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ORIGINAL PAPER

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EFFECTS OF PREHARVEST DEFICIT IRRIGATION TREATMENTS IN COMBINATION WITH REDUCED NITROGEN FERTILIZATION ON ORCHARD PERFORMANCE OF NECTARINE WITH EMPHASIS ON POSTHARVEST DISEASES AND PRUNING WEIGHTS

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ABSTRACT

Fruit production should be adapted to future scenarios that are frequently associated with scarce resources, especially freshwater and fertilizers. New biologically-based fruit production strategies, i.e. taking into account tree growth and water status, are required to optimize irrigation and fertilization under abiotic stress conditions. It was hypothesized that a moderate abiotic stress, here deficit irrigation with or without nitrogen deficit, in the preharvest period, could decrease postharvest losses due to diseases and pruning weights due to reduced vegetative growth, without sacrificing the yield and fruit quality. This study was conducted over two years using the same trees of 'Moncante' nectarine cultivar grown in a commercial orchard. Trees were assigned to three treatments: (1) full irrigation at 80% estimated crop evapotranspiration (ET_c), (2) deficit irrigation, i.e. at 75% of full irrigation, and (3) deficit irrigation and deficit nitrogen, i.e. at 75% of full irrigation and 75% of usual N-fertilization adopted by the grower in this commercial orchard. Deficit irrigation alone and in combination with deficit nitrogen reduced postharvest diseases and pruning weights without significant yield losses. Our results suggest that ET_c-based approaches of reduced water irrigation may be a sustainable way to decrease phytosanitary inputs and workload in the orchard while maintaining the orchard performance.

Key words: climate change, drought, fruit shelf-life, *Monilinia* sp., picking time, tree water status

INTRODUCTION

Peaches and nectarines are one of the most commercialized fruit crops in the world [Vendramin et al. 2014] with approximately 25 million tons produced worldwide in 2017 [FAO 2018]. Due to the increasing human population and climate change, the demand for useful water and food will shortly be severely increased [Jenkins 2003]. In that context, deficit irrigation is an option to reduce water use with low effect on yield and fruit quality [Naor 2006, Atay et al. 2017]. Deficit irrigation strategies can dramatically influence the orchard performance of nectarine [Atay et al. 2016]. Indeed, peach and nectarine fruit contain almost 87% water [Crisosto and Valero 2008]. This ratio is about 50–70% for leaf and wood

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tissues in fruit trees [Rom 1994]. Likewise, nitrogen is an essential element for plants, and nitrogen-based fertilization itself entails dramatic effects on orchard performance, because important compounds such as amino acids, proteins, enzymes, nucleic acids, and chlorophyll, contain nitrogen [Johnson 2008]. Under severe abiotic stress (e.g. severe water and nitrogen deficits), photosynthesis is reduced, which can penalize the orchard performance, especially yield and fruit quality [Atay et al. 2016, 2017]. Nectarine trees need severe pruning, and orchard practices that decrease pruning weight can reduce pruning costs. Also, the loss caused by postharvest diseases is the major factor in food and nutritional insecurity [Mditshwa et al. 2017, Zhang et al. 2017]. Postharvest diseases can be eliminated by synthetic fungicides [Sharma et al. 2009]. However, synthetic fungicides pose a health risk to humans, animals, and the environment, as well as the fungicide resistance by the pathogen [Zhang et al. 2017]. There are strict worldwide regulations on fungicides use, and their use in the postharvest period is completely banned in some European countries [Wisniewski et al. 2016]. Few works have focused on the impact of orchard practices on the postharvest diseases of horticultural crops [Mditshwa et al. 2017]. All in all, finding safe, eco-friendly and effective alternative methods to synthetic fungicides for postharvest disease control of horticultural crops, is very meaningful [Sharma et al. 2009, Wisniewski et al. 2016, Zhang et al. 2017]. In the present study, we hypothesized that deficit irrigation, possibly combined with deficit nitrogen, in the preharvest period, would have dual effects, firstly reducing vegetative growth and therefore decreasing the need for summer and winter pruning, and secondly increasing the peach firmness thus decreasing the postharvest disease incidence. Based on previous unpublished experiments, our objective was to determine practical routes for a good compromise between deficit irrigation and the maintenance of yield and fruit quality.

