WATER USE EFFICIENCY (WUE) IN A HIGH DENSITY OLIVE GROVE: VARIETY, PLANTING DENSITY AND IRRIGATION EFFECTS

Athanasios Gertsis[1]and Gregory Yannakis[1]
[1]Perrotis College-American Farm School, Thessaloniki, Greece
agerts@afs.edu.gr,gyiann@perrotis.edu.gr

ABSTRACT

The new production systems in olives, with high (HD) and super high planting (SHD) densities, adapted fully to mechanical harvesting with row harvesters, represent a great challenge for all olive production countries. The available information is scarce and very localized, in terms of irrigation amount needed by the systems around the world. Great variations also exist, indicating that new approaches must be adapted to minimize water resources and increase the water use efficiency (WUE) in a tree species, which is a historical and cultural trademark in the Mediterranean areas and is rapidly expanding in all over the world. This study presents data from along-term high-density olive grove in Greece, a unique study where all major agronomic inputs are evaluated (varieties, planting densities, irrigation and ground and foliar fertilization rates). Results in the past years revealed that there are many opportunities to increase irrigation water use efficiency (WUE) and achieve sustainable production. The study follows a holistic approach and precision agriculture technologies are applied to increase the overall sustainability value of these systems. The WUE of the super high densities were higher than the lower densities, in both varieties used (Koroneiki and Arbequina), while Koroneiki was higher than Arbequina in WUE and production. These trends were also shown in the past years, under different climate conditions, while 2018 year was adverse for olive production in Greece and in most Mediterranean areas.

Keywords:olive, high density, Water Use Efficiency (WUE), Koroneiki, Arbequina.

1. INTRODUCTION

The use of water in agriculture (both in crop and animal production systems) represents a very significant portion of the total deposits in Earth and is under strong monitoring globally in the last decades. Optimal use of irrigation water will result in a higher Water use efficiency (WUE). In a generic agronomic approach, the crop WUE is meant to be the ratio of total water used by crops (irrigation+rainfall) over the total economic yield achieved at field conditions (Kijne et al., 2003; Molden et al., 2010a). Olive production systems can be classified in two main groups, based on the final type of product: table olive production which requires significant amount of irrigation water, while olive oil production systems can be either rainfed or irrigated. Recently the new high-density linear systems require irrigation to produce annually and sustainably. However, there are controversial information on the literature about the amount as well as the WUE of these systems. The complexity of the irrigation scheduling is increased by the important changes in the climate and the new olive cropping systems that emerged over the last 25 years, and by the current wide diversity of production systems inputs and cultural practices (tree density, irrigation water availability and use, fertilization practices, etc.).Approaches to schedule irrigation are based on developing specific growth stage ET coefficients and specific ET models (Ortaz et al., 2016; Subedi and Chavez, 2015), or stem water potential (SWP) periodic measurements.

In the context of this study, the agronomic approach will be used, since the emphasis is on how much total water was provided to the field (total of rainfall and irrigation) and how much economic product was output. This is a simple but more realistic approach and easily measured even by farmers. Also, the irrigation timing was mainly based on "crop available water" sensed by the plant in the form of soil water potential (Ψs).

Increases in water use efficiency are commonly cited as a response mechanism of plants to moderate to severe soil water deficits, and has been the focus of many programs that seek to increase crop tolerance of drought e.g. project AZORT (http://www.cespevi.it/azort/azort.html). However, there is some question as to the benefit of increased water-use efficiency of plants in agricultural systems, as the processes of increased yield production and decreased transpiration water loss (that is, the main driver of increases in water-use efficiency) are fundamentally opposed (Bacon, 2004).If there existed a situation where water deficit induced lower transpiration rates without simultaneously decreasing photosynthetic rates and biomass production, then water-use efficiency would be both greatly improved and a desired trait in crop production.

This study is a follow up of the past years (Gertsis et al., 2017) and differentiates in the new approach with the use of water marks sensors to monitor the soil water potential (Ψs,) rather than the soil volumetric water content (VWC) or stem water potential (SWP) used in few studies reported. It is not a labor intensive and continuous monitoring is technically feasible.

2. METHODOLOGY

The Educational-Research-Demonstration olive grove (N40° 34' 13.42" and E22° 59' 12.25") was established in late 2011 in Perrotis College, American Farm School of Thessaloniki, Greece (Fig. 1). It aims in applications of precision agriculture methodologies (Gertsis et al., 2013) and in long-term evaluation of the new linear production systems using high planting densities and adapted to fully mechanical harvesting. The grove Includes the following main treatments: two varieties (Koroneiki and Arbequina), three planting densities acronym Super-High Density (SHD), High density (HD) and Medium (MD) density at 1670, 1000 and 500 trees/ha, correspondingly, two irrigation levels (Conventional irrigation- CIand Deficit irrigation -DI) and two fertilization levels (conventional fertilization and 50% less). A number of trees from each treatment were harvested manually. CI and DI were calculated based on ET and soil water potential (Ψs) monitored by watermark soil moisture sensors (Fig. 2) installed in 6 lines and at three depths (20-40-60 cm). The critical value of SWP (Soil Water Potential) for deficit irrigation was set at 120 mbars (0.012MPa), a reference set value based on the typical root depth system of the linear olive systems. It was observed that the majority of the active root system is within the reported depth of 0-60 cm, due to the drip irrigation system used, the high planting density and the tree height, usually not exceeding 2.5 m to facilitate mechanical harvesting with straddle type harvesters.

