Sorghum economics under different irrigation methods and water doses

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Jel classification: Q130, Q150

Abstract

In this study, an attempt has been made to evaluate the biomass production and the economic results of sorghum growing in Greece under surface and subsurface drip irrigation and with three different amounts of irrigating water: 100%, 70% and 50% of the daily evapotranspiration. Thus, a field experiment comprising a completely randomized block design with six treatments and four replications was conducted at the Experimental Farm Station of the University of Thessaly in 2007. Water needs were satisfied by using full (100% ET) and partial (70% and 50% ET) amounts of irrigating water. Crop production was measured in terms of dry biomass, while gross revenue, production costs and gross margin were the economic parameters to be measured and examined. The comparative data analysis of the two irrigation methods showed that the subsurface drip irrigation method was performing significantly better than the surface one in biomass production and other economic results.

Keywords: Gross revenue, production cost, gross margin, surface, subsurface drip irrigation, fibre sorghum, biomass production.

Résumé

Dans cette étude, nous avons essayé d'estimer la production de biomasse et les résultants économiques de la culture de sorgho en Grèce en comparant deux différentes méthodes d'irrigation goutte à goutte, de surface et souterraine, et trois différentes doses d'arrosage: 100%, 70% et 50% de l'évapotranspiration journalière. En 2007, auprès de la Station Agricole Expérimentale de l'Université de Thessalie, nous avons mené un essai de terrain qui a été mis en blocs aléatoires complets à six thèses et quatre répétitions. Les besoins en eau ont été satisfaits en apportant de doses d'arrosage qui intégraient la quantité totale (100%) ou partiale (70% et 50%) de l'eau évapotranspirée. La production a été mesurée en termes de biomasse sèche produite, tandis que le revenu brut, les couts de production et la marge brute ont représenté les paramètres économiques à mesurer et examiner. L'analyse comparative des données sur les deux méthodes d'irrigation goutte à goutte considérées a montré que l'irrigation souterraine est plus performante que l'irrigation de surface en termes de production de biomasse et d'autres résultats économiques.

Mots clés: *revenu brut, cout de production, marge brute, irrigation goutte à goutte de surface, irrigation goutte à goutte souterraine, sorgho fibre, production de biomasse.*

1. Introduction

Over the last few decades, a word-wide crisis related to energy needs has dramatically emerged. This energy crisis is due to the industrial revolution and the rapid growth of the world's population. The main impact of the industrial activity is the emission of air pollutants in the atmosphere and their effects on the human beings (Mastrorilli *et al.*, 1995). These pollutants contribute to the perpetuation and further development of global warming (Monti *et al.*, 2003). Therefore, the preservation of the environment should set the international energy policy in front of its liability at present and in the future. The reduction of emitted pollutants in conjunction with the use of renewable energy is the first step against environmental pollution. Besides, the continuous raise in the fossil fuels prices, particularly over the last two years, is another factor defining the use of renewable energy. Under those circumstances, new development strategies and rules to identify energy production and consumption must be globally formed. The Directive 30/2003 of the European Commission, which states that by the year 2010 a proportion of 5.75% of fuel consumed in transport means should be produced from renewable energy sources, is one of those strategies and rules (Ageridis *et al.*, 2006). Generally, 56% of biomass is used to produce energy (renewable source). Specifically, biomass from plants accounts for 18% of that amount. Taking into consideration the productivity potential of energy plants, an approximate number of 10 million acres should be cultivated with energy plants to achieve the European Commission's goals (Monti *et al.*, 2003).

