Table III). Thus, the highest agronomic productivities in *Citrus macrophylla* (6.53 kg/m³) and *Citrus volkameriana* (5.71 kg/m³) were obtained with the deficit dose D1 (2.1 l/h).

TABLE III
AGRONOMIC PRODUCTIVITY OF OROGRANDE VARIETY

Rootstocks	*C. macrophylla*			*C. volkameriana*		
Irrigation doses	D0 (3.6l/h)	D1 (2.1l/h)	D2 (8.5l/h)	D0 (3.6l/h)	D1 (2.1l/h)	D2 (8.5l/h)
Production (Kg/ha)	52 494	50 283	62 604	43 956	47 064	40 460
Water supplies (m³)	9420	7706	15 023	10 017	8241	15 819
Agronomic productivity (Kg/m³)	5.57	6.53	4.17	4.39	5.71	2.56

TABLE IV
ECONOMIC PRODUCTIVITY OF OROGRANDE VARIETY

Rootstocks	*C. macrophylla*			*C. volkameriana*		
Irrigation doses	D0 (3.6l/h)	D1 (2.1l/h)	D2 (8.5l/h)	D0 (3.6l/h)	D1 (2.1l/h)	D2 (8.5l/h)
Gross profit	54 098	54 090	60 813	33 221	44 899	8703
Water consumption (MAD)	18 963	15 364	30 729	20 217	16 487	32 401
Economic productivity (MAD/m³)	2.85	3.52	1.97	1.64	2.72	0.27

Table IV shows that the economic productivity of 3.52 MAD/m³ in Orogrande grafted on *C. macrophylla* and 2.72 MAD/m³ in Orogrande grafted on *C. volkameriana* was higher with the use of the d1 dose allowing water savings of 18% compared to the control.

The use of moderate irrigation involving water inputs of 50% or more of ETc does not affect fruit yield of Orogrande variety while providing a water saving of 15% [8].

IV. CONCLUSION AND RECOMMENDATIONS

In the final analysis, we conclude that the application of deficit irrigation during fruit growth stage:

- Enhances fruit quality by increasing sugar and juice content
- Improves agronomic and economic productivity of water
- Allows water saving of up to 18%

In the light of this, we recommend the application of deficit dose for citrus irrigation and the use of *Citrus macrophylla* rootstock which gives the largest fruit sizes and the highest yields.

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