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Impact assessment of deficit irrigation on yield and fruit quality in peach orchard

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ABSTRACT

The aim of the work was to assess if the irrigation target and frequency when using Regulated Deficit Irrigation strategy (RDI) does affect peach trees (Prunus persica (L.)) in terms of crop water uptake, water use efficiency (WUE) and Physiological responses like yield and fruit quality. Six treatments were applied: the control (T0) and five RDI treatments. The control received 100% of the crop water requirements (ETc) with 0.8mm per irrigation supply, whereas RDI100-0.4mm, RDI75-0.8mm, RDI75-0.4mm, RDI50-0.8mm, RDI50-0.4mm were respectively irrigated at 100%, 75%, and 50% of ETc. New technologies have been used to help on decision making for irrigation such as meteo-stations, Soil moisture sensor, Pulse flow meter and Telemetry system. Higher yield and good quality could be obtained with less irrigation water and adequate frequency (RDI75-0.4mm). The actual work recommends adopting RDI50-0.4mm in the early stages, and RDI75-0.4 during fruit development, although, just before maturity we can use RDI50-0.4 to accelerate the fruits maturity.

Keywords: Peach, Irrigation, WUE, RDI, Fruit quality.

INTRODUCTION

Demands on water resources worldwide are increasing as the world population keeps growing and quality of living keeps improving in many countries; world population is predicted to double in the next 50 years, so greater yields must be extracted from the current agricultural areas along with more marginal areas [1]; It is expected that in the next decade several countries in the arid and semiarid areas of the globe will be under water scarcity or stress [1]. Peach (*Prunus persica* (L.)) is one of the most important temperate fruit trees grown in the world, after crops such as apples or pears [2]. However, Souss Massa is a region with high risks regarding to water scarcity, irrigation needs are almost pumped from the water table which is being depleted by 2 meters per year [3]. For this reason, the optimization of irrigation efficiency using deficit irrigation strategies to maintain a maximum yield while reducing water use is of great importance in this region. Then, regulated deficit irrigation (RDI) may offer an approach to save water in this woody crop by minimizing or eliminating negative impacts on yield and crop revenue [4-6]. When elaborating RDI strategy, the key is to apply stress at tolerant periods in which yield and fruit quality are not adversely affected [7]. The impact of water stress depends on the deficit duration and its importance [7]. Some authors indicated that flowering depends on the severity water stress applied on postharvest period [7-9]. Also, it's indicated that adequate irrigation management during the rapid fruit growth stage is important in order to obtain marketable fruit size [10], water deficit imposed during the first stage of rapid growth significantly increase fruit size at harvest [10]. Drip and subsurface irrigation reduced evaporation and improved growth and early production of young peach trees over other irrigation methods commonly used [11].

The present study was carried out for one full season to determine the effects of irrigation scheduling on productivity of mature trees. It had as object to assess the effect of RDI strategy and irrigation frequencies on physiological parameters of old peach trees cultivated in open field. To achieve the objectives, we will compare two treatment that were irrigated with 100% ETM, two treatment that were irrigated with 75% ETM and two treatments that were irrigated at 50% of peaches trees water requirements. Each of this treatment was combined with two frequencies depending on soil capacity.

MATERIALS AND METHODS

Plant material and irrigation system

This study was conducted during one growing season. The experiment was carried out in the farm level called Salwa, located in Morroco, Souss Region – Ouled Berhil. The concerned area is 2000 m^2.

The materials selected for trial were commercial peaches that were grafted on “GF667”. The crop was nine years old planted at a spacing of 5 x 3m (density of 667 plants per hectare) and was trained like a vase-shaped tree with no central leader, but, several major branches angle outward and upward from the top of the trunk.

The irrigation was applied using double drip line with 75 cm spaced emitters dripping a flow of 4 L/h. Irrigation and fertilization management were made within a fertigation station throw electro-valves. Daily reference evapo-transpiration ETo was calculated using the Penmann monteith formula [12].

Crop water use was calculated as folowing:

$$Etc = ETO \times Kc \quad (1)$$

Where ETO and Kc represent the reference evapotranspiration and crop coefficient.