MATERIALS AND METHODS

Experimental site and plant material. This study was conducted in a commercial orchard of yellow-fleshed 'Moncante' nectarine on the seedling rootstock *Prunus persica* cv. 'Montclar', established in January 2009 at 6 m × 3 m spacing in Caissargues, located in the south-east Mediterranean region of France. Trees were trained since orchard establishment as goblets. The soil was clay loam with 50% to 60% of stones. Hand thinning after the physiological fruit drop was carried out to homogenize fruit load (1.6 to 2.0 fruit per shoot; 160 to 175 shoots per tree). Standard crop husbandry practices were applied to the orchard throughout the study.

Irrigation and nitrogen treatments. Irrigation and nitrogen (N) treatments were applied over two consecutive years (2013 and 2014) in three adjacent rows using the same trees for the same treatments in both years. Before this study, all trees in the orchard received full irrigation and standard rates of fertilizers. After verification of the homogeneity of the trees growth, water regimes were replicated five times randomly distributed along the rows including five uniform trees in each replication, yielding to 25 trees per treatment. Data were collected from the central three trees in each replication. The orchard was irrigated on a daily basis (4 pulses a day using an automatic timer) with a subsurface drip irrigation system. The irrigation system was placed at 0.25 m depth in the soil and 0.60 m apart from each tree towards the inter-row. Emitters had a debit of 1.6 l h^{-1} at 0.75 m spacing along the row. Trees were assigned to three treatments: control, i.e. full irrigation, FI, corresponding to grower irrigation at 80% of estimated crop evapotranspiration (ET_c); deficit irrigation, DI, was set at 75% of FI till the last fruit picking; and DI till the last picking with a deficit irrigation, DI, as previously, and a deficit N (DN) fertilization at 75% of the usual N fertilization (120 kg ha^{-1} per year, based on soil analyses) practice in this orchard (DI + DN). After harvest, N was applied at 20 kg ha^{-1} per year in all treatments. Irrigation water quantity for FI treatment was calculated according to ET_c values (plant coefficient, K_c = 0.8) using the FAO standardized Penman-Monteith equation, (ET_o × K_c)-rainfall, where ET_o represents the reference evapotranspiration [Allen et al. 1998]. Climate data were obtained from a nearby weather station (Fig. 1). Irrigation began in the first week of March and ended just before the autumn rains (beginning of September).

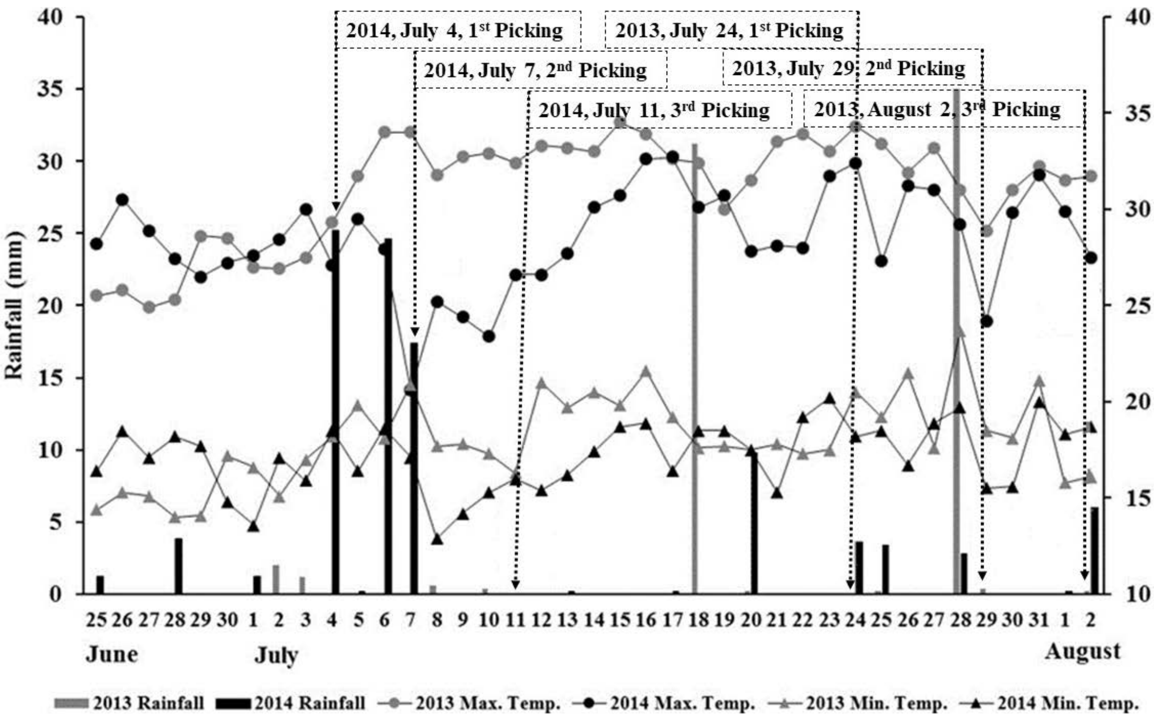


Fig. 1. Daily rainfall and temperature data recorded in the preharvest and harvest period at the experimentation area in 2013 and 2014. Arrows indicate rainfall at each picking time