Biomass is one of the renewable energy forms. Any material derived from living or recently deceased plant and animal organism is characterized as biomass (Biomass Energy Center, 2007). In the last 20 years, biomass has been identified as the most effective renewable energy source that contributes to the maintenance of carbon dioxide emissions at a fixed level or even to its reduction (Ageridis *et al.,* 2006; Monti *et al*., 2003). The quantity of CO_2 produced by biomass is exactly the same as the quantity absorbed by the plants to build themselves during the growing season (Monti *et al*., 2003). This means that the amount of CO_2 in the atmosphere remains stable. The residues of biomass combustion for energy production are biodegradable; therefore fewer pollutants are emitted to the atmosphere in comparison with the pollutant by-products from the fossil fuels use. Biomass produces and emits low

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or zero quantities of sulphur dioxide, nitrogen oxides, and aromatic hydrocarbonates during its combustion. Furthermore, energy-dependent countries gain the opportunity to become independent from imported fossil fuels. The use of biomass creates conditions for economic development and provides opportunities for restructuring the conventional crop rotation system. It also creates new jobs while reducing unemployment (Ageridis *et al*., 2006). Biomass plants can be used to produce biogas, biodiesel, ethanol, methanol, oil, gasoline and hydrogen (El Bassam, 1998). They can also be used for direct combustion and generation of heat for heating buildings and electricity production. However, energy from fossil fuels can not be totally replaced by energy-producing plants. What can be done is to use fossil fuels in activities that require high quality fuels, such as industrial uses, and renewable energy sources in activities where low quality fuels are required, as for example heating and electricity production (Monti *et al*., 2003).

Various species of plants can be used for biomass production: fibre sorghum, sweet sorghum, sugar beet, corn, sunflower, rapeseed and many tree species such as eucalyptus, *phoenix*, rubber tree, etc. (El Bassam, 1998). Among those species, sorghum (sweet and fibre) is the most interesting one. Sorghum (*Sorghum bicolor* L. Moench) is a tropical C4 plant. As C4 plant, sorghum has high photosynthetic rates when cultivated under proper conditions of light and temperature while it shows a high potential for biomass production. Even though it is a tropical plant, it can be grown in temperate climates where the growing season lasts from spring to autumn. The cultivated types of sorghum are commonly known as forage sorghum (Curt *et al*., 1995).

Sorghum plants are cultivated in 99 countries around the world. They cover 44 million hectares of land, mainly poor and semiarid areas, where maize cannot be cultivated. Sorghum sowing takes place when the temperature reaches up to 20^{o} C at depths of 2.5-5cm, depending on the soil type. Sorghum cultivation does not require large quantities of fertilizers. Generally, a quantity of 40-100Kg/ha of a complete fertilizer is satisfactory (Kneipp *et al*., 2006).

Sorghum is a water-tolerant crop. It is more productive than corn under deficit irrigation conditions (Shroyer *et al*., 2006; Farré *et al*., 2006). For maximum production, 450-560 mm of irrigating water is required, however depending upon the environmental conditions of the area. Sorghum plants have the ability to extract soil water at a lower percentage of available soil water without yield loss, when water is limited in the upper root zone (Shroyer *et al*., 2006). Because of this ability, sorghum is known as «camel plant» (Sakellariou-Makrantonaki *et al*., 2007). The general irrigation-management recommendation is to maintain soil water at 50% or more of the available water. However, grain sorghum can survive in conditions where the soil water is depleted to an average of 30 to 40% of the available water before grain yields are severely reduced.

Fibre sorghum is the main type of sorghum grown for dry biomass production suitable for direct combustion. Secondarily, it is also used to produce liquid fuels. Dry biomass production in European countries ranges from 27 to 40 tons/ha or more (Biomass Energy Center, 2007; Dolciotti *et al*., 1996), when irrigation water covers the proportion of 100% of water requirements, supplied by the subsurface drip irrigation method (Colaizzi *et al*., 2006). The equivalent of sugars, on the other hand, reaches 19.5% of the dry biomass (Dolciotti *et al.,* 1996, Dalianis *et al*., 1995). Lack of water during the flowering stage causes considerable damage to sorghum plants (reduction of dry biomass by 52%, reduction of grain production by 61%). At the stage of filling the grain, sorghum has less water requirements (Mastrorilli *et al*., 1995). The frequency of irrigation affects grain production. The plant height, the leaf area index and ultimately the production of dry biomass decrease as the amount of irrigated water declines. Thus, in semiarid areas grain sorghum should be frequently irrigated with small amounts of water (Saeed *et al*., 1998).

