Evaluation of Drip and Sprinkler Irrigation during the Germination period of Cotton Crop in Central Greece

Papanikolaou C., Giouvanis V.*, Dimakas D. Karatasiou E. And Sakellariou-Makrantonaki M.

University of Thessaly, Department of Agriculture Crop Production and Rural Environment, Fytoko Street, Nea Ionia, Volos, Greece, P.C. 38446, Tel.: +302421093062, +302421093093 Fax:+302421093074

*corresponding author: Giouvanis Vasileios

e-mail: vgiouvanis@uth.gr, hpapan@uth.gr

Abstract A research was conducted at the experimental farm of University of Thessaly, in Velestino, Central Greece, during 2015. Traditionally, Greek farmers use sprinkler irrigation after sowing and during the germination period of cotton and drip irrigation during the rest growing period. The economical cost to buy, maintain and use two different irrigation systems is not economically affordable for them, usually. The objective was to study if drip irrigation system could replace the traditional sprinkler one during germination of cotton. Three treatments in three replications were organized in a randomized complete block design: A) Sprinkler irrigation system (SPI), B) Drip irrigation system with emitter spacing at 0.33cm (DI33) and C) Drip irrigation system with emitter spacing at 0.80cm (DI80). After the seed emergence, the same drip irrigation system with emitter spacing at 0.80m was used in all treatments and the irrigation scheduling was based on the daily evapotranspiration (ETd) as it was calculated by the FAO Penman-Monteith method. The total number of germinated plants per m^2 as well as the final seed cotton production was measured. The results showed that between the treatments there were no differences in the total number of the germinated plants and the total cottonseed production ($P<0.05$).

Keywords: Drip, Sprinkler, Germination, Cotton.

1. Introduction

The cotton crop still is one of the most important crops for the Greek economy. The interest about cotton crop in the Plain of Thessaly is timeless, because it is a crop fully adopted in the local climatic and soil conditions, as well as its high economical profit for the local producers, in comparison with other row crops, and because it is a fully mechanized crop (Sakellariou *et al*., 2006). Additionally, cotton provides raw material for the textile industry and is one of the most important export products for Greece (Sakellariou and Papanikolaou, 2008). Under that point of view, a great number of people are working in the economical circle of cotton such as the cotton producers, employees in gin industries, in seed production companies, in agrochemical companies as well as civil servants in agencies (Papastylianou and Argyrokastritis, 2014). The last five years the cotton crop is in crisis as the high cost of labor and agrochemicals reduced the high economical profit of the past decade. Furthermore, the change in the European Committee's policy about the product made a number of cotton producers, who traditionally engaged with cotton, to turn their activities to other crops. However, the cotton production should be supported. Under that point of view measures and new techniques must be presented that could reduce the production cost and add extra economic value to the final product of cotton crop.

Under the Greek climatic conditions cotton needs irrigation for an optimum yield (Sakellariou and Papanikolaou, 2008). Traditionally, the cotton producers use two irrigation systems, the sprinkler one during the germination period of cotton and the drip irrigation for the rest of the growing period. Taking into consideration the economic crisis as well as the reduced economical profit from the cotton cultivation and the small size of the cotton farms, it is economically overwhelming for the cotton producers to buy, maintain and use two different irrigation systems. Under the climatic conditions in the Plain of Thessaly, during the period of cotton sowing and germination the wind speed is moderate to high that affects the sprinkler irrigation and its efficiency. Furthermore, the heavy soils have the characteristic to form crust when sprinkler irrigation or heavy rain followed by high wind speed and air temperatures. Cotton is a sensitive crop during the germination because of its germination physiology. After humidification, the cotton seed started to germinate and the hypocotyl elongates in form of a crook witch pushes the soil in order to pass through it and to appear on the soil surface. However, the soil crust causes damages to the new seedling (Ritchie *et al*., 2004). Having this in mind, the effectiveness of sprinkler irrigation is under dispute. On the other hand in drip irrigation the laterals are osculated with the seed line and the small water drops just flow to the soil and not falling on it from height (as in sprinkler irrigation). So, drip irrigation causes no crust to the soil. Furthermore, researches have shown that drip irrigation improve the water use efficiency in different crops including cotton (Sakellariou and Papanikolaou, 2008, Sakellariou *et al*., 2009, Sakellariou and Papanikolaou, 2012).