To avoid water loses, net maximum irrigation dose was determined referring to granulometric properties of the substrate using the following formula

$$NMD = f \times (Hcc - Hpf) \times Z \times PSH \quad (2)$$

Where, f is the allowed water stock decrease (10%), Hcc and Hpf are, respectively, field capacity and welting point substrate moistures, Z is the root depth and PSH is the percentage of the wetted zone.

Experimental Design

These experiments were conducted with a complete randomized design as showing in Fig. 1. Six treatments were then applied. Each treatment contains 5 plants per unit with four repetitions for each treatment.

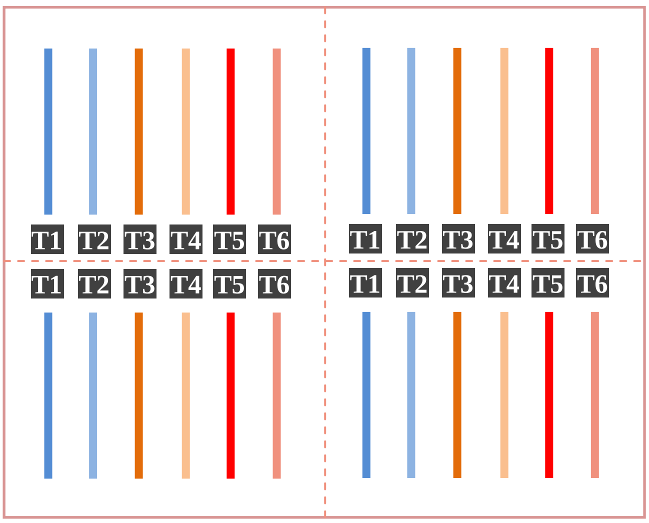

Fig. 1: Experimental design with complete randomized plot

In This work, treatments were adopted as following:
Besides the two controls treatments that received 100% of their daily water requirement, four Deficit Irrigation (DI) treatments were applied:

- **T1:** First control (C1) that receives 100% of crop water requirements with an irrigation dose of 0,8mm per each water supply.
- **T2:** Second control (C2) that receives 100% of crop water requirements but adopting a dose of 0,4mm per each water supply.
- **T3:** treatment combined RDI with 75% of crop water requirements and an irrigation dose of 0,8 mm per each water supply (RDI75-0.8mm).
- **T4:** treatment combined RDI with 75% of crop water requirements and an irrigation dose of 0,4 mm per each water supply (RDI75-0.4mm).
- **T5:** Treatment combined RDI with 50% of crop water requirements and an irrigation dose of 0,8 mm per each water supply (RDI50-0.8mm).
- **T6:** Treatment combined RDI with 50% of crop water requirements and an irrigation dose of 0,4 mm per each water supply (RDI50-0.4mm).

Two parameters were automatically and continuously measured: temperature and air relative humidity (ADCON Model TR1) (Fig. 2). Measures were used to determine vapor pressure deficit using the following formula:

$$VPD = e_s - e_a \quad (3)$$

Where, e_s is the saturation vapor pressure at a given air temperature and e_a is the actual vapor pressure.

- Irrigation water balance and water use efficiency was calculated as the ratio between total produced yield and total supplied water volume.
- Fruits number after first and second fruits thinning.
- Fruit growing between 15/03/2012 au 10/04/2012
- Total and cumulative yield (7 harvesting operations).
- Fruit quality

Fig. 2: Measuring tools used in the experiment: (A) Soil moisture sensor FDR, (B) Pulse flow meter, (C) Telemetry system and transmission unit

Statistical analysis for growth and production were analyzed by using MINITAB software ver 15.1. Treatments comparison includes an analysis of variance (ANOVA1) with a single classification criterion for each character. The data obtained was analyzed statistically and significance was calculated at $p < 0.05$ and $p < 0.01$ levels of probability. Each value is mean of four replicates.

RESULTS AND DISCUSSION

Climate and water supply

The Fig.3 shows that the daily air vapor pressure deficit and ETo values fluctuated, increasing from the beginning of the measurement period. The end of the first month of the year is characterized by a continuous VPD decrease that lasted for five months. At the end of that period, averaged diurnal VPD reached 5kPa and began an increase trend during the remaining period of crop cycle. The vapor pressure deficit presented many peaks during high evaporative demand period that started in the 110th day of the year. It reached its maximum level (10.61 kPa) during the 141th day of the year. Those VPD variations have a direct effect on the potential evapotranspiration level that follows the same trend since the 121th day where it began to increase during almost the remaining crop cycle period.