Data collection

Tree water status. To check tree water status in the three treatments, midday stem water potential (SWP) was measured nine times along the growing season beginning when maximal temperatures raised above 25°C. Measurements were made at solar noon with a pressure chamber (Arimad-3000; Plant Water Potential Measurement Device for Agricultural, Israel) using the leaves located in the inner part of tree canopy. Selected leaves were inserted into a plastic bag covered with aluminum foil at least one hour before measurement to ensure water equilibrium between leaves and stem [Naor et al. 2008]. At each measurement date, SWP was determined using seven leaves per treatment.

Fruit growth dynamics. In both study years, 125 fruit per treatment were tagged, and fruit cheek diameter at the closest mm was determined. Measurements started when the fruit reached approximately 40 mm in diameter and continued up to the first picking time.

Yield. Fruit that were tree-ripened were picked on July 24, July 29, and August 2 in 2013 and on July 4, July 7, and July 11 in 2014. Fruit picking was done at the beginning of sunrise and completed before midday. At each picking, fruit were immediately weighted, and yield was calculated in terms of t ha^{-1}, and yield efficiency (kg cm^{-2} trunk cross-sectional area (TCSA)) was described as the ratio of the weight of fruit per unit area of TCSA. Trunk girth (assuming circular cross-section) was measured at 20 cm above the budding point to determine TCSA (cm^2). The fruit were graded in terms of cheek diameter. On a sample of 30 fruit (20 fruit in 2014) per treatment taken from the most represented fruit size class at each picking time, fruit weight (g), fruit firmness (kg cm^{-2}), soluble solids content SSC (%), titratable acidity (g L^{-1}) and juiciness (ratio of the juice to dry matter) were measured with the computer-controlled quality control device − "Pimprenelle" [Setop Giraud Technologie, www.setop.fr].

Postharvest diseases. To reveal the effects of irrigation and N treatments on the postharvest diseases caused by fungal pathogens (*Monilinia* sp., *Rhizopus* sp. and *Botrytis* sp.), fruit were transported to the laboratory immediately after each picking, and placed in a cold storage at 0.5°C for pre-cooling during the first 24 hours. Then fruit were kept in another room at 22°C and 90% relative humidity for ten days. Observations of postharvest diseases were conducted 5, 7 and 10 days after picking (DAP) that are a critical time for retailers, supermarkets, and consumers, respectively. For the evaluation of postharvest diseases, a sample of 150 fruit without injuries taken from the most represented fruit size class was selected at each picking time. The most represented fruit size class was 73–79 mm for the first and second picking, and 67–73 mm for the third picking for all treatments in both study years. Harvest boxes were never used before for minimizing the sanitation issues. After each observation at 5 DAP and 7 DAP, damaged fruit by postharvest diseases were removed from the boxes to prevent further pathogen dissemination.

Pruning weights. Summer (mid-August, 2013 only) and winter (dormant, 2013 and 2014) pruning weights were recorded immediately following manual pruning.

Data analysis

All data were analyzed using SAS-JMP software version 7.0 (http://www.jmp.com/software/). The random-effect was included in the fit model, and mean values were separated using Least Significant Difference (LSD) multiple comparison tests. In all analyses, threshold for statistical significance was set at $P < 0.05$.

RESULTS

Tree water status. SWP was significantly lower in FI than in the other treatments commencing three weeks before the first picking in the preharvest period. After harvest, there were no significant differences among the treatments for SWP. SWP did not differ between DI and DI + DN over the season (Tab. 1).