The objective of the research was to study the effect of different irrigation method on cotton germination and the total number of cotton plants per m^2.

2. Materials and Methods

2.1. Soil type

The research was organized and implemented during the growing period of 2015 by the staff of the Laboratory of Agricultural Hydraulics, part of the Department of Agriculture, Crop Production and Rural Environment of University of Thessaly. The research took place at the Farm of University of Thessaly in Velestino area, Magnesia, Central Greece (latitude $39^0$22΄43΄΄N, longitude $22^0$44΄30΄΄E, altitude 70 m above the sea level). The soil is clay loam (30 % sand, 32 % silt, 38 % clay, mean values at 0–96 cm depth). Generally, this type of soil is characterized as heavy and is quite common type of the Greek cultivated soils (Mitsios *et al*., 2000).

2.1. Climatic data

The automated agrometeorological station of the farm was used to record the daily Meteorological data. A 25-year series of historical meteorological data about the area was used as the reference data. The location of the agrometeorological station was 30 m far from the area was used as the reference data. The location of the agrometeorological station was 30 m far from the study field. The area is characterized by a typical Mediterranean climate with hot and dry summers and cool humid winters. The air temperature and precipitation (10-day average values) prevailing at the experimental field during the growing period of 2015 were compared with the average values of the historical data and are presented in Figure 1.

It shows that in general, during the last 25 years, the daily average air temperature ranging from about 20 ^{o}C in mid-May to 25 ^{o}C in late June, remained almost constant at about 26–27 ^{o}C in July and early August, dropped in values between 22 and 24 ^{o}C from mid-August to mid-September and it remained below 20 ^{o}C until the first fortnight of October. 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 year 2015, the mean daily air temperature did not differ much from the average values of the past 25 years, except of a negative peak during the third 10-days of June. As for the mean precipitation values there was one high precipitation (35mm) event during the third 10-days of June, which was the reason of the negative peak of the mean daily temperature during the same period. The total precipitation during the cultivated period was 2550m^3/ha. Under these circumstances and more generally under the climatic conditions in Central Greece, most summer crops, as well as cotton, need irrigation to germinate and to reach acceptable yields.

2.3. Cultivation techniques

The seedbed preparation of the field started in autumn 2014. The cultivation techniques were the same as those the local cotton producers use, traditionally.

The sowing of cotton took place on May 14th and 25 kg/ha of cottonseed were used. To sow cotton, a typical four-row sowing machine was used.

Normally, the sowing period of cotton in the area is between 5 to 30 of April according to the precipitations and the mean daily temperature. Cottonseeds germinate between four to fourteen days after sowing (Ritchie *et al*., 2004). During 2015, the germination started 10 days after sowing, when 52 Daily Heat Units were accumulated, and completed 10 days later. The germination rate of cotton seeds is up to 95% as a result of the new technology that is used in cottonseed production procedure. On purpose the sowing of cotton was late because during the period between the second and the third 10-days of May there was little or no precipitation according to the historic meteorological data. According to the objective of the study it was crucial the precipitation to be completely absent that period of time it might affect the percentage of seed germination in the different treatments. It was used a common cotton variety for the area suitable for late sowing. No fertilization was applied in order to study the germination, growth rate and productivity of the crop under low-input agriculture. It was used a selective herbicide for cotton crop before sowing and the same one after the sowing and before the seed emergence so as the

