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EFFECT OF DEFICIT IRRIGATION STRATEGIES AND ORGANIC MULCHING ON YIELD, WATER PRODUCTIVITY AND FRUIT QUALITY OF NAVEL ORANGE UNDER ARID REGIONS CONDITIONS

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Abstract

Improving the water productivity under arid regions conditions is the main goal for all researchers who are working under sustainable and agricultural water management. Two experiments were conducted during the growing seasons at national research centre farm in Al-Nubariya Region, Al-Buhayrah Governorate, Egypt during seasons 2017/2018 and 2018/2019 to study the effect of deficit irrigation strategies and organic mulching by rice straw on the yield, water productivity and fruit quality of navel orange under arid regions conditions. The results of the study revealed that, increasing the amount of rice straw used in the mulching, the productivity, quality and water productivity values of the orange crop are improved, as well as when adding 100% of the water requirements and also when applying partial root-drying technique. The increase in the amount of the organic mulching of rice straw led to a decrease in evaporation from the soil surface and the moisture content remaining within the root zone for the longest period possible which helped reduce the period of exposure of the roots to water stress, which also led to increased absorption of water and nutrients added to the soil for the purpose of fertilization. The increase in the amount of organic mulching by rice straw also led to a decrease in the soil salts accumulation and that is logical, as the rate of evaporation from the soil decreases, the amount of accumulated salts decreases. The values of productivity, quality and water productivity improved when adding 100% of water needs, and this is logical, as the roots of orange trees are less prone to water stress as trees take on full water needs, but the thing that calls for research is obtaining the same high values of productivity and quality and much higher in the values of water productivity, where half of the water needs have been added by applying the technique of partial root drying, as this was due to several advantages of the partial root drying technology. Partial root drying technique reductions of stomatal conductance prevent serious water loss by transpiration. Finally, the best treatment which achieve the best results under arid regions conditions and limited water resources in Egypt is applying partial root-drying technique and mulching the laterals or drip lines by 9 ton ha^{-1} from rice straw under navel orange trees.

Key word: Deficit Irrigation Strategies, Partial Root Drying, PRD, Organic Mulching, Rice straw, Water Productivity, Navel Orange.

Introduction

In arid countries with large population growth and freshwater limitation, there is significant pressure on the agricultural sector to reduce freshwater water consumption for the urban and industrial sectors (Abdelraouf and Abuarab 2012) and (Hozayn, *et al.*, 2016). The agricultural sector faces a serious challenge in producing more food with less water, which can be accomplished by increasing crop water productivity (Abdelraouf *et al.*, 2013c). Increasing crop production is an important, important goal of increasing demand for high population growth (Bakry *et al.*, 2012) and (Abdelraouf and Ragab 2018). The limited water resources in Egypt suffer from severe water scarcity, which increases with the increasing population. The increasing competition for scarce water resources is competing for an innovative and new application of

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modified irrigation techniques to increase water productivity and improve crop productivity and quality (Abdelraouf and Habasha, 2014, Marwa, *et al.,* 2017). Water productivity in Egypt is extremely important because water resources are limited and precipitation is a limited factor (Hozayn *et al.*, 2013). Water scarcity is one of the main and serious problems facing crop production in Egypt, and it is necessary to reduce irrigation consumption by developing new and innovative technologies that can assist in these valuable inputs that are effective effectively (Abdelraouf *et al*., 2013b and El-Metwally *et al*., 2015). The application of modern irrigation methods is an important concept that you must do in arid regions such as Egypt to provide a portion of irrigation water due to limited water resources (El-Habbasha *et al*., 2014 and Abdelraouf *et al.,* 2012).

The application of highly efficient micro-irrigation systems is an important concept that must be implemented in Egypt to provide irrigation water due to limited water resources (El-Habbasha *et al*., 2014). There are many methods and techniques that have the potential to conserve and use these limited water resources efficiently. For example, drip irrigation systems, impotence irrigation application, especially root partial drying strategy, PRD, and post-harvest soil surface coverage with crop residues such as rice straw (organic mulching). Drip irrigation is one of the most efficient water-saving methods of irrigation because it has precise control over the amount of irrigation and targets the root zone only and thus increases the productivity of irrigation water (WP) by reducing percolation and evaporation losses (Camp, 1998). Deficit irrigation (DI) including partial root drying (PRD) is a water-saving irrigation strategy Disability irrigation (DI) including partial root drying (PRD) is a water-saving irrigation strategy (Kang & Zhang, 2004). PRD includes alternative irrigation for each side of the plant root system, which allows it to undergo moderate pressure leading to partial closure of the gaps to reduce transpiration losses without significantly affecting photosynthesis and yield. PRD has been found to be a promising strategy in many crops (Kang & Zhang, 2004). Davis and Hartung (2004) suggested that PRD can stimulate root growth while under DI, some roots may die if dry conditions are long. After that, it was decided to investigate whether the DI and PRD might be promising for irrigation strategies to apply to the citrus crops grown in sandy soil in Egypt.

Mulching is a technique for covering the soil surface with organic or synthetic mulch around the plants to create favorable conditions for the plant growth as well as proficient crop production (Chakraborty *et al.*, 2008; Kader *et al.,* 2017). Mulching help to improve growth of plants and yield as well as at the same time optimizes water use (Yu *et al.,* 2018). Mulches improving soil structure, soil aeration, regulating soil temperature, conserving moisture in-situ, organic matter, microbial flora, controlling weeds, reducing nutrient removal by weeds and decreasing soil erosion (Shirgure *et al.,* 2005 and Bhanukar *et al.,* 2015). Research results have presented that using mulch supplies many benefits to crop production by improving the chemical, biological and physical properties of soil (Cooper, 1973). Moreover, results showed that mulching modifying water retention capacity of the soil and reducing evaporation from the soil as well as increase soil moisture through increasing infiltration (Lal, 1974). On the other hand mulch decomposition and humus formation improved water holding capacity of the soil (Ji and Unger, 2001).

Organic mulches derived from animal and plant materials such as straw, husks, hay, sawdust, compost, wood chips, etc. are effective in improve soil physical properties, decrease of nitrates leaching, supply organic matter, regulate temperature and water retention, prevent erosion, take part in nutrient cycle, improve nitrogen balance as well as increase the biological activity (Muhammad *et al.,* 2009; Sarolia and Bhardwaj 2012). In this concern, mulching with synthetic materials and residues of plant is a well-established technique for growing the profitability of horticultural crops (Gimenez *et al.,* 2002). Sharma *et al.,* (2010) found that mulching is very useful for nutrient conservation and increase moisture, performing in improved soil conditions and increased productivity for cropping system. Liu *et al.,* (2014) illustrated that practices of mulching the soil may be affect positively on citrus fruit yield under extreme weather conditions. Wicks *et al.,* (1994) and Zhang *et al.,* (2015) detected that mulching with straw can significantly increasing of crop yield. Mulching with straw of the remaining plants has been used to decrease evaporation and to amend the soil as well as soil aggregates (Adams 1966; Kukal, Sarkar 2010). Finally, mulching with straw led to decrease of water requirement for crops (Liu *et al.,* 2009).

