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The Effect of Different Irrigation Methods in Biodiesel Production from Sunflower

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Abstract

The rational use of irrigation water and the production of energy from renewable sources are among the major concerns of the international scientific community in recent years. Against this background, the Agricultural Hydraulics Laboratory of the University of Thessaly conducted research related to the effect of two different irrigation methods in the production of biodiesel from sunflower crop. Two treatments were organized, in four replications for the growing seasons of the years 2011 and 2012. The treatments were: a) the surface drip irrigation in which the irrigation was scheduled by the Penman-Monteith method and b) the surface drip irrigation in which the irrigation was scheduled by an automatic evaporation pan.

Keywords: Sunflower; Methods of irrigation; Biodiesel; Saving irrigation water

Introduction

The global energy issue which is observed in modern times is growing due to the technological progress and the growth of the world population [1]. As reported by Raum [2], 60% more energy than today will be used in 2030 and according to estimations of experts, oil reserves are sufficient at least until then, although from 2015 onwards in many parts of the world the deposits will begin to run out [3]. Therefore, the scientific interest of the world scientific community about the use and the promotion of renewable energy sources including the energy crops are increasing [4,5]. The biomass that is produced by energy crops is one of the most promising alternatives to fossil fuels, because of its many advantages [6] and mainly because of the effective management of the emissions of greenhouse gases [7,8]. The term "biomass" characterizes each material derived from living or recently deceased, organisms either plant or animal [9]. In Greece, it is possible to cultivate different energy plant species [10], one of which is the sunflower (*Helianthus annuus* L.), which is a plant of high economic importance because of the oilseed.

The sunflower is cultivated worldwide mainly for the edible oil production [11,12] and for other edible compositions because of its high content of oil (about 50 wt%), that includes a high amount of protein, which is up to 50-60% [13]. Industrially it is used for the production of liquid biofuel, the biodiesel [14]. As a plant, it is considered to be relatively resistant to drought due to its deep root system [15], but its greater demands of water are presented from the unfolding of the inflorescences till the anthesis. In Greek conditions, quite satisfactory yields can be achieved by irrigation even if it is deficient [16]. Water saving and biodiesel production, use for irrigation methods applicable on sunflower plant. Furthermore, because of its root system, it uses effectively the nutrients of the soil elements [17], so the plant com is cultivated under low input circumstances.

Water constitutes an essential natural resource for the economic development of each country, based either on the farming or the industrial sector. But now, it is a crucial natural resource in limited availability. The main water user worldwide is agriculture. It uses approximately 80% of the total amount of water. In Central and Northern European countries, irrigation is carried out only during dry summers to improve production, while for the countries of southern Europe irrigation is necessary for the crops [18]. That is why in Greece, agriculture is the largest water consumer, with participation equivalent to the 87.4% of water. Many researchers have studied the dependence of agricultural production on the frequency and quality of irrigation water [19]. Generally it has been found that the existing regime in the irrigation sector is characterized by lack of water or waste of the existing. Based on the above, water saving and effective management, which requires the accurate determination of crop water needs, and are internationally recognized as key priorities [20,21]. The purpose of the effective management of irrigation water is to increase the economic value of a crop, reducing water and energy consumption [22,23]. Nowadays, the global scientific interest focuses on irrigation water saving, through the study of known irrigation scheduling methods using new technologies, as a small percentage saving can achieve huge amounts for the other competitive uses of water. This issue has preoccupied several researchers, including Sakellariou - Makrantonaki et al. [24]. For all the above reasons, it was necessary to study the effect of two irrigation scheduling methods, during the development and the production of the sunflower, as well as the irrigation water saving. The programming methods that were investigated were the widely known method of Penman-Monteith and the automatic evaporation pan. This research aims at maximizing energy benefits, namely the liquid biofuel production from the cultivation of the energy sunflower plant, using modern irrigation systems and also maximizing the irrigation water saving.