From what mentioned above, it becomes clear that sorghum should be considered as one of the most promising energy crops for future use, under deficient irrigation conditions. This is particularly true for the areas where lack of irrigation water is becoming keener. In these cases, sorghum could replace other conventional crops such as corn, sugar beet and cotton, which require the same or even higher amounts of water. For this purpose, the aim of the present study focuses on studying the effect of different irrigation methods (surface and subsurface drip irrigation), the impact of different amounts of water upon the biomass production, and the economic results of sorghum as energy plant.

2. Materials and Methods

A field study concerning the fibre type of sorghum (*Sorghum bicolor* L. Moench ssp., variety H132) was conducted in 2007 at the Experimental Farm Station of the University of Thessaly in Velestino, Magnesia, Greece (latitude 39^{o}23′ N, longitude 22^{o}45′ E). The crop was sown on a typical xerorthent soil, characterized by a particle-size distribution of 48% sand, 29% silt and 23% clay. The pH value was 7.8 and the organic matter was 0.97% (Mitsios *et al.,* 2000). Six fully randomized treatments in four replications were organized and a total area of 2,000 square meters was covered. Two irrigation methods, the conventional surface and the modern subsurface drip irrigation, were used. Each treatment area occupied 224 square meters. Each treatment consisted of 6 rows of 12.5 meters in length and 4 meters in width. The total area of each replication was 50 sq metres. The six treatments were:

a) Surface drip irrigation with supplied amount of water equal to 100% of the daily evapotranspiration (DI100% ET);

b) Surface drip irrigation with supplied amount of water equal to 70% of the daily evapotranspiration (DI70% ET);

c) Surface drip irrigation with supplied amount of water equal to 50% of the daily evapotranspiration (DI50% ET);

d) Subsurface drip irrigation with supplied amount of water equal to 100% of the daily evapotranspiration (SDI100% ET);

e) Subsurface drip irrigation with supplied amount of water equal to 70% of the daily evapotranspiration (SDI70% ET); and

f) Subsurface drip irrigation with supplied amount of water equal to 50% of the daily evapotranspiration (SDI50% ET).

An A class evaporation pan was used for matching the daily evaporation (Smajstrla *et al.,* 2000). Forty-eight soil samples at depths of 0-30 cm and 30-60 cm were taken from the experimental field and tested to determine the field capacity (FC=32.68%v/v) of the soil and its permanent wilt point (PWP=18.5%v/v). The available water of the soil, at 0.6m depth, was measured with pressure plates (Papazafeiriou, 1994).

The average climate conditions of the area follow the typical Mediterranean pattern with hot-dry summers and cool-humid winters. However, 2007 was drier than previous years. Daily values of mean temperature and rainfall amounts were recorded in a weather station located at the Experimental Station. The rainfall amount for the whole growing season reached up to 145 mm while 116 mm of it had fallen till the end of the irrigation period (14/9/2007). Under those conditions, all summer crops, including sorghum, needed irrigation to reach acceptable yields. The mean value of the evapotranspiration (ET) reference of the area, from sowing to maturity, was found to be 732 mm (Sakellariou-Makrantonaki *et al.,* 2006).

2.1. Cultural practices

Seedbed preparation of the experimental field started from autumn 2006, soon after the previous crop residue was cut and spread in the field. Sowing sorghum took place on 14 May. 0.65 kg/ha of sorghum seed were used. Germination started seven days after sowing and completed three days later with a plant rate of 10 plants/m^2. The germination rate of sorghum seeds fluctuated between 65 and 70% (Shroyer *et al*., 2006). No fertilization or any other chemical intervention was applied. After seed emergence, the same cultural practices were applied to all treatments. Those practices included three hand weed controls and a chemical application of glyphosate.