Adeoye,(1984) found that the highest values of soil moisture content up to a depth of 60 cm in mulched soil with grass. An increase in soil moisture content was achieved with using a variety of mulch types so as a result of reduced evaporation from the soil surface compared to that of un-mulched soil (Maged, 2006). The higher moisture content of the soil was obtained in the soil layer (0-60 cm) which mulched compared to bare soil (Ramakrishna *et al.,* 2006). Diaz *et al.,* (2005) found that the largest increase in soil moisture content values when the soil was mulched with10 cm (92%), followed by the soil moisture content values when it was mulched with 5 cm (83%) and 2 cm (52%).

Salt accumulation under mulching the soil was decreased when plants were irrigated with a high saline irrigation (Zang *et al.,* 2008), and reduced salinity of the soil (Abou -Baker *et al.,* 2011). Alharbi (2015) presented that mulching reduced salinity of the soil for surface layers compared to the un-mulched layer.

Rice straw is considered one of the most important agricultural wastes at present. The farmers can be used rice straw as mulch. In addition, rice straw is cheap and available source of mulching material and therefore can be economically utilized.

The citrus, makes up 50% from total fruit production, primarily oranges that represent about 85% from total citrus production. Over the last three decades that the fruit-planted area has expanded to reach about 200 000 fed. (El Shereif, 2016). The most species which cultivated from citrus varieties are oranges, and farmers prefer to cultivate oranges upon other fruit due to their value and high export demand. Almost the oranges are cultivated in all of Egypt's governorates (Abobatta, 2018). Egypt ranking as sixth between the biggest producers of orange throughout the world after Brazil, China, US, EU, and Mexico (USDA) (2016/2017) statistics). Production quality of citrus fruits is highly dependent on the soil moisture availability.

García-Tejero *et al.,* (2011) on sweet orange, Abo El-Enin (2012) and Zayan *et al.,* (2016) on Washington Navel, Panigrahi *et al.,* (2014) on 'Kinnow' mandarin and Fiorella *et al.,* (2015) on mature orange trees *cv.* "Tarocco Meli". They observed that the highest values of water productivity (WP) and field water use efficiency (FWUE) were achieved under treatment of deficit irrigation (Irrigation at 50% of control), while the lowest values were obtained from control treatment (Actual irrigation practiced in the orchard (control) 100%FI) due to much of irrigation water which be applied .Values of water productivity also has an important value for farmers through increasing their income from using less amounts of irrigation water.

Therefore, this study has been carried out to study the effect of organic mulching by rice straw under water deficit irrigation strategies on water stress, soil salts accumulation, nutritional status of naval orange trees and yield as well as water productivity and fruit juice chemical properties of navel orange under arid regions conditions in Egypt.

Materials and methods

Location and climate of experimental site: The field experiments were conducted during 2017/2018 and 2018/2019 seasons at the research farm station of National Research Centre (NRC) (latitude 30^{o} 30' 1.4''N, longitude 30^{o}19' 10.9'' E, and 21 m + MSL (mean sea level) at Al-Nubariya Region, Al-Buhayrah Governorate, Egypt. The experimental area has an arid climate with cool winters and hot dry summer. The data of average temperature, relative humidity and wind speed were obtained from the local weather station at El-Nubaryia farm, as shown in table 1.

Physical and chemical properties of soil and irrigation water: Irrigation water source was an irrigation channel passing through the experimental area, with an average pH of 7.37 and 0.42 dS m^{-1} as electrical conductivity (EC). The main physical and chemical properties of the soil are shown in table 2.

Irrigation system components: Irrigation system components consisted of control head, pumping and filtration unit. It consists of centrifugal pump with 45 m^{3}/h discharge and it was driven by electrical engine and screen filter and back flow prevention device, pressure regulator, pressure gauges, flow-meter, control valves. Main line was of PVC pipes with 110 mm in diameter (OD) to convey the water from the source to the main control points in the field. Sub-main lines were of PVC pipes with 75 mm diameter (OD) was connected to the main line. Manifold lines: PE pipes was of 63 mm in diameter (OD) were connected to the sub main line through control valve 2" and discharge gauge. Emitters, built in laterals tubes of PE with 16 mm diameter (OD) and 50 m in long (emitter discharge was 4 lph at 1.0 bar operating pressure).

Experimental design: Experimental design and treatments was split plot with three replications. Deficit irrigation strategies (75% Full irrigation "FI", 50% FI and PRD technique compared with 100% FI) in main plots and organic mulching by rice straw [0 (without mulching "O1"), 1 layer of rice straw " O2 " = 5 tons ha^{-1}, 2 layers of rice straw "O3" = 7 tons ha^{-1}, 3 layers of rice straw "O4" = 9 tons ha^{-1})] were used in sub main plots as shown as in Fig. 2 and 3.

Estimation the seasonal irrigation water requirement for navel orange: Seasonal irrigation water requirement was estimated according to the meteorological data of the Central Laboratory for Agricultural Climate (CLAC), Agricultural Research Center, Dokki, Egypt depending on Penman-Monteith equation. Seasonal irrigation water requirement for navel

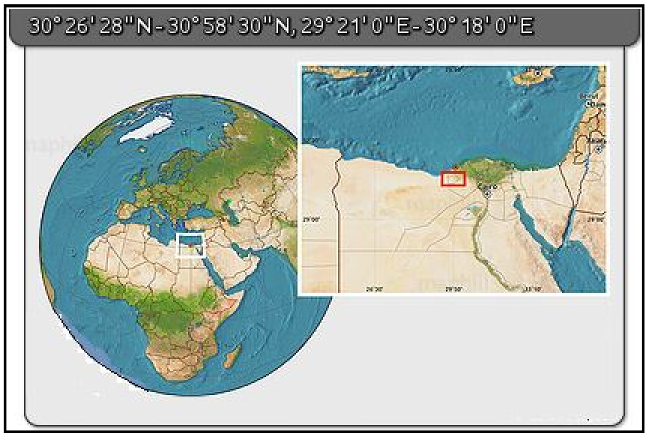

Fig. 1: Location of study site in Al Buhayrah governorate in Egypt.

orange crop were 7200 m^3. ha^{-1} for 2017/2018 and 7500 m^3 ha^{-1} for 2018/2019. Daily irrigation water was calculated by following equation (1) for two seasons 2016/2017 and 2017/2018 under drip irrigation system:

$$IRg = [(ET_O \times Kc \times Kr)/Ei]-R+LR \quad (1)$$

Where: IRg: Gross irrigation requirements, mm/day, ET_O: Reference evapotranspiration, mm/day, Kc : Crop factor (FAO-56), Kr: Ground cover reduction factor , Ei: Irrigation efficiency, %, R: Water received by plant from sources other than irrigation, mm (for example rainfall), LR: Amount of water required for the leaching of salts, mm

Evaluation parameters

Water stress in the effective roots zone: Soil moisture was measured in effective roots zone before and after irrigation, field capacity and wilting point were taken as evaluation lines in consideration as an evaluation parameter for exposure range of the plants to water stress "WS" (Abdelraouf, 2014). Measurements were taken at soil depths at every growth stage. Soil moisture was measured by profile probe device.

Soil salts accumulation inside root zone: Measuring the soil salts concentration in the root zone at

Table 1: The data of average temperature, relative humidity and wind speed were obtained from the local weather station at El-Nubaryia farm.