Table 1. Midday stem water potential (SWP, MPa) values of 'Moncante' nectarine in 2013 in response to irrigation and N treatments

Period	Date	FI	DI	DI + DN	*P*
Postharvest	June 18	–0.71 ±0.17	–0.98 ±0.22	–0.91 ±0.11	0.0643
	June 20	–0.46 ±0.06	–0.52 ±0.10	–0.50 ±0.09	0.5854
	June 25	–0.65 ±0.05	–0.70 ±0.18	–1.07 ±0.25	0.0664
	July 2	–0.56 ±0.0b	–1.34 ±0.3a	–1.33 ±0.23a	0.0001
	July 10	–0.90 ±0.1b	–1.64 ±0.10 a	–1.59 ±0.30a	0.0001
	July 17	–1.26 ±0.0b	–1.66 ±0.2a	–1.81 ±0.17a	0.0016
	August 13	–0.96 ±0.09	–0.87 ±0.06	–0.91 ±0.11	0.3590
	September 3	–1.12 ±0.12	–1.05 ±0.04	–1.09 ±0.08	0.6821
	October 3	–1.13 ±0.10	–1.10 ±0.09	–1.03 ±0.08	0.0796

Values are means ±standard deviation (SD). Within each measurement date, different letters indicate significant differences at $P < 0.05$
FI: full irrigation; DI: deficit irrigation; DI+DN: deficit irrigation with deficit N

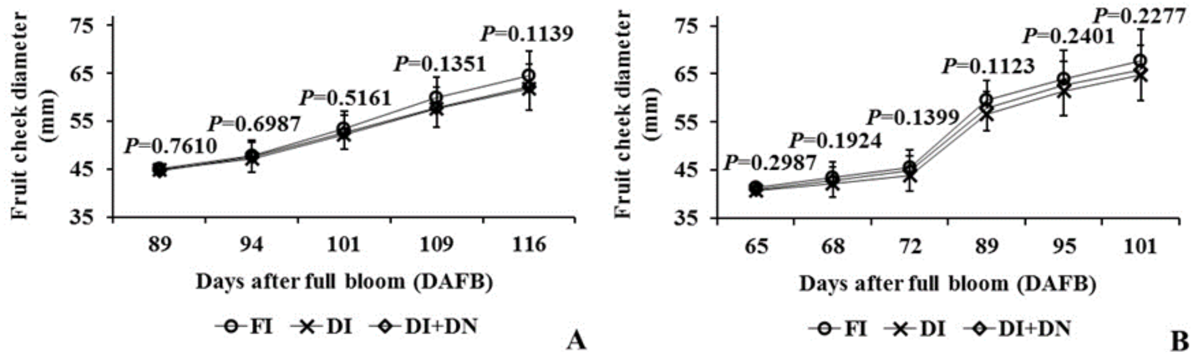


Fig. 2. Time-dependent changes of fruit cheek diameter of 'Moncante' nectarine in response to irrigation and N treatments. (A) 2013 and (B) 2014. The values are means ±SD. FI: full irrigation; DI: deficit irrigation; DI + DN: deficit irrigation with deficit N

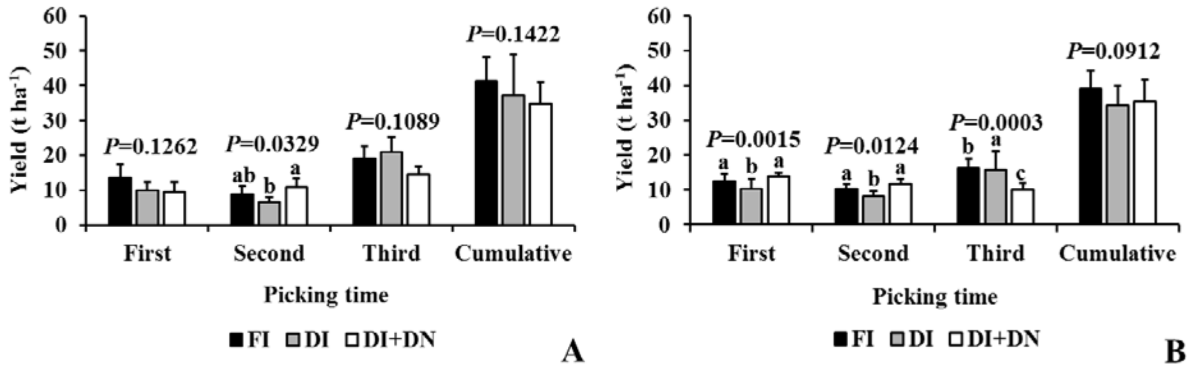


Fig. 3. Effect of irrigation and N treatments on the yield of 'Moncante' nectarine at each picking time. (A) 2013 and (B) 2014. The values are means ±SD. Within each picking time, different letters indicate significant differences at $P < 0.05$. FI: full irrigation; DI: deficit irrigation; DI + DN: deficit irrigation with deficit N