According to the climatic conditions, three or four sprinkler irrigations are needed during the germination period. These irrigations started just after sowing and stopped when the plants developed root system capable to extract available water from deeper soil layers (35-45cm). The root system of sorghum is able to extract water from 45cm in depth late June. The irrigation period (the period when drip irrigation methods were used) lasts from early July to mid-September. During the whole irrigation period (from 2nd half of May to 2nd half of September), 25 irrigations were performed and the amount of water supplied (sprinkler and drip irrigation) was 364.48 mm, for treatments SDI50% ET, DI50% ET, 462.48mm for treatments SDI70% ET, DI70% ET and 609.52mm for the remaining two treatments DI100% ET and SDI100% ET.

2.2. Measured Parameters

The main growth stages of sorghum are hereafter described.

The seed germination usually takes place in late May, followed by a period of rapid growth until mid-August, when the formation of the head is completed and becomes visible. Panicles ripen during the last 15 days of September. Since then, the grain is no longer increasing in dry weight and plants come to the ageing period. The harvest takes place from late September to late October when the grain moisture content falls down from 25-40% to 8-14% (Shroyer *et al.,* 2006). Thus, the measured physiological characteristics of the plant were the height, the leaf area index and dry biomass. The determination of gross revenue, gross margin, and total direct cost was based on the dry biomass.

Harvest was done by hand along two medium-sized rows of each replication. The period of maximum biomass production was determined by recurrent harvests of a random plant from the same two medium-sized rows. The final production of a hectare was determined by weighing those samples in an accurate scale.

Both growth and economic data were recorded during the whole growing season. Those data were necessary to calculate biomass production, gross revenue, production costs and gross margins among all treatments and based on dry biomass. The whole analysis of the relevant data was based on the gross margin factor (Kitsopanidis *et al.,* 2003; Kitsopanidis, 2006; Lampkin, 1990). Because this is a comparative study concerning production costs and economic results, gross margin analysis gives a full and clear view of the measured parameters.

All data recorded during the growing season were statistically analyzed. The analysis of variance (ANOVA) at 5% level of significance was employed to evaluate the statistical effect of irrigation treatments on sorghum biomass and the relevant economic results. The SPSS 14 statistical package was used and Duncan's multiple range tests were applied to evaluate statistical differences between treatment means (Fotiadis, 1995).

3. Results and Discussion

3.1. Biomass production and economic results

Table 1 presents the relevant data recorded during the growing season of the year 2007, and the estimated ones. It must be noted that the total cost of the irrigation equipment based on the prices of 2007 and the total expenditures were divided by the years of the effective life for each part of the irrigation equipment. For example, the effective life of each lateral and the other plastics was 15 years (Ayars *et al*. 1999).

Table 1 – *Biomass production, revenue, expenses, direct cost and gross margin of sorghum cultivation in 2007 in Greece.*

Items / Treatments	DI70	SDI70	DI50	SDI100	SDI50	DI100
Biomass (Kg/ha)	30380	33565	27195	42875	32585	35525
Biomass price (€/Kg)	0.065	0.065	0.065	0.065	0.065	0.065
Gross revenue (€/ha)	1975	2182	1768	2787	2118	2309
Herbicide cost (€/ha)	30	30	30	30	30	30
Seed cost (€/ha)	15.66	15.66	15.66	15.66	15.66	15.66
Strain cut 2006 (€/ha)	20	20	20	20	20	20
Heavy cultivator (€/ha)	50	50	50	50	50	50
Light cultivator (€/ha)	60	60	60	60	60	60
Sowing (€/ha)	40	40	40	40	40	40
Hand hoeing	900	900	900	900	900	900
Installation / removal of surface irrigation system (€/ha)	60	0	60	0	0	60
Harvesting (€/ha)	150	150	150	150	150	150
Irrigation Fees (€/ha)	301	301	219	429.5	219	429.5
Subsurface Installation (€/ha)	0	22	0	22	22	0
Other Equipment (€/15 years)	5	5	5	5	5	5
PVC Laterals 20mm in diameter (€/ha divided by 15 years)	98	98	98	98	98	98
Vacuum Valve (€)	0	6	0	6	6	0
Land read (€/ha)	500	500	500	500	500	500
Subsurface Weed Control (€/ha divided by 2 years)	0	88	0	88	88	0
Permanent Capital Interest	3.1	3.3	3.1	3.3	3.3	3.1
Running Capital Interest	24.4	25.1	23.2	27.1	23.9	26.3
Total Direct expenses (€/ha)	2257	2314	2174	2444	2231	2388
Direct production cost (€/kg)	0.075	0.070	0.080	0.057	0.069	0.068
Gross margin (€/ha)	-282	-132	-406	342	-113	-78