Climatic mean values, 2017/2018								
Months	**SRAD**	**TMAX**	**TMIN**	**RAIN**	**WIND**	**TDEW**	**TMean**	**RH**
January	12.38	17.61	5.97	0.00	3.67	3.54	10.92	61.22
February	15.21	20.01	6.71	0.00	3.51	4.94	12.41	60.56
March	19.80	24.05	10.13	0.00	4.21	5.95	16.27	51.50
April	23.66	28.46	12.24	68.08	4.30	6.58	19.85	43.50
May	27.23	33.42	16.82	0.00	4.44	9.40	24.72	39.09
June	29.57	36.62	19.80	0.00	4.41	12.60	27.98	39.43
July	29.13	38.64	22.14	0.00	4.35	15.54	29.92	42.32
August	26.92	37.08	22.17	0.00	4.02	16.69	29.03	47.36
September	23.58	30.47	15.47	0.00	4.07	11.33	22.17	45.26
October	18.85	29.52	16.33	0.00	3.98	11.37	22.17	51.20
November	13.98	24.25	12.23	0.00	3.42	8.98	17.35	58.36
December	10.36	21.29	10.32	0.00	3.64	7.92	14.92	63.50
Climatic mean values, 2018/2019								
January	11.40	18.82	8.70	34.48	5.33	5.95	13.07	67.83
February	14.03	19.73	8.98	17.60	5.67	6.88	13.98	67.00
March	17.95	21.55	10.70	9.63	6.12	7.68	15.90	61.00
April	21.45	24.70	13.05	0.00	6.05	8.52	18.62	59.00
May	25.08	28.15	16.23	0.00	5.45	10.23	21.73	58.33
June	28.35	30.58	19.58	0.00	5.55	12.22	25.03	60.00
July	27.67	31.52	21.60	0.00	5.47	11.97	26.37	65.67
August	25.58	32.00	21.90	0.00	4.63	11.22	26.67	68.00
September	21.88	30.73	20.42	0.00	4.32	10.08	25.13	65.83
October	17.12	28.37	18.07	0.00	4.00	8.68	22.68	66.83
November	12.45	24.38	14.35	19.12	4.13	6.88	18.73	69.17
December	10.55	20.35	10.52	31.05	5.13	6.12	14.77	69.83

SRAD: (MJ/m^2/day, TMAX: Maximum Air Temperature (degrees C), TMIN: Minimum Air Temperature (degrees C), RAIN: Average Precipitation (mm/day), WIND: Wind Speed (m/s), TDEW: Dew/Frost Point Temperature (degrees C), TMean: Average Air Temperature (degrees C), RH: Average Relative Humidity (%).

the beginning of the season and after the harvesting process.

Nutritional status of naval orange trees: In this regard leaf macro nutrient elements contents (N, P and K, %) in response to the various deficit irrigation strategies and organic mulch by rice straw were investigated as an indicator of nutritional status for Washington navel trees. Samples from the fourth and fifth leaves of base shoot were collected in October during both seasons. The samples were thoroughly washed with tap water, rinsed twice with distilled water and oven dried at 80°C till a constant weight and finely ground for determination of (1) Total Nitrogen: Total leaf (N) was determined by the modified micro Keldahl after (Pregl, 1945), (2) Total phosphorus: Total leaf (P) was determined by wet digestion of plant materials after the methods described by (Piper, 1958) and (3) Total potassium: Total leaf (K) was determined photometrically after (Brown and Lilliand, 1946).

Yield of navel orange: At harvest time of navel orange, yield as number of fruits Kg per tree and converted to ton per hectare were calculated.

Water productivity of navel orange: "$WP_{Navel\ orange}$" was calculated according to James (1988) by equation (2) as follows:

$$WP_{Navel\ orange} = Ey/Ir \quad (2)$$

Where: $WP_{Navel\ orange}$ is water productivity of navel orange ($kg_{Navel\ orange}/m^3_{irrigation\ water}$), Ey is the economical yield ($kg_{Navel\ orange}$/ha./season); Ir is the applied amount of irrigation water ($m^3_{irrigation\ water}$/ha./season).

Fruit juice chemical properties of navel orange: The following four fruit juice chemical properties of mature fruits were determined according to the A.O.A.C (1985) as follows: (1) Total soluble solids percentage (TSS %) fruit juice was determined using a Carl Zeiss hand refractometer. (2) Total titratable acidity percentage: Total acidity of fruit juice was estimated as g citric acid/100 ml juice according to the method described in A.O.A.C. (1990). (3) Vitamin C (mg/100 ml juice) was determined as the method described in A.O.A.C. (1990).

Table 2: Physical and chemical properties of the soil of the experimental area.

Physical properties				
Soil layer depth (cm)	0–25	25-50	50-75	75-100
Location of taking soil sample	12.5	37.5	62.5	87.5
Texture	Sandy	Sandy	Sandy	Sandy
Course sand (%)	46.66	54.74	37.86	38.77
Fine sand (%)	49.83	41.58	58.53	56.42
Silt+ clay (%)	3.51	3.68	3.61	4.81
Bulk density (t m^{-3})	1.68	1.67	1.67	1.69
Chemical properties				
$EC_{1:5}$ (dS m^{-1})	0.46	0.55	0.99	1.67
pH (1:2.5)	8.40	8.64	9.12	9.14
Total $CaCO_3$ (%)	7.04	2.42	4.68	5.51

Statistical Analysis

All the obtained data in the two combined seasons of the study were statistically analyzed using the analysis of variance method according to Snedecor and Cochran (1980). While, the values of least significant differences (L.S.D. at 5% level) were calculated to compare the means of different treatments.

Results

Water stress in the effective roots zone of naval orange tree

Water stress was studied to the roots of navel orange trees under different patterns of irrigation deficiency and different amounts of organic mulching with rice straw. Through the data shown on Fig. 4, it was found that the increase in the amount of rice straw used in the mulching process decreased water stress, and this was inferred by the approximate moisture content of field capacity and spacing from the permanent wilt point. It was the least water stress when 100% of total irrigation was added and the amount of rice straw mulching was 9 tons per hectare, and then came the arrangement after the treatment of partial root drying with organic mulching by rice straw with 9 tons per hectare. The biggest water stress on the navel orange trees roots was when 50% of the water needs were added without mulching.

Soil salts accumulation inside root zone

The soils salt concentration was measured for all treatments before the start of the season and then was measured after the end of the harvest season. The accumulation of soil salts in the area of root spread under the conditions of the factors under study was studied by the difference between the concentration of soil salts before and at the end of the season. It became clear from Fig. 5 that with the increase in the amount of organic mulching of rice straw, the accumulation of salts decreased in the area of root spreading, as well as the accumulation of soil salts by decreasing the amount of added irrigation water. The largest amount of soil salts accumulation was in the soil when the soil was not covered with organic mulching and when adding 100% of the irrigation needs, while the lowest amount of soil salts accumulation was when the soil was covered with 9 tons of rice straw/ha under partial root drying technique.