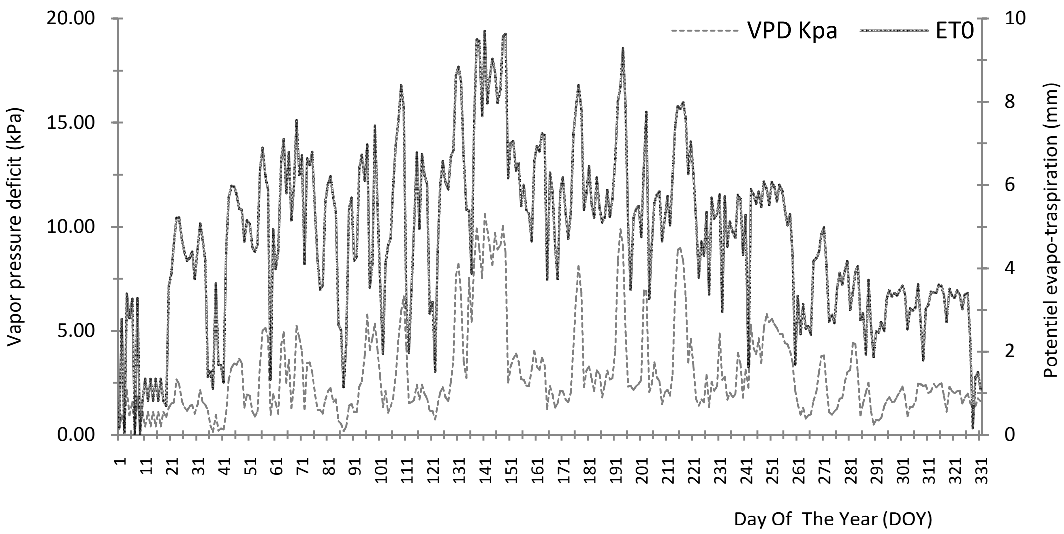

Fig. 3: Air Vapor pressure deficit (VPD, dashed line), Crop reference evapotranspiration (ETo, Solid line) during the year of the trial.

In this study water was supplied in the active season between 10 February and 25 October (257days), water supply was daily quantified by using Pulse Flow Meter for each treatment. The (**Table 1**) summarizes total supply for each treatment.

Table 1: Water requirement satisfaction, amount of water per irrigation and total supply of water for all treatments

Treatment	Water requirement satisfaction	Dose of irrigation in mm/Supply	Total supply in mm
T1 (C1)	100%	0.8	565.6
T2 (C2)	100%	0.4	559.6
T3 (RDI75-0.8mm)	75%	0.8	424.0
T4 (RDI75-0.4mm)	75%	0.4	424.4
T5 (RDI50-0.8mm)	50%	0.8	282.4
T6 (RDI50-0.4mm)	50%	0.4	282.8

The total water supply for mature peach was evaluated at 565.6mm (2.2mm/day) of water during the growing season (February to October). A study was conducted in central California (Same climate as Souss Massa) by David & all**.** [11] to compare the effect of the type of irrigation in growth and early production of peach, the total supply that was applied is between 233 and 743 mm/year. In comparison with the water need for mature peach reported by Goldhamer & Snyder [13] the total water requirement is approximately 850 mm, this value is higher, it can be explained by the scheduling of irrigation adapted in this study.

In our study the total crop reference evapotranspiration was about 1370 mm, and the rainfall doesn't exceed 53mm during the trial period.

Produced yield

Fruits number

To evaluate the impact of regulated deficit irrigation (RDI) on yield, the fruits number was counted (Fig. 4).

The statistical analysis of the data shows that fruit numbers is significantly affected by the irrigation target and frequency. Moreover, the treatment T1, T4, and T5 has given more fruits than others treatments (between 160 and 180 fruits), then T2 and T3 gave a small fruit number (Between 120 and 140). The trial conducted by Li & all. [10] to evaluate the effect off the water stress in fruit of peach, founds that the number of fruits can be affected by water stress, fruit numbers can varied from 83 to 380 fruits per tree. Lopez & all. [14] reported that fruit load ranged from 90 to 450 fuits / tree.