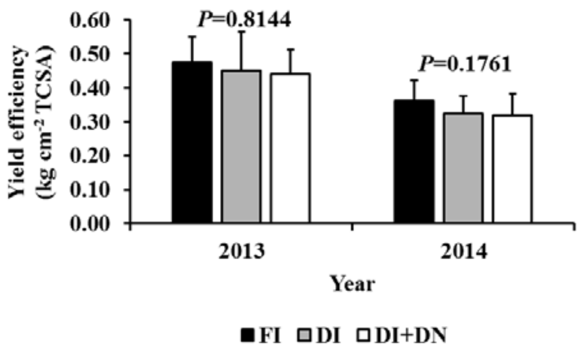


Fig. 4. Effect of irrigation and N treatments on yield efficiency of 'Moncante' nectarine. The values are means ±SD. FI: full irrigation; DI: deficit irrigation; DI + DN: deficit irrigation with deficit N

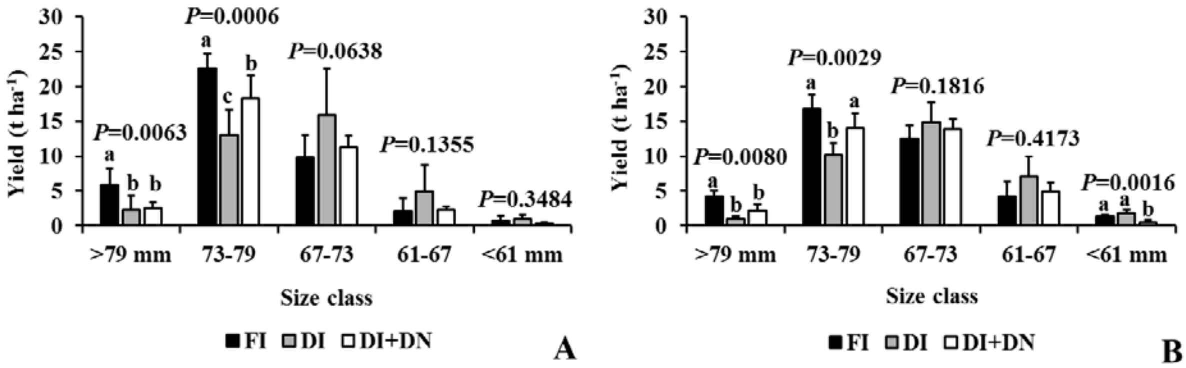


Fig. 5. Effect of irrigation and N treatments on fruit size class distribution of 'Moncante' nectarine. (A) 2013 and (B) 2014. The values are means ±SD of all three picking times. Within each size class, different letters indicate significant differences at $P < 0.05$. FI: full irrigation; DI: deficit irrigation; DI + DN: deficit irrigation with deficit N

Table 2. Fruit weight, soluble solids content (SSC), firmness, acidity and juiciness of 'Moncante' nectarine in response to irrigation and N treatments

Year	Treatment	Weight (g)	SSC (%)	Firmness (kg cm^{-2})	Acidity (g L^{-1})	Juiciness
2013	FI	203 ±17	11.70 ±1.18b	5.59 ±1.09b	8.05 ±0.70	7.43 ±0.72a
	DI	196 ±20	13.75 ±1.23a	6.04 ±0.97a	7.57 ±1.45	6.40 ±0.69b
	DI + DN	201 ±18	13.70 ±1.62a	5.75 ±1.02ab	7.43 ±0.61	6.70 ±0.55b
	P	0.1015	0.0001	0.0301	0.4567	0.0166
2014	FI	190 ±25 a	10.86 ±1.48b	6.12 ±0.97b	8.07 ±0.70	3.57 ±0.72
	DI	174 ±24 b	13.00 ±1.48a	6.94 ±0.99a	8.80 ±1.45	2.40 ±0.69
	DI + DN	176 ±24 b	10.33 ±1.07b	5.88 ±0.97b	7.83 ±0.61	3.83 ±0.55
	P	0.0003	0.0001	0.0002	0.1311	0.0894

The values are means ±SD of the three picking times. Within columns, different letters indicate significant differences at $P < 0.05$. FI: full irrigation; DI: deficit irrigation; DI + DN: deficit irrigation with deficit N

Fruit growth dynamics and yield. In 2013 (Fig. 2A) and 2014 (Fig. 2B), fruit cheek diameter was not different between treatments over the whole season. Cumulative yield in both 2013 (Fig. 3A) and 2014 (Fig. 3B) was unaffected by treatments. In general, the effects of treatments on yield differed depending on the picking time without clear propensity within the two years. As a whole, there were no significant differences in cumulative yield among the treatments. Yield efficiency was not affected by treatments in both study years (Fig. 4).