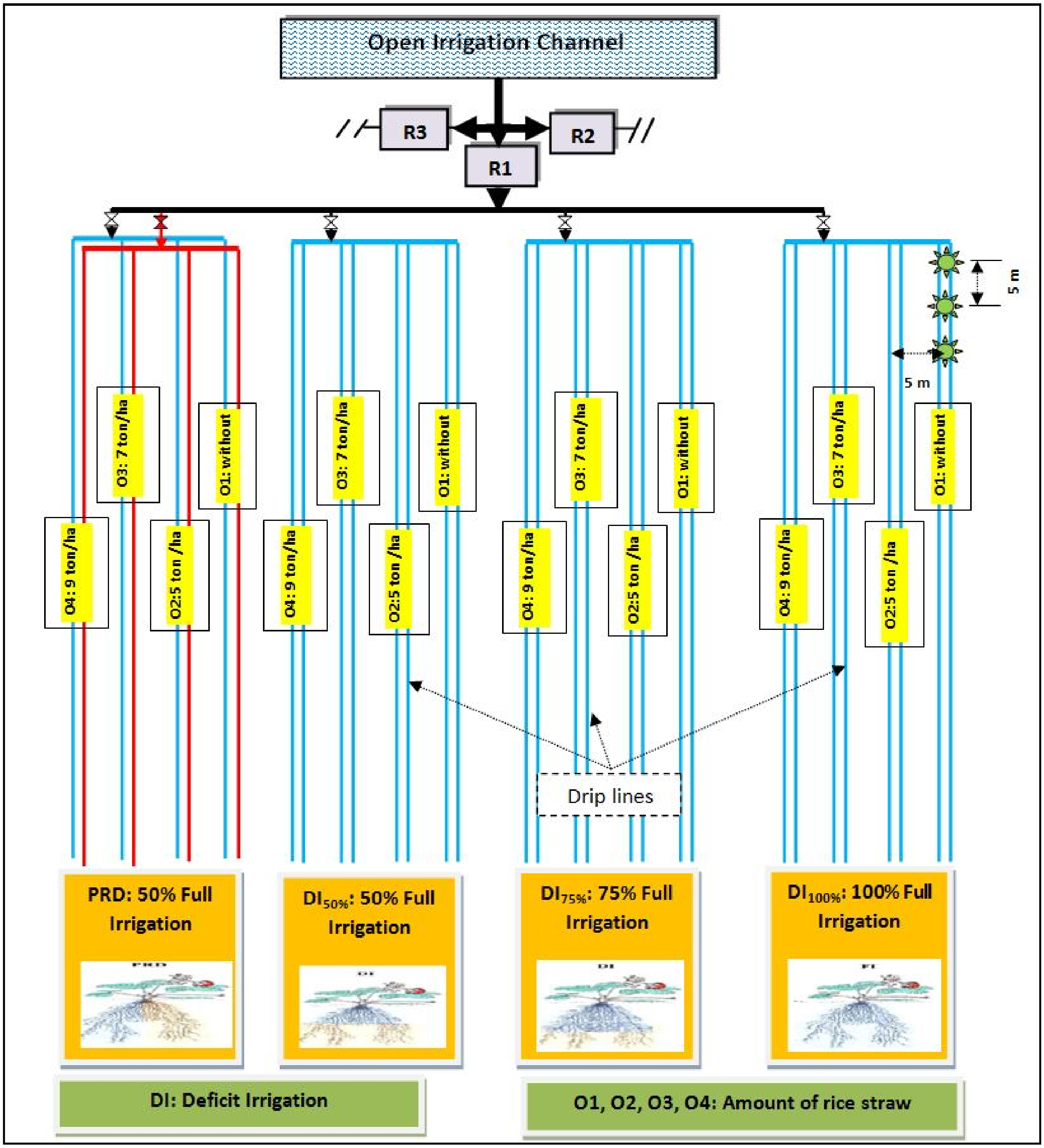

Fig. 2: Layout of the experimental design.

Nutritional status of naval orange trees

The nutritional status of navel orange trees was studied by measuring the concentration of some nutrients (N, P and K) inside the leaves of navel orange tree under all the factors under study. Fig. 6 illustrates the importance of organic mulching of rice straw, where by increasing the organic mulching rate of rice straw, the content of leaves increases from the nutrient elements. The highest values of leaf contents (N, P and K) were from nutrients when the organic mulching was 9 tons of rice straw for a hectare, with the addition of 100% of irrigation needs and with no significant differences between these high values and the application of the partial root drying technique at the same amount of organic mulching as rice straw. The lowest values of leaf contents were from

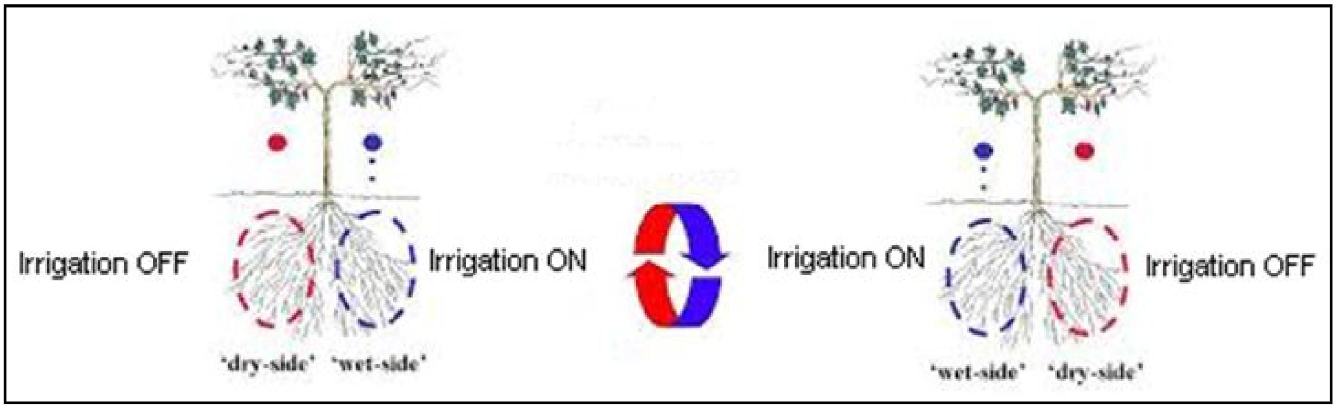

Fig. 3: Partial root zone drying technique, PRD.

nutrients (N, P and K) when adding 50% of the irrigation water requirement with no mulching of the soil surface.

Yield of navel orange

Fig. 7 and data in table 4 contain the effect of irrigation water applied; *i.e.* 100%, 75% and 50% of evapotranspiration (ETo) and PRD technique on yield of

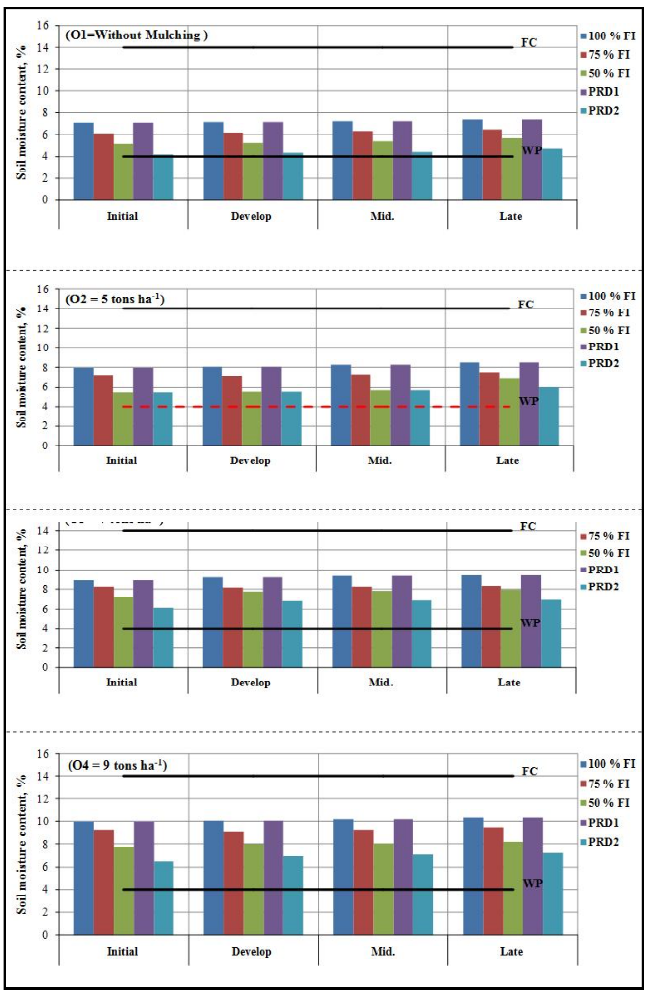

Fig. 4: Effect of deficit irrigation strategies and organic mulching by rice straw on water stress for the navel orange roots trees from the starting season to the end for seasons 2017/2018 and 2018/2019.