Fruit quality and size

To know if RDI affects the fruit size, measurement of fruit was made before harvest (from 15/03/2011 to 09/04/2011). Fig. 5 is showing the obtained results after statistical analysis.

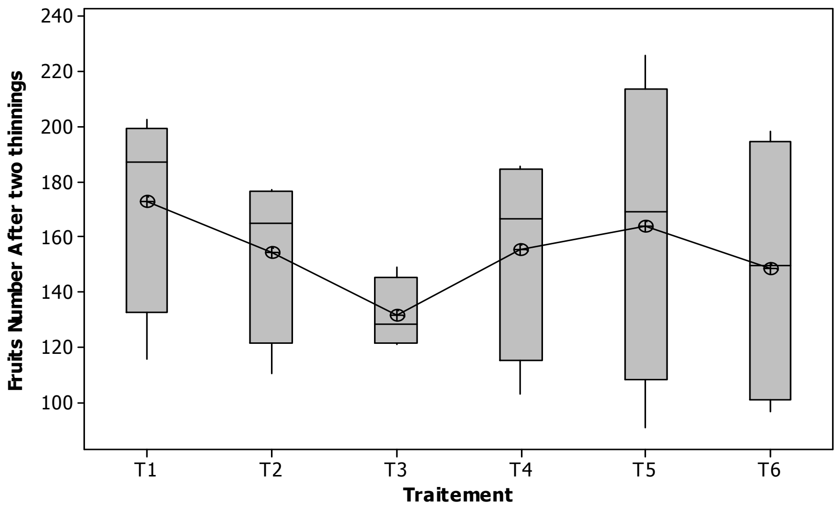

Fig. 4: Registered fruits number for each treatment: T3, T4, T5, T6 and controls T1 & T2 after the second thinning out

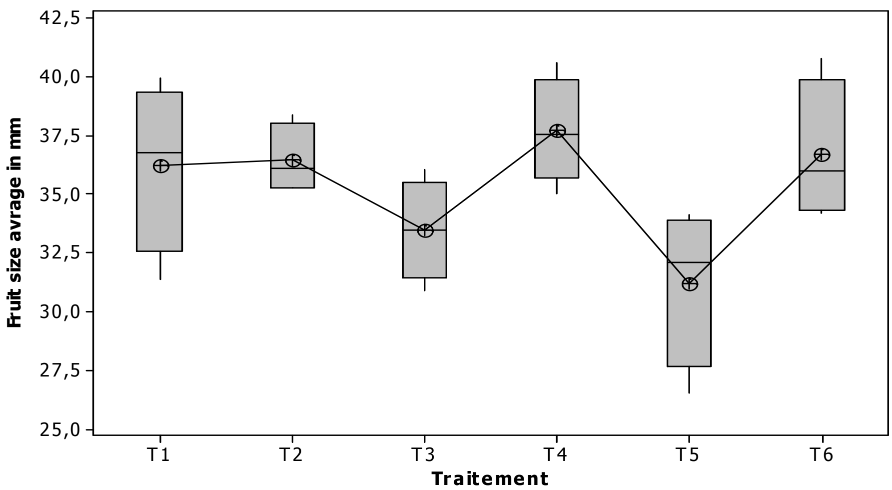

Fig. 5. Fruits size distribution of peach from trees irrigated by T1, T2, T3, T4 T5 and T6. Measurements were made before fruit harvesting

In the present study, the most effective irrigation target and frequency, can affect final fruit size. In fact, irrigation treatment can increase the fruit size average, reduce the number of non marketable fruit, and improve marketable yield.

Statistical analysis confirms that we can obtain good fruit size with less irrigation supply, the T4 give the best size (from 36 to 40mm**),** and the second fruit size has given by T1 and T6 with respectively 36.20 mm and 36.7 mm.