FI resulted in a higher yield in the '>79 mm' size class compared to the other treatments in both years. Proportion of fruit in the 73–79 mm and 67–73 mm size class that covers the greatest part of the total yield was 48% and 33% (Fig. 5A) and 37% and 38% (Fig. 5B) in 2013 and 2014, respectively.

In 2013, FI resulted in lower SSC in comparison to other treatments. Acidity was unaffected by treatments. Juiciness was higher in FI than in the other treatments (Tab. 2). In 2014, FI resulted in higher fruit weight in comparison to the other two treatments. SSC was higher in DI that also had a higher firmness than the other treatments. Acidity and juiciness were unaffected by treatments (Tab. 2).

Postharvest diseases. In 2013, the effect of treatments on postharvest diseases interacted with the picking time at 5 DAP. Effects of FI and DI + DN on postharvest diseases were similar in all picking times. The third picking had the highest postharvest diseases at 7 and 10 DAP (Tab. 3).

In 2014, an interaction between treatment and picking time was found at 7 DAP. Effects of DI and DI + DN on postharvest diseases were similar at both 7 DAP and 10 DAP (Tab. 4).

Pruning weights. Winter pruning weight in both 2013 (Fig. 6A) and 2014 (Fig. 6B) was higher in FI than in the other treatments. FI had the greatest, and DI + DN had the least, cumulative pruning weight in 2014 (Fig. 6B).

Table 3. Losses caused by postharvest diseases in response to irrigation and N treatments at days 5, 7 and 10, after each picking in 2013

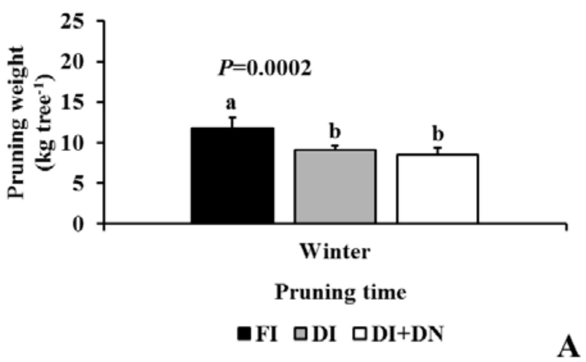
Test	Treatment	Picking time	Losses (%)		
			5 DAP	7 DAP	10 DAP
	FI	first	16.57 ±9.12	22.86 ±12.29	46.86 ±15.47
		second	3.43 ±2.39	8.00 ±7.67	28.00 ±12.02
		third	4.00 ±4.33	9.14 ±5.50	25.71 ±8.08
	DI	first	7.73 ±7.45	68.57 ±15.91	82.86 ±11.25
		second	6.29 ±8.43	37.14 ±9.48	62.86 ±12.12
		third	4.00 ±3.26	56.00 ±25.44	72.57 ±24.63
	DI + DN	first	22.99 ±10.58	81.71 ±7.17	89.71 ±4.33
		second	9.71 ±6.58	74.86 ±16.59	84.57 ±9.39
		third	28.57 ±3.50	89.14 ±7.40	93.71 ±5.11
Mean	FI		15.43 ±10.57	57.71 ±28.49 a	73.14 ±22.10
	DI		6.48 ±6.43	40.00 ±30.39 b	58.48 ±26.27
	DI + DN		12.19 ±12.48	51.43 ±36.92 a	64.00 ±32.63
Effect	*P*		0.0153	0.0326	0.0913
Mean		first picking	8.00 ±8.38	13.33 ±10.83 c	33.52 ±14.98 c
		second picking	5.90 ±6.43	53.90 ±21.49 b	72.76 ±17.97 b
		third picking	20.19 ±10.66	81.90 ±12.06 a	89.33 ±7.28 a
Effect	*P*		0.0007	0.0001	0.0001
Treatment × picking time interaction	*P*		0.0034	0.1501	0.2326

The values are means ± SD. Data are transformed (trigonometric-arcsin) to stabilize variance. Within columns means with different letters among treatments and picking times are significantly different at $P < 0.05$. DAP: days after picking. FI: full irrigation; DI: deficit irrigation; DI + DN: deficit irrigation with deficit N

Table 4. Losses caused by postharvest diseases in response to irrigation and N treatments at days, 5, 7 and 10, after each picking in 2014