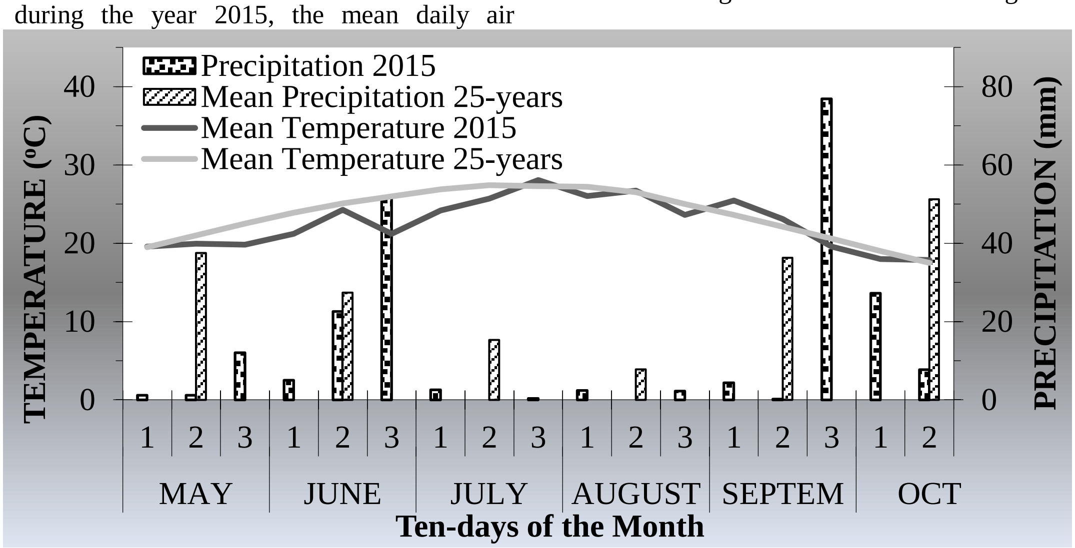

Figure 1. Mean precipitation and mean temperature of the year 2015 and their average values of the last 25 years.

weed seeds to be controlled. After cottonseed emergence, the same cultural practices were applied to all treatments. These practices included one hand-weed control and a chemical application with the non-selective herbicide glyphosate. The objective of this cultivation technique was to keep the plots free of weeds.

2.3. Irrigation

2.3.1. Germination period

Traditionally, the local cotton producers use the sprinkler irrigation during the germination period of cotton. According to them, it is the most effective method to achieve the higher rate of seed emergence. Normally, during the April and May cotton needs two or three irrigations for an optimal emergence according to the number and amount of the precipitations in that period. During the same period of 2015 only one precipitation took place at the third 10-days of May and the amount of water was only 12.00mm when the mean daily evapotranspiration was 4.00mm. Such amount of water is not enough for cotton emergence taking into consideration that 20mm of water are needed in order the herbicides to be activated efficiently.

Three treatments in three replications following a randomized complete block design were organized. Each replication plot consisted of four (4) rows of cotton, 10.0m in length and 4m in width. The total area of each replication was $40m^2$. The treatments were:

i.Sprinkler irrigation system (SPI) consisted of small impact rotor sprinklers with a rate of 200 lh^{-1}. Two sprinklers per plot were used.
ii.Drip irrigation system with emitter spacing at 0.33cm (DI33) and water rate 4.0 $lh^{-1}$and
iii.Drip irrigation system with emitter spacing at 0.80cm (DI80) and water rate 4.0 lh^{-1}.

In the drip irrigation treatments Polyethylene laterals of 20mm inside diameter with enclosed emitters were used. The applied amount of water was the same for all treatments. A flowmeter was used in each plot in order the amount of irrigation water to be measured.

Three irrigation control valves were connected to a microcontroller in order to the irrigation be fully automated and the duration of each one to be controlled accurately. The irrigation started the same day and the same time for all the treatments. The irrigations for each treatment took place the same day and the three treatments started to irrigate the same time too. Totally, three irrigations took place during the germination period. The amount of water was $428m^3$/ha, $420m^3$/ha and $429m^3$/ha in SPI, DI33 and DI80 treatments respectively.