The study that was conducted by Li & all. [10] shows that seasonal fruit growth of peaches shows a classical pattern of tree distinct growth period, and the water stress imposed on trees did not influence fruit growth until the end of the second phenological season. Fruit size was considerably improved by the treatment water stress on the first stage of development. This consequence confirms the result obtained in our study.

Harvest and yield effect

To understand the effect of RDI on harvesting and yield of peaches trees, we counted the number of harvested fruits (Fig. 6).

Fig. 6 is showing that for all the treatments the harvested fruits are following the same variation. In the first harvest no significant difference between treatments was observed, but we can see that T5 was better performing in the second harvest, thus, this treatment is given an early maturity. In fact, the number of harvested fruits varies from 200 to 280 fruits in the first harvest, and from 450 to 600 fruits in the third harvest.

Significant differences between treatments have been observed in the number of harvested fruits in the 4th and 5th harvest. It's evident that T4 is the best treatment, from the point of view of fruits number, followed by T5.

Fruits number is affected by several stress caused by RDI corresponding to T6 irrigation scheduling, therefore this treatment gives the less number of fruits over all harvests.

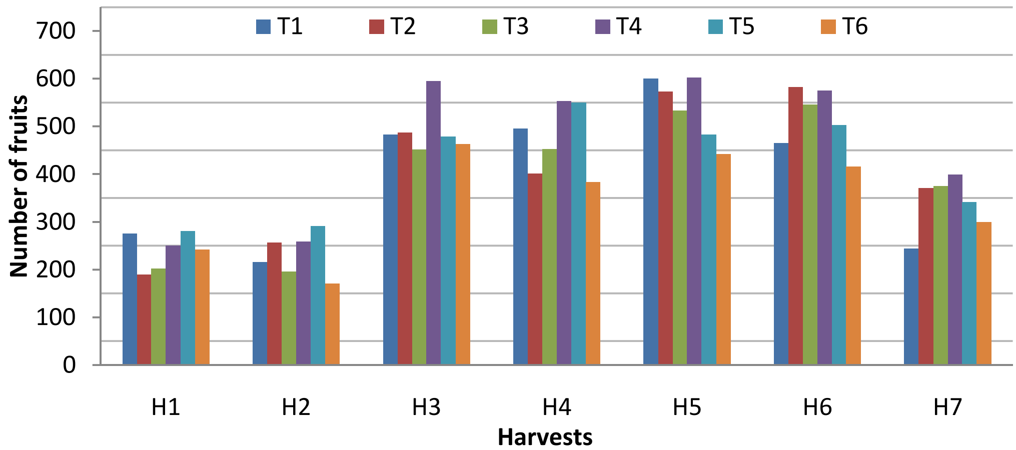

Fig. 6. Evolution of harvested fruits of peaches trees irrigated with T1, T2, T3, T4 T5 and T6. Measurements were made after each fruits harvesting in seven different days

This result was perfectly confirmed by Garcia & all**.** [14], they found that the RDI during stage II of fruit development is also associated to the benefit of reducing the labor, water supply, and giving important fruit size. But a long application of RDI after stage II of fruit development can have negative effects Girona & *all.* [15]. Taking into account our results and previous research reporting negative long-term effect following deficit irrigation [16], it seems that the RDI corresponding to the T6 is the best example showing this negative effect.

Harvest quality

The quality can be judged from several criteria, such as, the earliness maturity, number of fruit per harvest and fruit size. The Fig. 7 & 8 show the average of harvested fruits and marketable size for each treatment.

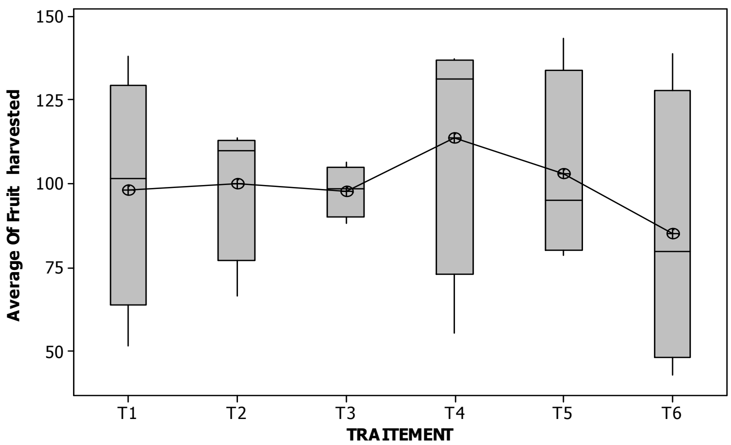

Fig. 7: Average of harvested Fruits from peaches trees irrigated by T1, T2, T3, T4 T5 and T6. Measurements were made after each fruit harvesting in seven different days