navel orange in 2017/2018 and 2018/2019 experimental seasons respectively. It is clear from that there were significant differences due to variation of irrigation rates on navel orange yield in both growth seasons. Where, the results were showed that irrigation at irrigation at either 100% or 75% ETc followed by PRD irrigation showed significant increases values comparable to 50% of ETc treatment on both seasons, respectively.

Fig. 7 and data in table 4 showed the effect of organic mulching rate, *i.e.* (0, 1 layer of rice straw (5 tons ha^{-1}), 2 layers of rice straw (7 tons ha^{-1}), 3 layers of rice straw (9 tons ha^{-1})) on yield of navel orange. It is clear from the obtained results that, in the two seasons, the yield of navel orange showed significant increases when the soil were covered with 3 layers of rice straw compared with either 1 layer of rice straw and 2 layers of rice straw. In addition, 0 (without mulching) exhibited significantly the lowest value in the same regard on both seasons.

Significant differences due to interaction between deficit irrigation and organic mulching were detected regarding the yield of orange, on both seasons as shown in Fig. 7 and data in table 4. It could be concluded that 3 layers of rice straw (9 tons ha^{-1}) followed by 2 layers of rice straw (7 tons ha^{-1}) treatment obtained significant increase in yield of navel orange compared with the other treatments under both PRD technique and 75% ETc as well as 100% ETc in the two seasons. It is obvious that the yield of orange decreased with decreasing water supply and no mulching, where the lowest values were recorded when the trees of navel orange were irrigated with 50% ETc under either 0 (without mulching "WM") or 1 layer of rice straw (5 tons ha^{-1}) in both seasons respectively.

Water productivity of navel orange

Water productivity of orange in the two experimental seasons of 2017/2018 and 2018/2019 was exhibited in Fig. 8 and data in table 4. Data showed that water productivity of navel orange in two seasons was significantly affected by irrigation water treatments. Irrigation with PRD surpassed significantly the other three levels of irrigation in water productivity of navel orange. Meanwhile irrigation at both 75%, 50% and 100% ETc recorded the lowest significant in water productivity values of navel orange on both seasons, respectively.

Effect of organic mulching on water productivity of navel orange is exhibited in Fig. 8 and table 4. Significant differences due to organic mulching were attained in water productivity of navel orange parameter in both experimental seasons. The highest significant values of water productivity were 4.229 and 3.977 $kg_{oranges\ fruits}$ m^{-3}_{water} on both seasons respectively under 3 layers of rice straw (9 tons ha^{-1}) treatment. Meanwhile, the lowest significant values of water productivity were 2.182 and 2.053 $kg_{oranges\ fruits}$ m^{-3}_{water} on both seasons respectively under WM.

As noticed in Fig. 8 and table 4 data showed that water productivity of navel orange had significant differences respond to interaction effect in the first and the second seasons. However, the water productivity of navel orange increased under PRD technique and organic

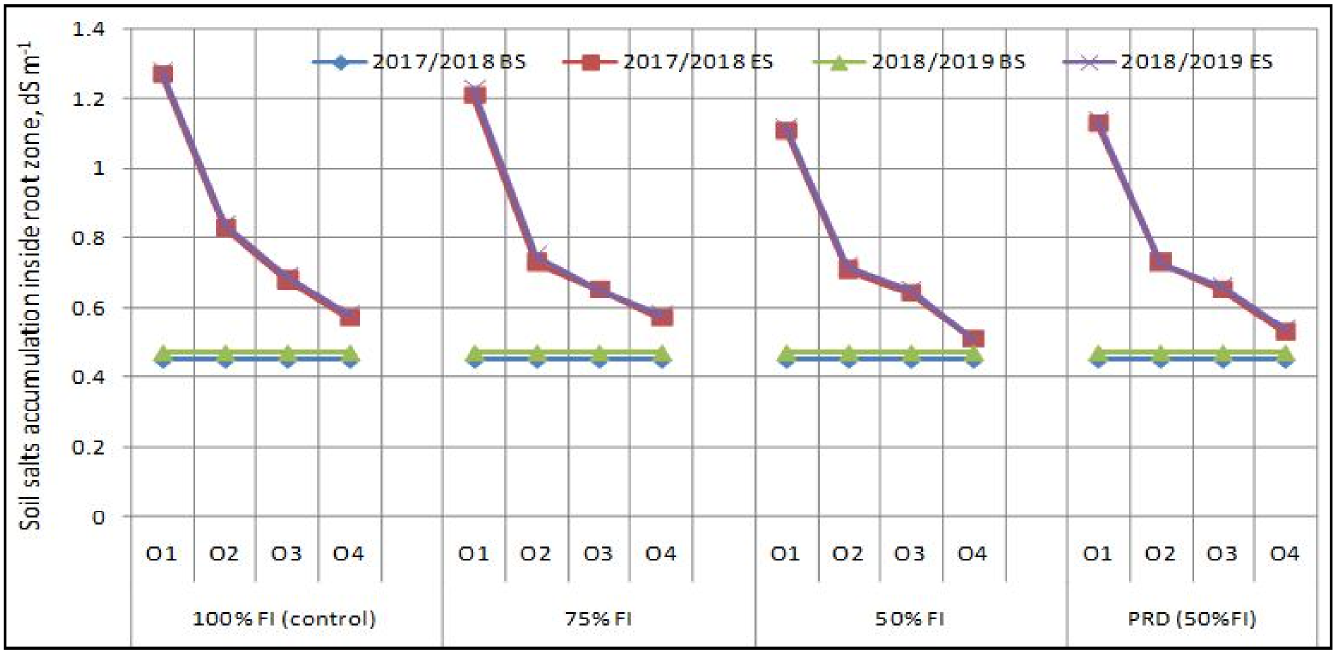

Fig. 5: Effect of deficit irrigation strategies and organic mulching by rice straw on soil salts accumulation inside root zone for seasons 2017/2018 and 2018/2019.