- Biomass production lies between a lower lever of 27195Kg/ha for DI50%ET treatment and an upper one of 42875Kg/ha for SDI100%ET treatment. All other treatments were classified between those two levels.

- Gross revenue, which is the outcome of the yield multiplied by selling prices 0.065€/kg, follows the same pattern being lower than 1768€/ha for DI50%ET treatment and higher than 2787€/ha for SDI100%ET, while all the other treatments are included between those two values.

- Total direct expenses present a similar picture with a lower value of 2174€/ha for DI50%ET treatment and a higher value of 2444€/ha for SDI100%ET, and all the other treatments lie between those two values.

- Completely different is the situation regarding the direct production cost. Treatment SDI100%ET is the one with the lowest production cost that was equal to 0.057€/Kg, far from the other treatments, while DI50%ET treatment has the highest 0.080€/Kg.

- Finally, regarding gross margin of sorghum growing, the picture is the following: all treatments appeared with negative values, except for SDI100%ET treatment, which is the only one that showed positive results with a profit of 342€/ha, very far from all other treatments. Again treatment DI50%ET is the worst exhibiting the highest loss of -406 €/ha, while the remaining ones had various losses fluctuating between -282€/ha and -78€/ha.

3.1.1. Biomass production

Going a step further and statistically analyzing the above-mentioned data, the results are shown in Table 2.

Focusing on two irrigation methods, it is obvious that the subsurface method significantly excels the surface one in biomass production and other economic results. This can be easily seen by comparing the biomass mean values of the two methods. Mean production of the subsurface treatments rises up to 36342kg/ha, while the correspondent one of surface treatments is only 31033kg/ha. This means a difference of 5309kg/ha or 17% more in favour of the subsurface drip irrigation method. More specifically, treatment SDI100%ET presents the highest average biomass production that reaches 42875kg/ha. This great performance shows the important role of subsurface method in supplying the necessary amount of water to sorghum plants. Subsurface drip irrigation method supplies the whole amount of water directly to the effective plant root zone, resulting in a more efficient use of it and avoiding water evaporative losses. Hence, plants more efficiently use the supplied water.

Table 2 – *Biomass production and economic results of sorghum cultivation in 2007 in Greece for each treatment.*

Items / Methods-Treatments	Subsurface irrigation method				Surface irrigation method			
	SDI50% ET	SDI70% ET	SDI100% ET	Average	DI50% ET	DI70% ET	DI100% ET	Average
Biomass production (Kg/ha)	32585	33565	42875	**36342**	27195	30380	35525	**31033**
Gross revenue (€/ha)	2118	2182	2787	**2362**	1768	1975	2309	**2017**
Total expenses (€/ha)	2231	2314	2444	**2330**	2174	2257	2388	**2273**
Direct production cost (€/kg)	0.069	0.070	0.057	**0.065**	0.080	0.075	0.068	**0.074**
Gross margin (€/ha)	-113	-132	342	**32**	-406	-282	-78	**-255**

Treatment DI100%ET ranks second, but its yield was much lower falling to 35525kg/ha, a difference of 7350kg/ha or 20.69% less. This is mainly duo to evaporative water losses, which cannot be avoided with that irrigation method. Therefore, a part of irrigation water never reaches the plant roots creating a water deficit around them and negative implications on plant development and production.

Third in classification was the SDI70%ET treatment with a mean yield of 33565kg/ha, followed by treatment SDI50%ET with mean yield of 32585kg/ha. The fifth place was covered by treatment DI70%ET with 30380kg/ha and the last was the treatment DI50%ET, with 27195kg/ha. Statistical analysis of biomass production is presented in Table 3.