Materials and Methods

The experimental procedure for achieving this objective was held at the Farm of University of Thessaly, Greece, during the years 2011 and 2012. A completely randomized design was used and included two treatments, in four replications (Figure 1). The treatments were organized as: a) surface drip irrigation, where the irrigation was scheduled by the Penman – Monteith method (PM) and b) surface drip irrigation where the irrigation was scheduled by an automatic evaporation pan (AUTO (E)). The irrigation dose which was applied

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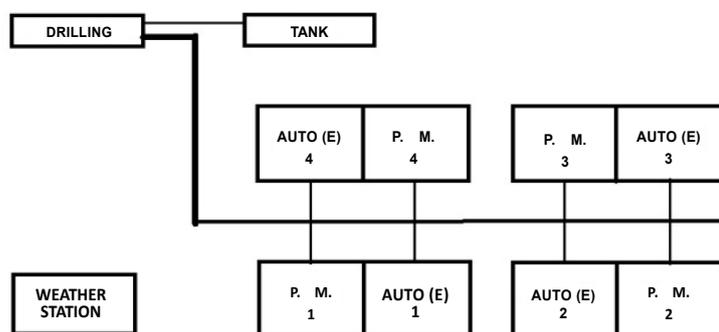
Figure 1: Layout of the treatments and replications in the experimental field.
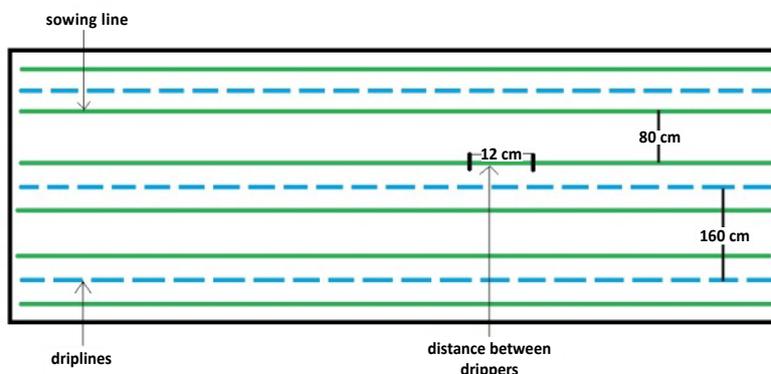

Figure 2: Layout of the seed lines and the drip irrigation pipes.

was equal to 100% of the crop water needs, for both treatments. Furthermore, the cultivation tasks that were used were the same for all the treatments and in accordance with the general cultivation practice in the region.

Soil characteristics

The mechanical composition of the soil of the experimental plot upon analysis was 48% sand, 23% clay and 29% silt, while the soil pH was 7.8 and the organic substance was 0.97% [25]. Before the initial installation of the crop in the experimental field, soil samples were taken, in order to measure in the laboratory the soil parameters which included the field capacity, the permanent welting point and the bulk density.

Cultivation

The area of each experimental unit (plot) was about 56 m² and included six seeding lines. The distance between rows was 80 cm, while the distance of the plants on the line was about 12 cm. The drip lines were constructed from 20 mm diameter polyethylene and spaced apart 160 cm (Figure 2). The drippers were self-cleaning and self-regulating, with an equidistance of 80 cm. The value of the emitter flow rate was 2.3 litre/h. The sowing was performed using a crop seeder for linear cultivations with four units, in the first ten days of April for both periods. A Pioneer brand sunflower hybrid was used (PR64A63), in an amount of 0.89 kg/ha for both periods. During the two growing periods pre-emergent and post-emergent herbicides were used. The quantity of the application of STOMP herbicide was 350 cc/ha. During the growing periods no kind of fertilization was carried out in the context of low input.

Measurements

An automatic weather station was used for the collection of meteorological data (MetosCompact, of Pessl Instruments GmbH Company), and was located within 50 m from the experimental plot. It had the ability to record at 12 min the air temperature (ºC), the relative air humidity (%), the rainfall (mm), the wind speed at 2 m above ground level (m*s⁻¹) and the solar radiation (W*m⁻²). Moreover, it could calculate the reference evapotranspiration with Penman-Monteith method, through an equation. In surface drip irrigation, in which the scheduling of irrigation was based on the method of Penman – Monteith, the meteorological station and a programmer, which defined the beginning and the duration of irrigation, had been used. The start of the irrigation was carried out when 30 mm of evaporation was concentrated. In both treatments, the limit of 30 mm of irrigation dose was set so as to be less than or at most equal to the practical irrigation dose, as estimated by the hydrodynamic parameters of the experimental field soil (the water retention, the permanent wilting point, the specific gravity ground effect) the depth of the root zone of the crop, the daily evapotranspiration reference etc. The interruption of the irrigation was set to be done when a specific number of hours were completed. The number of hours was related to the hourly flow of water drippers, their distance on and between the irrigation lines.