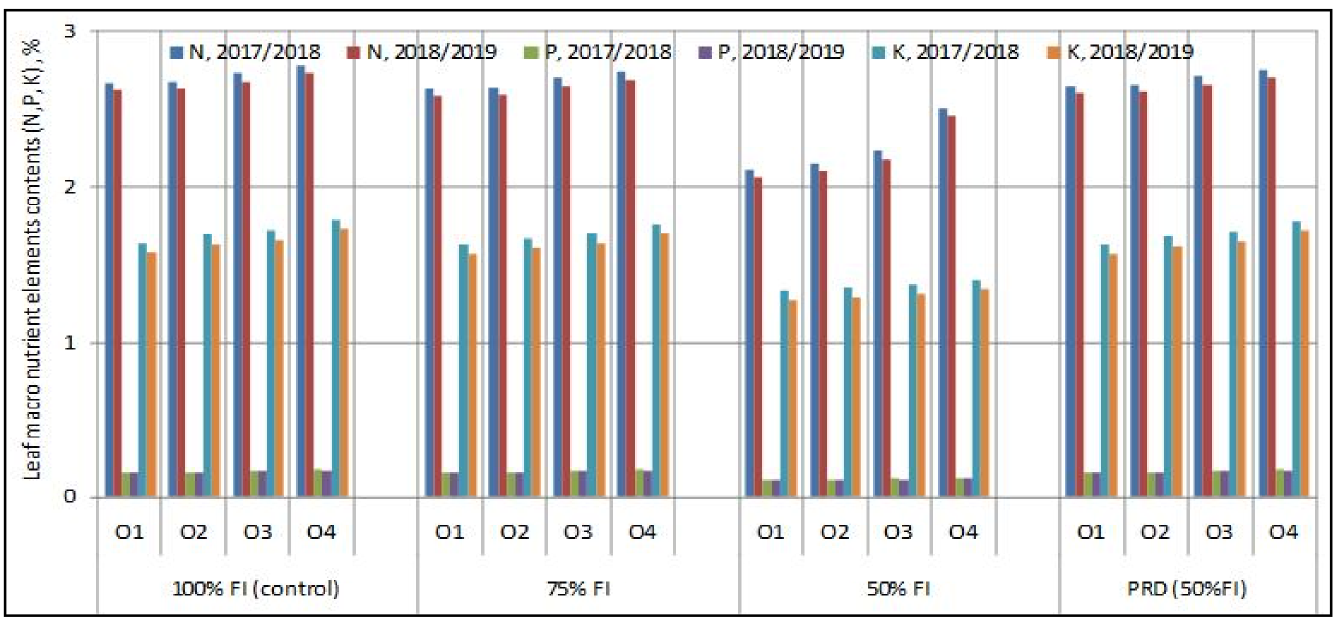

Fig. 6: Effect of deficit irrigation strategies and organic mulching by rice straw on nutritional status of naval orange trees for seasons 2017/2018 and 2018/2019.

values in both two growing seasons.

Some fruit juice chemical properties of navel orange

The effect of deficit irrigation strategies and organic mulching on some properties of chemical quality on orange juice during the two seasons of the study was also studied. The chemical properties of navel orange juice quality were also affected by the change of the study factors. All the characteristics under study improved by increasing the amount of organic mulching by rice straw and when applying the partial root drying technique and there was no significant difference between the values of quality properties in the previous treatment and adding 100% of the irrigation needs with adding 9 tons per hectare as a layer of organic mulching of rice straw as shown in the data shown in Fig. 8 and table 5.

Discussion

After analyzing and studying the data that we obtained and shown in the figures and tables above, it was revealed that by increasing the amount of rice straw used in the mulching, the productivity, quality and water productivity values of the navel orange crop improved, as well as when adding 100% of the water requirements and also when applying the partial root-drying technique due to the following reasons. First of all, The increase in the amount of the organic mulching of rice straw led to a decrease in evaporation from the soil surface and the moisture content remaining within the root zone for the

Table 3: Effect of deficit irrigation strategies and organic mulching by rice straw on leaf macro nutrient elements contents of fruitful navel orange trees during both 2017/2018 and 2018/2019 seasons.

Deficit Irrigation	Organic mulching by rice straw, ton ha^{-1}	N, %		P, %		K,%	
		2017/2018	2018/2019	2017/2018	2018/2019	2017/2018	2018/2019
Effect of deficit irrigation strategies on leaf macro nutrient elements contents of fruitful navel orange trees							
100% FI		2.72 a	2.67 a	0.17	0.16	1.71 a	1.65 a
75% FI		2.68 b	2.63 b	0.17	0.16	1.69 b	1.63 b
50% FI		2.25 c	2.20 c	0.13	0.12	1.36 c	1.30 c
PRD		2.69 ab	2.64 ab	0.21	0.20	1.70 ab	1.64 ab
LSD at 5%	0.032	0.032	N.S	N.S	0.017	0.017	
Effect of organic mulching by rice straw on leaf macro nutrient elements contents of fruitful navel orange trees							
	0	2.52 d	2.47 d	0.15	0.15	1.56 d	1.50 d
	5	2.53 c	2.48 c	0.19	0.19	1.60 c	1.54 c
	7	2.59 b	2.54 b	0.16	0.16	1.63 b	1.57 b
	9	2.70 a	2.65 a	0.17	0.16	1.68 a	1.62 a
LSD at 5%	0.017	0.017	N.S	N.S	0.019	0.019	
Effect of the interaction between deficit irrigation strategies and organic mulching by rice straw on leaf macro nutrient elements contents of fruitful navel orange trees							
100% FI	0	2.67 fgh	2.62 fgh	0.16	0.16	1.64	1.58
	5	2.68 efg	2.63 efg	0.16	0.16	1.69	1.63
	7	2.73 bcd	2.68 bcd	0.17	0.17	1.72	1.66
	9	2.78 a	2.73 a	0.18	0.17	1.79	1.73
75% FI	0	2.63 i	2.58 i	0.16	0.16	1.63	1.57
	5	2.64 hi	2.59 hi	0.16	0.16	1.67	1.61
	7	2.70 def	2.65def	0.17	0.17	1.70	1.64
	9	2.74 bc	2.69 bc	0.18	0.17	1.76	1.70
50% FI	0	2.11 m	2.06 m	0.12	0.12	1.33	1.27
	5	2.15 l	2.10 l	0.12	0.12	1.35	1.29
	7	2.23 k	2.18 k	0.13	0.12	1.37	1.31
	9	2.51 j	2.46 j	0.13	0.13	1.40	1.34
PRD	0	2.65 ghi	2.60 ghi	0.16	0.16	1.63	1.57
	5	2.66 ghi	2.61 ghi	0.16	0.16	1.68	1.62
	7	2.71 cde	2.66 cde	0.17	0.17	1.71	1.65
	9	2.75 ab	2.70 ab	0.18	0.17	1.78	1.72
LSD at 5%		0.034	0.034	N.S	N.S	N.S	N.S

FI: Full Irrigation, PRD: Partial Root zone Drying, O: Organic mulching by rice straw longest period possible which helped reduce the period of exposure of the roots to water stress, which also led to increased absorption of water and nutrients added to the soil for the purpose of fertilization that result agree with Eid and Negm (2018). The second reason, the increase in the amount of organic mulching by rice straw also led to a decrease in the accumulation of soil salts and that is logical, as the rate of evaporation from the soil decreases, the amount of accumulated soil salts decreases.