Test	Treatment	Picking time	Losses (%)		
			5 DAP	7 DAP	10 DAP
	FI	first	0.19 ±0.74	4.95 ±4.64	14.48 ±10.88
		second	1.71 ±2.11	20.38 ±11.32	25.90 ±14.06
		third	−	2.67 ±3.49	12.38 ±9.39
	DI	first	0.00 ±0.00	2.48 ±2.83	7.81 ±7.44
		second	1.33 ±2.38	10.48 ±9.39	14.86 ±11.13
		third	−	0.00 ±0.00	9.52 ±8.55
	DI + DN	first	0.00 ±0.00	0.95 ±2.57	8.00 ±6.85
		second	0.38 ±1.02	8.19 ±3.87	15.81 ±5.39
		third	−	0.00 ±0.00	9.33 ±6.15
Mean	FI		0.95 ±1.73	9.33 ±10.71	17.59 ±12.83 a
	DI		0.67 ±1.79	4.32 ±7.15	10.73 ±9.46 b
	DI + DN		0.19 ±0.72	3.05 ±4.53	11.05 ±6.93 b
Effect	*P*		0.1786	0.0015	0.0001
Mean		first picking	0.14 ±0.82 b	2.81 ±3.99	9.62 ±8.71 b
		second picking	1.05 ±2.04 a	13.10 ±10.12	18.91 ±12.11 a
		third picking	−	0.71 ±2.08	10.71 ±9.26 b
Effect	*P*		0.0040	0.0001	0.0037
Treatment × picking time interaction	*P*		0.1678	0.0066	0.4650

The values are means ±SD. Data are transformed (trigonometric-arcsin) to stabilize variance. Within columns means with different letters among treatments and picking times are significantly different at $P < 0.05$. −: data not collected. DAP: days after picking. FI: full irrigation; DI: deficit irrigation; DI + DN: deficit irrigation with deficit N



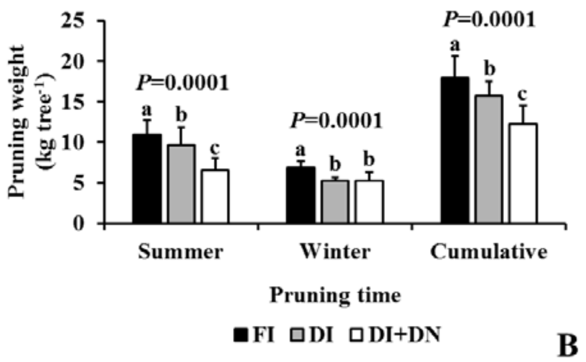


Fig. 6. Effect of irrigation and N treatments on fresh pruning weights of 'Moncante' nectarine. (A) 2013 and (B) 2014. The values are means ±SD. Within each pruning time, different letters indicate significant differences at $P < 0.05$. FI: full irrigation; DI: deficit irrigation; DI + DN: deficit irrigation with deficit N

DISCUSSION

Fruit growth dynamics and yield. No distinct 'plateau phase' was seen during the fruit growth of 'Moncante', a mid-season nectarine cultivar. The plateau phase is in fact very short in early-ripening peach and nectarine cultivars [Bassi and Monet 2008]. In general, fruit size values, measured either from cheek diameter or fruit weight, was higher, but SSC was lower, in fruit from FI-treated trees. Our results thus confirmed the literature references stating that fruit size is tightly associated with irrigation water quantity used, and that deficit irrigation reduces the fruit size [Naor 2006], but increases SSC [Crisosto et al. 1997, Atay et al. 2017].

Cumulative yield and yield efficiency of FI-treated trees were rather similar to the other two treatments in both study years. Strong deficit irrigation reduces the yield [Naor 2006]. To minimize twin fruit, yield and fruit quality problems, the threshold level of SWP has been suggested as –2.0 MPa in the case of postharvest irrigation of nectarines in Israel conditions [Naor 2006]. This threshold is close to the maximal negative values obtained in our experiment for DI and DI + DN, around –1.81 MPa ±0.17, in comparison to FI-treated trees (max. –1.26 ±0.08). A deficit irrigation as done here could then be considered as moderate. Because this threshold level is influenced by orchard to orchard, regional experiments are recommended [Johnson 2008].