The total amount of water used as irrigation and was rainfall 484 mm for the season to harvesting (Figure 3). It was monitored by a nearby installed automated weather station (Davis Vantage Pro, http://www.davisnet.com/solution/vantage-vue/) in the growing season ending to before harvesting, and was used to estimate WUE (total water used/total yiled) The average yield for each planting density across all irrigation treatments values and varieties will be presented.

Figure 1. The Educational-Research-Demonstration olive grove in Perrotis College, American Farm School of Thessaloniki, Greece

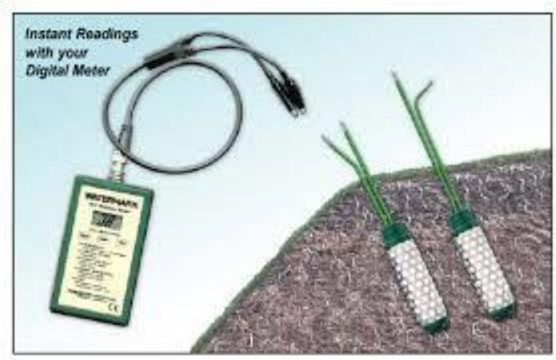

Figure 2. The soil sensors (watermarks) measuring soil water potential at 3 depths (20-40-60 cm)

3. Results

The results from the yield and the WUE for each planting density and the 2018 growing season are shown on Table 1.

Table 1. Yield, irrigation, and Agronomic Water Use Efficiencies (WUE) for the three planting densities (SHD-HD-MD) in 2018 season

Irrigation treatment	Variety	Average yield/tree (kg)			Total irrigation (mm)		
		SHD	HD	MEDIUM	SHD	HD	MD
Full	KORONEIKI	3.22	3.12	4.12	72.65	43.50	21.75
Deficit	KORONEIKI	3.15	2.95	4.09	44.59	26.70	13.35
Full	ARBEQUINA	1.80	1.95	2.01	72.65	43.50	21.75
Deficit	ARBEQUINA	1.67	1.72	1.98	44.59	26.70	13.35

AVERAGE YIELD (Kg/ha) adjusted			WUE(kg m^{-3})		
SHD	HD	MD	SHD	HD	MD

6990.6	4056.0	2678.0	1.26	0.77	0.53
6838.6	3835.0	2658.5	1.29	0.75	0.53
3907.8	2535.0	1306.5	0.70	0.48	0.26
3625.5	2236.0	1287.0	0.69	0.44	0.26

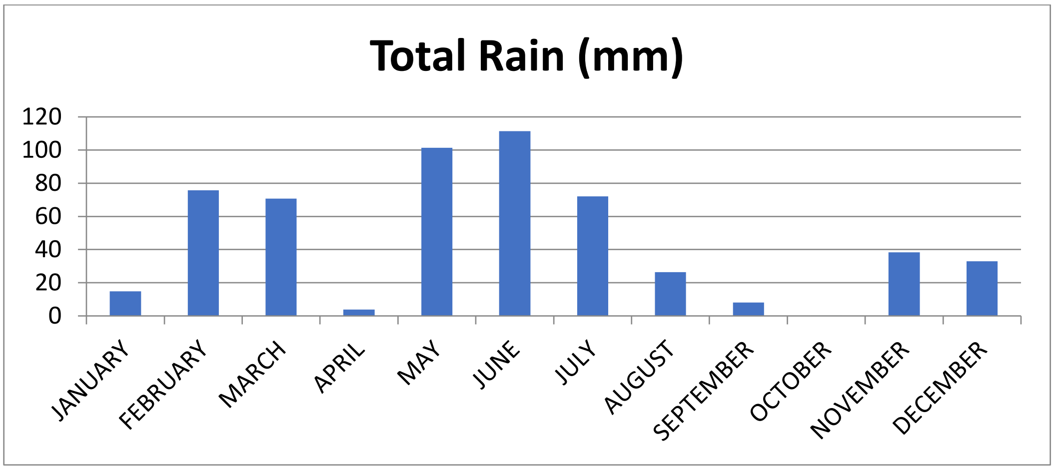

Figure 3. Rainfall amount and distribution in 2018 (Thessaloniki, Greece)

4. DISCUSSION

Table 1 presents the calculated WUE for all three planting densities as an average across irrigation treatments and varieties for the 2018 growing season. The WUE trend of the high density systems shown is in close agreement but lower, when adjusted, with other conventional olive production systems (Hijazi et al., 2014 and Nuberg and Yunsua, 2003). Since all the trees are relatively young in age (< 7-8 years), the WUE was affected by the planting density and so, the SHD system produced the highest WUE as compared with the HD and the MD density. It must be mentioned that this year (2018) was considered one of the worst in terms of production in Greece, for both table olives and olive oil. This was due to unusual climate conditions (heavy rainfall in the flowering period (April-May) and in summer (May to early August. In addition it was followed by a continuous drought period from early August to October and the high damages caused by the insect *Bactrocera* (Dacus) *oleae* and the fungus *Colletotrichum*, and mainly by C. *gloeosporioides*, C. *acutatum* και C. *clavatum*. Therefore, the data presented herein are indicative of a comparatively very low yielding olive production season. The olive oil quality reported in another study, followed the same trends with yield and WUE among all treatments and in general was low.