The values of productivity, quality and water productivity improved when adding 100% of water needs, and this is logical, as the roots of navel orange trees are less prone to water stress as trees take on full water needs, but the thing that calls for research is obtaining the same high values of productivity and quality and much higher in the values of water productivity, where half of the water needs have been added by applying the technique of partial root drying, as this may due to several advantages of the partial root drying technology, including the following: The theoretical background to PRD is that watering one part of the root maintains the top of the crops in favorable water conditions, while dehydration in another part of the roots leads to the formation of radical chemical signals (mainly hormones). Chemical signals generated from the root are transmitted to the top of plants to induce reduction in stomata conduction and fire growth (Dodd *et al*., 2006). PRD cuts from stomatal

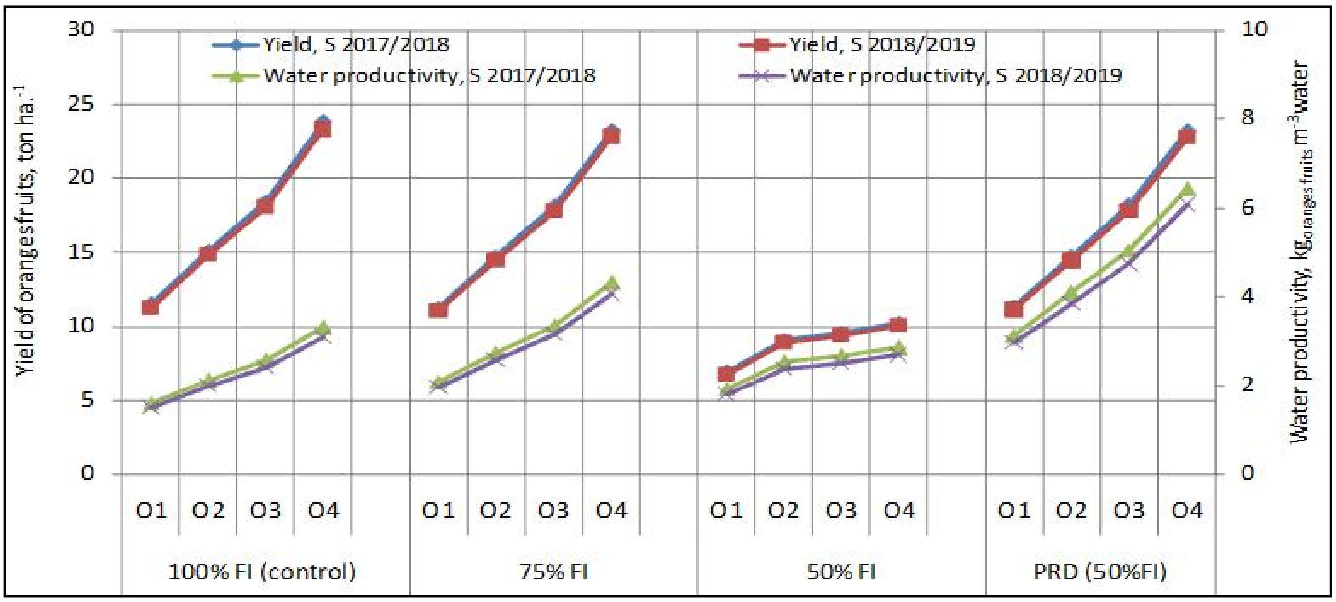

Fig. 7: Effect of deficit irrigation strategies and organic mulching by rice straw on the yield and water productivity of navel orange for seasons 2017/2018 and 2018/2019.

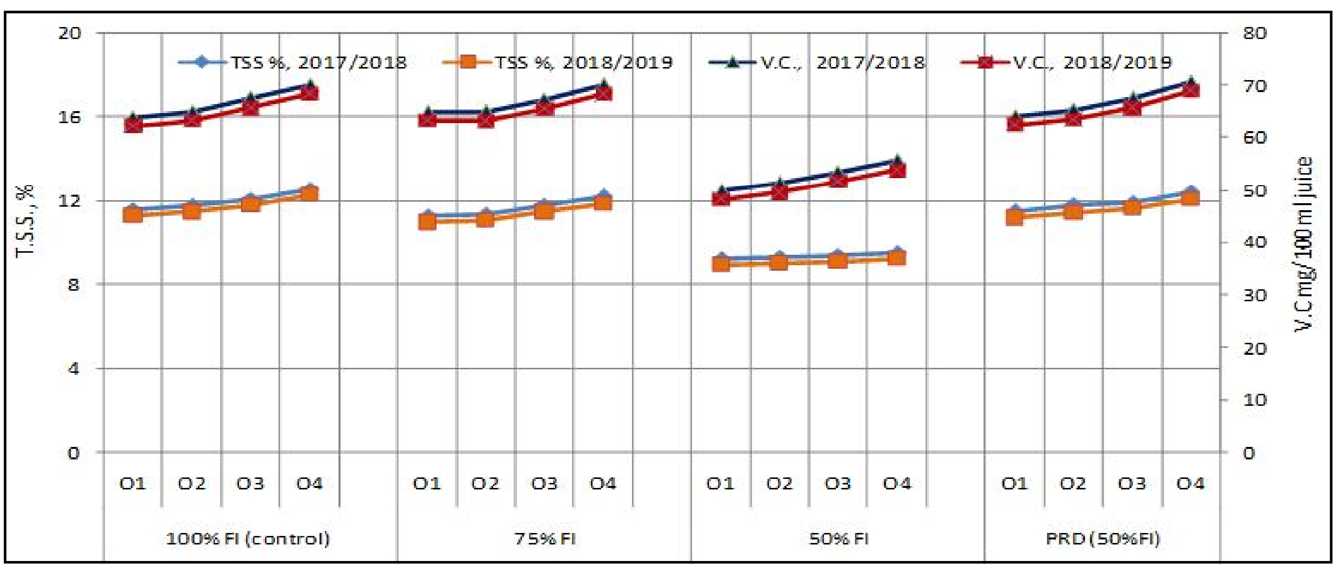

Fig. 8: Effect of deficit irrigation strategies and organic mulching by rice straw on some fruit juice chemical properties of navel orange for seasons 2017/2018 and 2018/2019.

conduction prevent serious water loss by transpiration (Chaves *et al.*, 2007). Several data from the literature have shown that impotence irrigation techniques, especially PRD, may increase water productivity while maintaining or improving the yield of irrigated plants. These effects can be explained by a wide range of positive responses to PRD stations. Changes in the stomatal morphological characteristics of the mouth observed in PRD plants (smaller guard cells and low stoma density) and decreased conductivity affected the transpiration and contributed to increased water productivity, in addition to enhancing the ability of photosynthesis having a positive effect on net photosynthesis (Wang *et al.*, 2012 b; Yan *et al.*, 2012). Also, reduced vegetative activity and the canopy area allowed better grain / fruit exposure to solar radiation (more light penetrates the canopy) and stimulated stimulation from plant tissue to fruits / grains that could thus improve yields and their quality (dos Santos *et al.*, 2007; Chaves *et al.*, 2010; Yang and Zhang, 2010; Zhang *et al.*, 2010; Price *et al.*, 2013).

Finally, the best treatment which achieve the best results under arid regions conditions and limited water resources in Egypt is applying partial root-drying technique and mulching the laterals or drip lines by 9 ton ha-1 from rice straw under navel orange trees.

Conclusion

By increasing the amount of rice straw used in the coverage, the productivity, quality and water productivity values of the orange crop improved, as well as when

Table 4: Effect of deficit irrigation strategies and organic mulching by rice straw on the yield and water productivity of navel orange for seasons 2017/2018 and 2018/2019.