During the germination period the number of plants was measured. The measurements were taken in one square meter at the middle rows of each plot and converted to number of plants per hectare.

2.3.2. Growing period

After the cotton emergence the laterals in SPI and DI33 treatments were replaced by Polyethylene ones of 20mm inside diameter with enclosed emitters spacing at 0.80m that delivered water at a rate of 4.0 lh^{-1}. The laterals spaced 1.9m each other so as every one of them to irrigate two cotton rows.

The irrigation scheduling was based on the daily evapotranspiration (ETd) as it was calculated by the FAO Penman-Monteith method (Allen *et al*., 1998). The practical irrigation dose and the irrigation interval were calculated taking into consideration the soil parameters.

After the complete emergence of cotton seeds, in the same square meter of the middle rows, where the number of the germinated plants was measured, measurements of plant height were taken every week. In the first 10-days of November took place the harvest of the matured cotton bolls from the same two rows and the total seed cotton production calculated.

2.4. Statistical analysis

The recorded data during the whole cultivating season (Germination and growing period) were analyzed statistically. Analysis of variance (ANOVA) at 5% level of significance was employed to evaluate the effect of the different irrigation method on the total number of cotton plants that fully germinated and on the final production. The Minitab Statistical package was used, and Tukey's multiple range tests were applied to evaluate statistical differences between the means of the cotton plant number and the seed-cotton production (Montgomery and Runger, 2003).

3. Results and Discussion

3.1. Number of cotton plants per m^2

According to the cottonseed producers and the bibliography the optimum mean number of cotton plants per m^2 is 18 plants. The measured number of plants in this research for the year 2015 is shown in Figure 2.

The results showed that there were no statistical differences between the treatments as for the total number of cotton plants per m^2. Analytically, the mean number of plants per m^2 in the SPI treatment was almost 17 while in the DI33 and DI80 was 16 and 15 respectively. In other words, the difference between the SPI and DI33 treatments was 5.88% while between SPI and DI80 was 11.76% and between DI80 and DI33 was 6.25%. As it was expected, because of the soil type and the application technique, the drip irrigation method gave almost the same number of plants in comparison to the sprinkler one. Especially, the DI33 treatment was closer to the sprinkler one while the remained non-wetted soil was enough to allow the movement of light tractors on them. The almost equal number of plants per m^2 between the three treatments is a quite noticeable result because the cotton producers, who have not the economical effort to buy and manage two different irrigation systems, using this irrigation procedure can apply drip irrigation not only during the developing stage of cotton but also during germination period. Additionally, they save money as they have to buy, maintain and use only one irrigation system, the drip one, instead of two (Sprinkler during germination period and drip afterwards).

Also, it must be taken into consideration that the cost of a drip irrigation system such that of DI80 or DI33 treatment costs from 8.000 to 10.000€, respectively, for 5 hectares while a combination of sprinkler irrigation and drip one (DI80 or DI33) costs about the double for the same field area. Furthermore, another advantage of the proposed procedure is that the same small-size cotton producers need less space to store one irrigation system than two ones.

3.2. Plant height

The plant height was measured every week from the 24th of June 2015 (35th Day After Sowing, DAS) to the27th of August (98th DAS) in the middle rows of each plot. The results showed that there were no statistical differences between the three treatments. The slightly higher plants (64.67[a]cm) that observed in the SPI treatment were more due to coincidence rather than the effect of different irrigation methods on germination process (64.04[a]cm in DI33 treatment and 62.80[a]cm in the DI80 one). The cotton plant height progression is shown in Figure 3.