Table 3 – *Statistical analysis of Biomass production data for the first year cultivation of sorghum in Greece.*

		TREATMENTS	N	Classification (Subset for a = 0.05)		
				1	2	3
Biomass Production	Duncan[a]	DI50	4	27195		
		DI70	4	30380	30380	
		SDI50	4	32585	32585	
		SDI70	4		33565	
		DI100	4		35525	
		SDI100	4			42875
F=8.532		Sig.	4	.062	.082	1.000

a. Uses Harmonic Mean Sample Size = 4,000.

From that Table the following results can be drawn:

a) Biomass production of treatment SDI100%ET was statistically significant with respect to all other treatments.

Treatment DI50%ET has also statistically-significant lower production compared to the other treatments apart from the DI70%ET and SDI50%ET ones.

Treatments DI100%ET, SDI70%ET, SDI50%ET and DI70%ET differ each other, but not significantly. Among them, treatment DI100%ET tends to have the highest biomass production.

d) In pairs, treatments DI100%ET and SDI70ET%, SDI50%ET and DI70%ET tend to have equal biomass production because of the water losses in the surface treatments or because of the effective use of water in the subsurface ones.

e) Finally, according to biomass production, treatments are classified in decreasing order as follows: SDI100% ET[a], DI100%ET[b], SDI70%ET[b], SDI50%ET[bc], DI70%ET[bc] and DI50%ET[c], where the different exhibitors represent significant statistical differences between the treatments (one exhibitor) or no significant differences (two exhibitors).

3.1.2. Economic analysis

3.1.2.1. Gross revenue

Table 2 also gives an overview of the economic results. Among them, gross revenue is a very important element determined by multiplying the amount of biomass per hectare with the price per kilogram of product (Kitsopanidis *et al.*, 2003; Kitsopanidis, 2006; Papanagiotou, 2008; Batzios, 2001). Gross revenue (mean value) of subsurface drip irrigation method was 2362€/ha while the corresponding one for the surface method was 2017€/ha, a difference of 345€/ha or 17.1% higher in subsurface method. This difference is the result of the higher productivity of all subsurface treatments in comparison with the surface ones. In Table 2, it can be easily observed that treatment SDI100ET% has the highest gross revenue, i.e. 2787€/ha, and treatment DI50%ET the lowest, i.e. 1768€/ha, while all the other treatments are ranking similarly to biomass production mentioned above. Statistical analysis of the gross revenue data is presented in Table 4.

From the table above, it can be seen that the main conclusions remained unchanged as already mentioned before, since the gross revenue is the gross product of biomass production multiplied by the product's price, which is single. Thus, it can be concluded that:

Table 4 – *Statistical analysis of gross revenue data for the first cultivation period of sorghum in Greece.*

		TREATMENTS	N	Classification (Subset for a = 0.05)		
				1	2	3
Gross Revenue	Duncan[a]	DI50	4	1767.6750		
		DI70	4	1974.7000	1974.7000	
		SDI50	4	2118.0250	2118.0250	
		SDI70	4		2181.7250	
		DI100	4		2309.1250	
		SDI100	4			2786.7500
F=8.530		Sig.		.062	.082	1.000

a. Uses Harmonic Mean Sample Size = 4,000.

a) Treatment SDI100%ET gives statistically significant higher gross revenue than other treatments.

b) Treatment DI50%ET also gives statistically significant lower gross revenue than DI100%ET, SDI70%ET treatments, but it presents no statistical difference in comparison with DI70%ET and SDI50%ET.

c) Treatments DI100%ET, SDI70%ET, SDI50%ET and DI70%ET appear to have differences among them, but those differences are not significant, while treatment DI100%ET tends to have the best performance.

d) According to the gross revenue values, treatments are classified as follows: SDI100%ET[a], DI100%ET[b], SDI70%ET[b], SDI50%ET[bc], DI70%ET [bc] and DI50%ET[c].