Deficit Irrigation	Organic mulching by rice straw, ton ha^{-1}	Yield of oranges fruits (ton ha^{-1})		Water productivity (kg$_{oranges\ fruits}$ m^{-3}$_{water}$)	
		2017/2018	2018/2019	2017/2018	2018/2019
Effect of deficit irrigation strategies on the yield and water productivity of navel orange					
100% FI		17.20 a	16.86 a	2.390 c	2.246 c
75% FI		16.86 a	16.52 a	3.122 b	2.937 b
50% FI		8.948 b	8.770 b	2.486 c	2.338 c
PRD		16.84 a	16.51 a	4.678 a	4.402 a
LSD at 5%	0.4320	0.4238	0.1094	0.3159	
Effect of organic mulching by rice straw on the yield and water productivity of navel orange					
	0	10.22 d	10.02 d	2.182 d	2.053 d
	5	13.42 c	13.15 c	2.862 c	2.690 c
	7	16.08 b	15.75 b	3.404 b	3.202 b
	9	20.13 a	19.73 a	4.229 a	3.977 a
LSD at 5%	0.6361	0.6237	0.1410	0.1305	
Effect of the interaction between deficit irrigation strategies and organic mulching by rice straw on the yield and water productivity of navel orange					
100% FI	0	11.47 d	11.24 d	1.593 h	1.497 h
	5	15.13 c	14.83 c	2.103 g	1.977 g
	7	18.43 b	18.07 b	2.560 f	2.407 f
	9	23.77 a	23.29 a	3.303 d	3.103 d
75% FI	0	11.25 d	11.02 d	2.083 g	1.960 g
	5	14.76 c	14.47 c	2.733 ef	2.570 ef
	7	18.17 b	17.80 b	3.363 d	3.163 d
	9	23.27 a	22.80 a	4.310 c	4.053 c
50% FI	0	6.880 f	6.743 f	1.913 g	1.797 g
	5	9.080 e	8.900 e	2.523 f	2.370 f
	7	9.567 e	9.373 e	2.657 ef	2.500 ef
	9	10.27 de	10.06 de	2.850 e	2.683 e
PRD	0	11.30 d	11.08 d	3.137 d	2.957 d
	5	14.70 c	14.41 c	4.087 c	3.843 c
	7	18.13 b	17.77 b	5.037 b	4.737 b
	9	23.23 a	22.77 a	6.453 a	6.070 a
LSD at 5%	1.272	1.247	0.2820	0.2611	

FI: Full Irrigation, PRD: Partial Root zone Drying, O: Organic mulching by rice straw adding 100% of the water requirements and also when applying the root-drying technique.

The increase in the amount of the organic cover of rice straw led to a decrease in evaporation from the soil surface and the moisture content remaining within the root zone for the longest period possible which helped reduce the period of exposure of the roots to water stress, which also led to increased absorption of water and nutrients added to the soil for the purpose of fertilization.

The increase in the amount of organic cover in rice straw also led to a decrease in the accumulation of salts. This is logical, as the rate of evaporation from the soil decreases, the amount of accumulated salts decreases.

The values of productivity, quality and water productivity improved when adding 100% of water needs, and this is logical, as the roots of orange trees are less prone to water stress as trees take on full water needs, but the thing that calls for research is obtaining the same high values of productivity and quality and much higher in the values of water productivity, where half of the water needs have been added by applying the technique of partial root drying, as this was due to several advantages of the partial root drying technology. Partial root drying technique reduction of stomatal conductance prevent serious water loss by transpiration.

The best treatment which achieve the best results under arid regions conditions and limited water resources in Egypt is applying partial root-drying technique and mulching the laterals or drip lines by 9 ton ha^{-1} from rice straw under navel orange trees.

Table 5: Effect of deficit irrigation strategies and organic mulching by rice straw on some fruit juice chemical properties of navel orange for seasons 2017/2018 and 2018/2019.

Deficit Irrigation	Organic mulching by rice straw, ton ha^{-1}	TSS %		Total acidity %		Total sugars, %		V.C mg/100 ml juice	
		2017/2018	2018/2019	2017/2018	2018/2019	2017/2018	2018/2019	2017/2018	2018/2019
Effect of deficit irrigation strategies on some fruit juice chemical properties of navel orange									
100% FI		12.02 a	11.73 a	0.79 b	0.77 b	8.29 a	8.09 a	66.66a	64.96a
75% FI		11.68 c	11.38 c	0.79 b	0.77 b	8.26 a	8.06 a	66.84a	65.14a
50% FI		9.39 d	9.09 d	0.97 a	0.95 a	6.38 b	6.18 b	52.63b	50.93b
PRD		11.91 b	11.61 b	0.81 b	0.79 b	8.28 a	8.08 a	66.97a	65.27a
LSD at 5%		0.095	0.095	0.045	0.045	0.089	0.089	0.530	0.530
Effect of organic mulching by rice straw on some fruit juice chemical properties of navel orange									
	0	10.91 d	10.61 d	0.87 a	0.85 a	7.60 d	7.40 d	60.87d	59.17d
	5	11.08 c	10.78 c	0.85ab	0.83ab	7.77 c	7.57 c	61.64c	59.94c
	7	11.32 b	11.02 b	0.84 b	0.82 b	7.85 b	7.65 b	63.96b	62.26b
	9	11.69 a	11.39 a	0.81 c	0.79 c	7.99 a	7.79 a	66.64a	64.94a
LSD at 5%		0.160	0.160	0.027	0.027	0.038	0.038	0.489	0.489
Effect of the interaction between deficit irrigation strategies and organic mulching by rice straw on some fruit juice chemical properties of navel orange									
100% FI	0	11.60	11.30	0.82	0.80	8.13 d	7.93 d	64.05	62.35
	5	11.80	11.50	0.80	0.78	8.26bc	8.06bc	65.01	63.31
	7	12.10	11.80	0.79	0.77	8.32 b	8.12 b	67.46	65.76
	9	12.60	12.30	0.76	0.74	8.44 a	8.24 a	70.12	68.42
75% FI	0	11.30	11.00	0.81	0.79	8.10 d	7.90 d	65.00	63.30
	5	11.40	11.10	0.80	0.78	8.23 c	8.03 c	64.93	63.23
	7	11.80	11.50	0.79	0.77	8.30bc	8.10bc	67.38	65.68
	9	12.20	11.90	0.76	0.74	8.40 a	8.20 a	70.06	68.36
50% FI	0	9.25	8.95	1.00	0.98	6.03 h	5.83 h	50.11	48.41
	5	9.34	9.04	0.97	0.95	6.33 g	6.13 g	51.33	49.63
	7	9.41	9.11	0.96	0.94	6.47 f	6.27 f	53.49	51.79
	9	9.56	9.26	0.93	0.91	6.68 e	6.48 e	55.59	53.89
PRD	0	11.50	11.2	0.83	0.81	8.13 d	7.93 d	64.33	62.63
	5	11.77	11.47	0.81	0.79	8.25bc	8.05bc	65.27	63.57
	7	11.97	11.67	0.80	0.78	8.31 b	8.11 b	67.50	65.80
	9	12.40	12.10	0.78	0.76	8.42 a	8.22 a	70.78	69.08
LSD at 5%		N.S	N.S	N.S	N.S	0.075	0.075	N.S	N.S

FI: Full Irrigation, PRD: Partial Root Drying, OM: Organic mulching by rice straw

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