Hijazi et al. (2014) reported from an olive grove in Syria, WUE values ranging from 0.4 to 2.1 kg $m^{-3}$for a range of irrigation systems. Average production of fruits was 8.53 tons/ha or 48 kg/tree and a planting density of 180 trees/ha. Using drip irrigation, WUE increased from 1.3 kg/m^3 to 2.36 kg/m^3 compared with surface irrigation. These values are for conventional planting systems and older trees (18 years old) and are comparable to the high-density systems of the presented study under drip irrigation, considering approximately similar tree age and yields/ha. Nuberg and Yunusa (2003) reported for Australia the WUE for two years ranged from 0.4 to 2.1 kg/m^3.

The SHD olive systems have an advantage during the first 4-10 years, due to higher population per unit area and, therefore, more efficient use of water and fertilizer inputs; however, the yield of the SHD systems was reported to level-off or slightly decreasing after 8-10 years. In this later period, the HD systems may have an overall advantage in WUE. This is a speculation not yet reported for Greece.

Comparing the CI and DI irrigation treatments, it was shown that the deficit irrigation has a very similar WUE to the conventional while Koroneiki variety had a much higher WUE compared to Arbequina, under the same irrigation amounts provided to both varieties. The performance of Koroneiki, was consistent in previous years, under more optimum climatic conditions (Gertsis et al., 2017).

5. CONCLUSIONS

It appears that olive trees in super high density (SHD) systems utilized better the total water in the field, per unit area, than the lower density systems and resulted in a higher WUE. These results followed the same trends shown in previous years (Gertsis et al., 2017) although this year was an exceptionally low production situation. Koroneiki out-yielded Arbequina in a variety of climate conditions. An important conclusion, verified again in this year, is that the WUE of the low irrigation levels are very competitive and can result in significant savings of irrigation and other production inputs for the new olive production systems. This long-term study will produce in the forthcoming years, additional data to further evaluate the interaction of WUE and the Total Fertilizer Use Efficiency (TFUE), in an effort to increase the WUE of the systems evaluated and provide more practical information to olive farmers for optimal management of high density olive systems in Greece and worldwide.

ACKNOWLEDGMENTS

The authors express their gratitude to Anastasopoulos Nurseries, Greece (www.anastasopoulos-nurseries.com), for providing the plant materials, their harvesting equipment and their valuable know-how on these olive production systems.

REFERENCES

Bacon, M. 2004. Water Use Efficiency in Plant Biology. Oxford: Blackwell Publishing Ltd.

Gertsis, A., D. Fountas, I. Arpasanu and M. Michaloudis. 2013. Precision Agriculture applications in a high density olive grove adapted for mechanical harvesting in Greece. Procedia Technology 8 (2013) 152-156

Gertsis, A., K. Zoukidis and A. Mavridis. 2017. Evaluation of the water footprint and water use efficiency in a high density olive (*Olea europea* L.) grove system. *European Water* Special Issue III-59. Paper No. 49. EWRA2017 - 10th Word Congress on Water Resources and Environment). http://www.ewra.net/ew/issue_59.htm

Hijazi, A., M. Doghoze, N. Jouni, V. Nangia, M. Karrou, and T. Oweis. 2014. Water requirement and water-use efficiency for olive trees under different irrigation systems. 7th International Conf. on Water Resources in the Mediterranean Basin, Oct 10-12, Marrakech, Morocco.

Kijne, J.W., Barker, R., and Molden, D. (eds) 2003. Water Productivity in Agriculture: Limits and Opportunities for Improvement. Comprehensive Assessment of Water Management in Agriculture Series 1. CAB International, Wallingford, UK in association with International Water Management Institute (IWMI), Colombo.

Molden D, Oweis T, Steduto P , Bindraban P, Hanjra MA , Kijne J. 2010a. Improving agricultural water productivity: Between optimism and caution. Agricultural Water Management 97: 528–535

Nuberg, I. and I. Yunusa. 2003. Olive water use and yield – monitoring the relationship. RIRDC Publication No 03/048 RIRDC Project No UA-47A

Orgaz, F., Testi, L., Villalobos, F.J., Fereres, E. 2006. Water requirements of olive orchards II: determination of crop coefficients for irrigation scheduling. Irrigation Science, 24:77-84.

Subedi, Abhinaya and José L. Chávez. 2015. Crop Evapotranspiration (ET) Estimation Models: A Review and Discussion of the Applicability and Limitations of ET Methods. Journal of Agricultural Science; Vol. 7, No. 6; 2015.

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