In surface drip irrigation, the irrigation scheduling was performed by the automatic evaporation pan, in which there was a water-level measuring probe (WL_1), and the operation of the irrigation was based on the method of evaporation pan type A. By using this system, the physical presence of the operator to obtain the indication

of evaporation, for the beginning and the end of irrigation, is not required. The sensor recorded the change in the value of the electric potential in the perforated pipe within the basin of the evaporation pan, where it was positioned. The change in value of the electric potential was transferred to the Data logger and translated by the equation in mm of water which existed in the pan. In the Data logger a command was set to sum the difference of daily evaporation rates and then give the command in Relay to start the irrigation when the sum mentioned before reached the 30 mm.

By the use of the statistical package SPSS Version 18, data processing was carried out. The statistical analysis was held by the method of Analysis of Variance (ANOVA) (at the 5% significance level) and the classification of averages was done by the application of Duncan's multiple-range test [26].

During the growing periods 2011 and 2012 weekly measurements of crop growth characteristics were carried out from the middle sowing lines of each plot, in order to avoid interactions from neighboring seed lines and experimental plots. Also, indications of the hydrometers were taken before and after for each irrigation. After the appropriate laboratory analysis of the final seed production, the production of sunflower oil was revealed and therefore the energy (biodiesel), which is the main objective of this investigation.

Results

The climate data of the growing periods 2011 and 2012 and of the last twenty five years are presented in Figure 3. The figure shows that the air temperature during the period of the study did not fluctuate much from the values of an average year. Generally, in the last 25 years (including 2011 and 2012), the daily average air temperature ranging from about 20°C in mid-May to 25°C in late June remained constant at about 24–27°C in July and early August and dropped in values between 18 and 23°C from mid-August to mid-September. The total average

rainfall, in June and July over the past 25 years, has been about 44 mm. The rest of the growing period is usually dry with only 96.4 mm of rain falling from mid-July until mid-October. Especially during the years 2011 and 2012, the mean daily air temperature did not differ much from the average values of the past 25 years. However, the mean daily precipitation was higher during May of 2012 than the average values of the last 25 years while during the August of 2011 the precipitation was higher than the average. Under these circumstances and more generally under the climatic conditions in Central Greece, most summer crops, including sunflower, need irrigation to reach acceptable yields.

The amount of water that was applied for irrigation is presented in (Table 1). During the two growing periods, no difference occurred between the treatments at the 5% significance level. Water saving was carried out in the treatment where the irrigation scheduling was based on the automatic evaporation pan (AUTO (E)) (about 3, 5% of the average of two years). In addition, statistically significant difference in the applied amount of water between the growing periods was not presented.

The same table presents the final seed production (kg/ha) for both periods, which is the final product that is marketed by the producer and it is important for this research. There was no difference at the 5% significance level for treatments between the growing periods, while statistically significant difference between treatments was presented during the growing season of 2011 due to the randomness of the sample. The PM treatment showed a slight tendency of superiority as for the final product. That superiority seems to be a result due to the random sampling and less because of the effect of any other factor. Finally, the same table also presents the irrigation water use efficiency (W.U.E.), which is the ratio of the total production to the total irrigation water [26]. No difference appeared in the W.U.E. at the 5% significance level for the treatments between the same growing season and between the two growing periods.
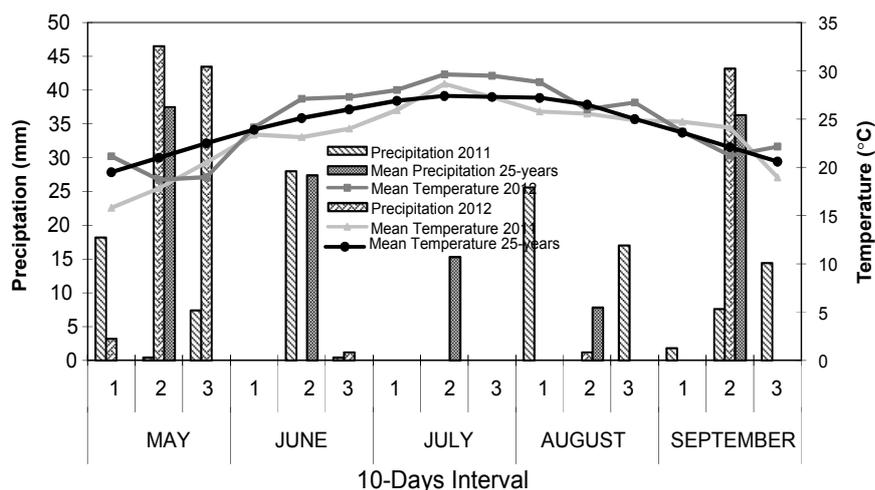

Figure 3: Climate data of the growing periods 2011 and 2012 compared to the last 25 years.