Postharvest diseases. Our results showed that, at least in 2014, deficit irrigation associated or not with nitrogen deficit could decrease the postharvest diseases, however, with possible interactions with picking time, the third picking having a higher frequency of postharvest diseases, especially after a longer storage time. In the present study, we can deduce that DI alone and in combination with DN reduced the postharvest diseases. Perez-Pastor et al. [2007] found that fungal attacks mainly caused by *Rhizopus* sp. and *Monilinia* sp. decreased during the storage of apricot under deficit irrigation. Cuticle and epidermis anatomy of fruit can vary with orchard practices [Konarska 2014], and DI and DN may increase continuous and thicker cuticle that protects the fruit against pathogens [Daane et al. 1995, Crisosto et al. 1997]. Because direct penetration of fungal pathogens to fruit through an intact cuticle has never been seen, cuticular microcracks, occurring as the fruit grows naturally, and deeper spontaneous cracks in the wall of epidermis, create a convenient site for pathogen attacks in nectarine [Nguyen-the 1991, Konarska 2014]. In the present study, probably both types of cracks were more abundant in fruit from FI-treated trees, in comparison to the others. Three hypotheses may be proposed. This could be first due to an increased frequency of cracks positively related to a higher fruit volume surface in slightly larger fruit in FI. Secondly, while the number of stomata on the fruit is established at anthesis, stomatal behavior differs during the fruit growth [Ishida et al. 1990]. Stomatal opening in the epidermis, which makes the fruit more susceptible to pathogens, decreases with increasing abscisic acid (ABA), the synthesis of which increases under abiotic stress (e.g. DI) [Terry et al. 2007]. There is a good positive correlation between midday SWP and midday stomatal closure [Marsal and Girona 1997]. Thus, in the present study, SWP in the preharvest period was higher/more negative in DI and DI+DN-treated trees in comparison to FI-treated trees (see Tab. 1). Thirdly, secondary metabolites (e.g. amino acids, alkaloids, phenolics, phytoalexins), that are key components of defense mechanisms, increase in response to abiotic stress factors [Sahebi et al. 2017].

The incidence of postharvest diseases was higher at the third picking in 2013, while it was higher at the second picking in 2014. Overall, postharvest diseases remained relatively lower in 2014 than in 2013. Losses caused by postharvest diseases could be affected by relative air humidity occurring a few days before and during the picking time. Thus, the relative humidity in the ambient air is determined by temperature and water vapor in the surrounding area, and total rainfall during the fifteen-day period during the preharvest and harvest period at the research area was two-fold higher in 2014 (72 mm) than in 2013 (36 mm) (see Fig. 1). However, mean maximum temperature values in the same fifteen-day period were lower in 2014 (27°C) than in 2013 (32°C). The trend of minimum temperature in the same fifteen-day period was similar to that of maximum temperature, being close to 16°C and 19°C in 2014 and 2013, respectively. Microcracks on fruit surface increase with increasing rainfall [Konarska 2014]. Thus rainfall triggers relative air humidity, especially in hot days. Also, stomatal opening increases with increasing relative humidity in the ambient air [Urban et al. 2017]. As mentioned above, both microcracks and stomatal opening constitute open ways to pathogen spores that decay fruit in a short time frame.

Pruning weights. In the present study, DI combined with DN was the most effective treatment in reducing the cumulative pruning weight. DI decreases the pruning weight [Miras-Avalos et al. 2017]. Peach and nectarine trees respond very dramatically to N applications that promote vegetative growth [Crisosto et al. 1997]. Our results suggest that reducing N fertilization, here by 25% compared to the conventional inputs in this orchard, may be an efficient way to reduce pruning weights.

CONCLUSIONS

From the scientific perspective, the most important output of the present study is that deficit irrigation alone and in combination with a deficit in nitrogen could reduce the pruning weights and also partly losses caused by postharvest diseases. From a practical perspective, deficit irrigation and a deficit in nitrogen can be used as levers to partly decrease the use of chemicals (e.g. fungicides and stearic acid), physical treatments (e.g. ultraviolet irradiation and hot water dips) and microbial antagonists (e.g. yeasts and bacteria) that are commonly used to reduce postharvest diseases in fruit crops. Deficit irrigation, especially when it is associated with a deficit in nitrogen resulted in less pruning weight than FI, which can reduce labor costs for pruning. Moreover, it is likely that the reduction of shoot growth could also reduce aphid infestation indirectly [Grechi et al. 2008] and therefore pesticide needs along the season. DI and DI + DN resulted in a slight decrease in large fruit frequency but with non-consistent effect on cumulative yield. As a whole, we consider that deficit irrigation and deficit in nitrogen should be considered with more attention in the future to implement less workload and less chemical demanding peach and nectarine orchards.

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