To understand the effect of irrigation scheduling on peaches quality, the average of harvested fruits were counted and compared in the Fig. **7**. It's shown that RDI75-0.4mm is the best regime, it gives a lot of fruits and good average per harvest (113.8fruits/harvest), RDI50-0.8 comes in the second position with (103.2 fruits/harvest). In the last position we find T6 with (85.3 Fruits/harvest).

Other criteria were analyzed to evaluate the effect of irrigation scheduling on fruits quality; the Fig. 8 is showing statistical analysis of fruit size.

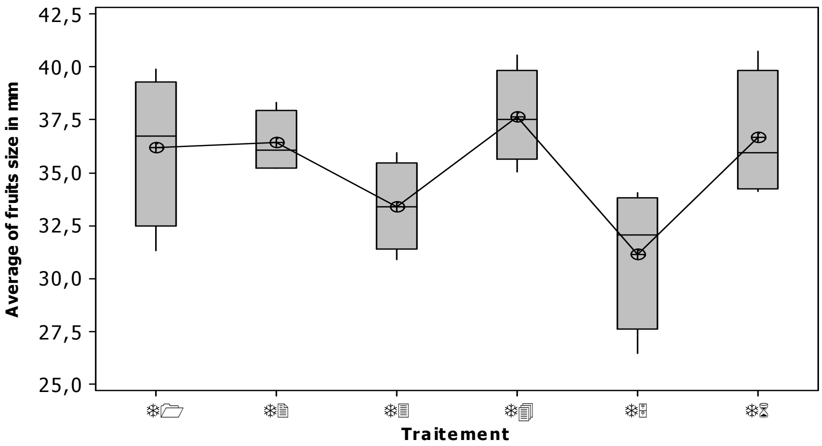

Fig. 8. Fruits size average from peaches trees irrigated by T1, T2, T3, T4 T5 and T6. Measurements were made after each fruit harvesting in seven different date

The same quality status were observed when analyzing the average of harvested fruits, we can observe that the RDI relative to T4 is giving the biggest size of marketable fruits (average =37.7mm) with less fruit size variability (between 35.0mm and 40.6mm), followed by RDI50-0.4 (T6) with (average =36.7mm) and more fruit size heterogeneity (from 34.1mm to 40.7mm).

The RDI that gives more fruits homogeneity is RDI (T2) with average of marketable fruits (from 35.2mm to 38.3mm). However, the result obtained by RDI –T5 shows that this one is not suitable to irrigate peaches. When irrigation intervals are long, soil water content is depleted and trees are exposed to higher level of water stress [17]**.** Even mild water stress can induce fresh fruit weight loss and lower profit at harvest as reported by Berman & DeJong [18]**.** In other ways, our results were confirmed by other authors [19, 20], they found that high frequency irrigations using surface and subsurface drip may have enhanced fruit development.

CONCLUSION

The trial showed that the targets and frequencies applied with RDI strategy affected considerably the physiological parameters of peaches orchard. In fact, applying 50% of water requirements with 0.4 mm per application can give a satisfactory result like the example of RDI50-0.4mm (T6), but the best performance in quality and quantity can be obtained with RDI75-0.4mm corresponding to T4 with 75% of water requirement and higher frequency irrigation. Storage depletion within the dry side of rootzone seems to enhance water shortage resistance. RDI75-0.4mm appears more productive and more efficient, then, it performs the highest water use efficiency (WUE). In the end, higher yield and good quality can be obtained with less irrigation water and adequate frequency. In fact, to have a good yield but saving water, we must combine more than one scheduling and deficit strategy, we recommended to adopt RDI50-0.4mm in the early stages, then RDI75-0.4 during fruit development, and just before harvest we can use RDI50-0.4 to accelerate the fruits maturity.

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