3.1.2.2. Direct cost

Table 2 also shows the total expenses for both irrigation methods. As it can be seen, the mean value of production expenses in subsurface drip irrigation method was 2330€/ha while in the surface one it was 2273€/ha, a difference of 57€/ha or 2.5% higher for the subsurface drip irrigation treatments. This difference between the two methods is mainly due to extra equipment needed in subsurface method and also to extra expenses for its installation and removal in surface one. From the above-mentioned values, the production cost per unit of product can be determined dividing the total expenses by the overall biomass production (Kitsopanidis *et al.,* 2003; Kitsopanidis, 2006). Mean cost in the subsurface drip irrigation method reached 0.065€/Kg, while in the surface irrigation method it reached 0.074€/Kg. The difference was 0.009€/Kg or 13.85% higher for the second irrigation method.

More analytically, SDI100%ET treatment appears with the lowest cost value of 0.057€/Kg followed by DI100%ET treatment with a production cost of 0.068€/Kg. Two treatments, SDI70%ET and SDI50%ET, are ranked third and fourth with almost the same value of production cost, 0.070€/Kg and 0.069€/Kg respectively, followed by DI70%ET and DI50%ET treatments with production costs of 0.075€/Kg and 0.080€/Kg respectively. Statistical analysis of production cost data is presented in Table 5.

Table 5 – *Statistical analysis of direct production cost data for the first cultivation period of sorghum in Greece.*

		TREATMENTS	N	Classification (Subset for a = 0.05)		
				1	2	3
Direct production cost	Duncan[a]	SDI100	4	.05700		
		DI100	4	.06500	.06500	
		SDI50	4	.06800	.06800	
		SDI70	4		.06900	.06900
		DI70	4		.07500	.07500
		DI50	4			.08050
F=4.832		Sig.		.060	.094	.050

a. Uses Harmonic Mean Sample Size = 4.000.

Focusing on Table 5, the following results can be drawn:

-Treatment SDI100%ET with the lowest production cost significantly differs from all other treatments, except for treatment DI100%ET.

-All other treatments appeared to have no significant statistical difference among them.

-According to direct cost values, treatments are classified as follows: SD I100%ET[a], SDI70%ET[ab], DI100%ET[ab], S-DI50%ET[bc], DI70%ET[bc] and DI50%ET[c].

3.1.2.3. Gross margin

Finally, gross margin, i.e. the main economic result of comparison in this study, was deeply examined (Kitsopanidis *et al.*, 2003; Kitsopanidis, 2006; Lampkin, 1990). In Table 2, it can be easily observed that the mean values of the data showed negative results for both methods, subsurface and surface drip irrigation. The subsurface irrigation method had an average gross margin value of 32€/ha, while the surface method had a very low, equal to -255€/ha, a difference of 287€/ha, or 896.88% less in case of the surface method.

Considering each treatment separately, it was found that SDI100%ET treatment had a quite high positive gross margin of 342€/ha. Treatment DI100%ET ranks second with a negative gross margin of -78€/ha. Third was the treatment SDI50%ET with gross margin of -113€/ha and forth was the SDI70%ET treatment with a gross margin of -132€/ha. The two other surface treatments, DI70%ET and DI50%ET, were placed in the fifth and sixth position with a gross margin of -282€/ha and -406€/ha respectively.

From the analysis above, it is clearly illustrated that cultivating sorghum gives a positive economic result (342 €/ha) only in the subsurface full irrigated treatment. This is due to the highest amount of biomass production and gross revenue of that treatment (42875Kg/ha and 2787€/ha respectively), compared to other treatments, despite the fact that it had the highest production expenses (2444€/ha).

To improve the performance of other treatments, the gross revenue of cultivating sorghum must be increased. This can be done either by increasing biomass production, as selling prices are out of the farmers' sphere, or by decreasing production costs. Increase in biomass production can be achieved by improving agronomic techniques concerning irrigation, fertilization, weed control, etc. Decrease in production expenses, on the other hand, can be obtained by eliminating or better manipulating cultivation inputs and/or by using new technologies.