Treatment	Irrigation Water Quantity (m³/0,1ha)		Final Production Seed (kg/0,1 ha)		W.U.E.	(kg/mm H$_2$O)
	2011	2012	2011	2012	2011	2012
PM	541ᵃ	521ᵃ	399,4ᵃ	395,8ᵃ	0,74ᵃ	0,75ᵃ
AUTO (E)	508ᵃ	517ᵃ	348,4ᵇ	361,6ᵃ	0,69ᵃ	0,69ᵃ

Table 1: Total quantity of irrigation water (m³/0,1ha) applied per treatment and growing period, final seed production (kg/0,1ha) and irrigation water use efficiency (kg/mm H$_2$O).
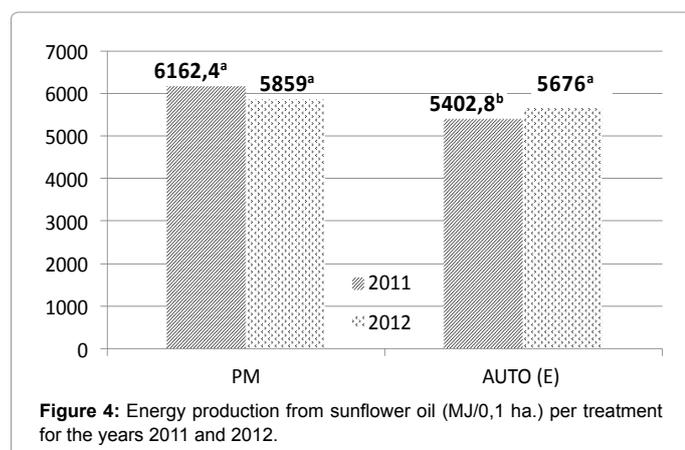
Figure 4: Energy production from sunflower oil (MJ/0,1 ha.) per treatment for the years 2011 and 2012.

Considering the fact that each liter of oil corresponds to 1.13 L of sunflower oil, the calorific value of the oil is 44 MJ/L and the calorific value of the sunflower oil is 33.5 MJ/L, the quantity of sunflower energy extracted is shown in Figure 4. There was a statistically significant difference between the treatments during the growing period of 2011, because of the difference that occurred in the seed production. A statistically significant difference did not appear during the growing period of 2012. No difference was presented between the two growing periods at the 5% significance level.

Conclusion

From the above it is clear that for Greece in the near future, sunflower could be an alternative cultivation due to the advantages it offers. Biodiesel is produced from oil seeds and solid biofuels from crop residues, so the sunflower can be included in the system of "contract farming". As energy plant it could be used in rotation systems in low input agriculture so as to be maximized the economical profit for the farmers.

In this research the automated method of surface drip irrigation using automatic evaporation pan was studied, which showed good results as to the quantity of water consumed, as well as to the production. Its use brought many advantages such as reducing travel to and from the field, optimization of water use and avoidance of the waste of energy. Furthermore, the irrigation programming with evaporation pan class A is still convenient and friendly to the farmers in comparison with the more complicated and expencive Penman – Monteith method as it needs many climatic parameters to give the reference evapotranspiration through an agrometeorological station. It also gave slight irrigation water saving while it was close enough to the accuracy of the Penman – Monteith method.

The results of laboratory analysis of sunflower seeds show that their oil content is not directly correlated with the amount of seed. The smaller amount of irrigation water applied to AUTO (E) during the two growing periods had apparent effect on seed production, but not in the production.

Based on the results obtained from this research, the cultivation of sunflower is suggested for the production of energy using the Penman - Monteith method for more accurate irrigation planning of irrigation when an agrometeorological station is available. The higher accuracy of this method tends to give higher seed production, which is the final product marketed by the producer, without requiring the application of significant additional amounts of irrigation water. It can also be used with automations utilizing the advantages of using new technology in irrigations.

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