Statistical analysis of gross margin data is presented in Table 6. The findings of that table are summarised bellow:

a) Treatment SDI100%ET presents the highest gross profit value, which differs statistically from the gross profit values of other treatments.

b) Treatment DI50%ET presents the lowest gross with respect to the remaining treatments but it is not significantly different.

Table 6 – *Statistical analysis of gross margin data for the first cultivation period of sorghum in Greece.*

		TREATMENTS	N	Classification (Subset for a = 0.05)	
				1	2
Gross margin	Duncan[a]	DI50	4	-406.2350	
		DI70	4	-282.4400	
		SDI70	4	-132.3450	
		SDI50	4	-112.7950	
		DI100	4	-78.4600	
		SDI100	4		342.3750
F=4.598		Sig.		.094	1.000

a. Uses Harmonic Mean Sample Size = 4.000.

c) According to gross profit values, treatments are classified as follows: SDI100%ET[a], DI100%ET[b], SDI50%ET[b], SDI70%ET[b], DI70%ET[b] and DI50%ET[b].

From the above analysis, it can be concluded that biomass production and gross profit are positively correlated, while gross profit and direct cost are negatively correlated.

To expand the above research a step further, the concept of the break even point was evaluated. The break even point shows the situation where gross revenue and production expenses have the same value (Kitsopanidis, 2006; Panagiotou, 2008; Batzios, 2001). At that point, production expenses and gross revenue have the value of 2362€/ha. Gross revenue of 2362€/ha corresponds to a biomass production of 36339Kg/ha (2362/0.065). To achieve this biomass value, the average sorghum biomass production must be increased by 2651Kg/ha. Thus, biomass production, which is above the level of 36339Kg/ha with selling price equal to 0.065€/Kg along with production expenses less than 2362€/ha, can make sorghum crop profitable under Greek conditions.

Production expenses, on the other hand, could be reduced if some of the highest input expenditures are better controlled. A simple observation of Table 1 reveals the largest expenditure was the amount of money paid for hand hoeing. Weed control cost for three applications was 900 €/ha. A second high expenditure was also the amount of money spend for irrigation fees during the irrigation period, which ranged between 219€/ha (SDI50%ET and DI50%ET treatments) and 430€/ha (SDI100%ET and DI100%ET treatments). Any reduction in those expenditures would significantly improve the economics of the crop.

Concerning the first case, a reduction of production expenses could be achieved if herbicides are used parallel to hand hoeing. For example, a double or triple chemical weed control costs from 120 (2*60) to180 (3*60) €/ha, and such a procedure could radically reduce the number of weeds. If weed control was carried out in combination with three chemical applications and two hand hoeings, production expenditures could be reduced by 180€/ha or by 420€/ha if three chemical applications are combined with only one hand hoeing. This cultivating technique could have positive economic results for all treatments, even for treatment DI50%ET, whose gross margin value was equal to -406€/ha (when one chemical application and three hand hoeings are used).

In the second case, because the fees of irrigation water are standard, maximizing the production per water unit reduces the cost and consequently increases the gross margin.

4. Conclusions

Based on the first-year study, the conclusions drawn from the work are summarized as follows:

Biomass production and economic results of cultivating sorghum in Greece were affected both positively and negatively when different irrigation methods (surface and subsurface drip irrigation) and different amounts of water were applied.

Higher biomass production, gross revenue and gross margin along with lower production cost were achieved when the subsurface drip irrigation method was used. The full irrigated subsurface treatment produced 42875Kg/ha with a gross margin value equal to 342€/ha.

Treatment SDI100%ET had statistically significant differences from other treatments concerning biomass production, gross revenue, production cost and gross margin.

Treatment DI50%ET tends to be the worst treatment in terms of the examined parameters.

The biomass production and economic results of other treatments were fluctuating between those two treatments with no statistical differences among them.

Theoretically, the optimization of economic results of cultivating sorghum under Greek conditions could be achieved by a better management of cultivating techniques such as those relating to irrigation water and especially weed control (data recorded in 2008 seem to corroborate that point of view).

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