3.3. Total cotton production

The total number of matured cotton bolls was measured every week from 22nd of July (63 DAS) to the 27th of August (98 DAS). The final harvest, taking into consideration the local practice for late season cotton sowing took place at 11 of November 2015. The sampling was from the same rows and plants where the height was measured. The seed cotton from each plot was collected and weighted. The mean values per m^2 converted to the total seed cotton production per ha.

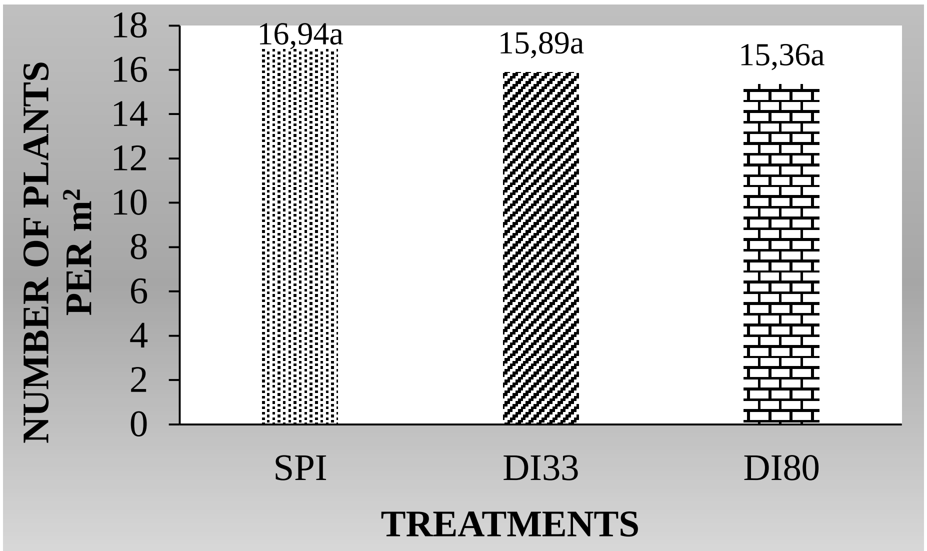

Figure 2. Mean number of cotton plants per square meter.

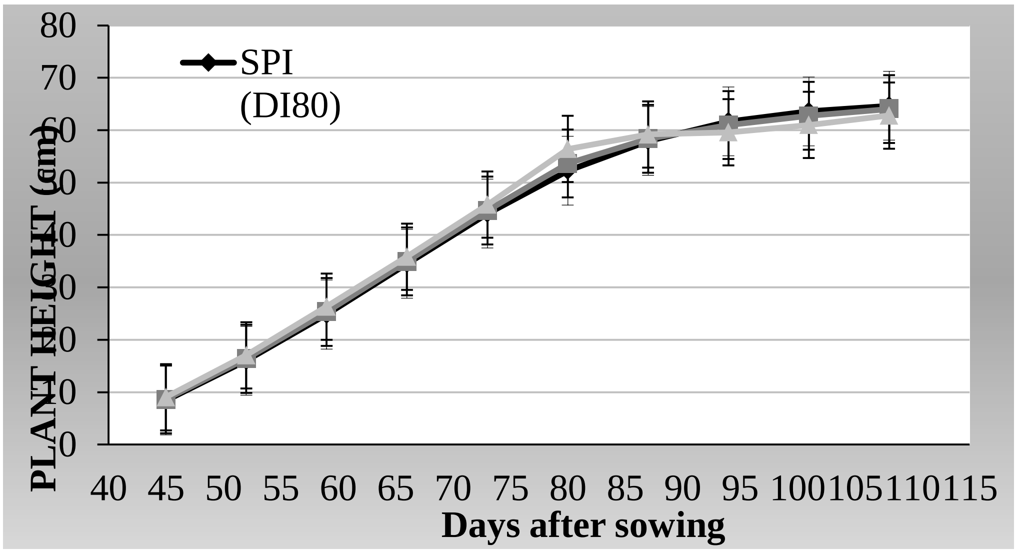

Figure 3. The development of cotton plant height during 2015.

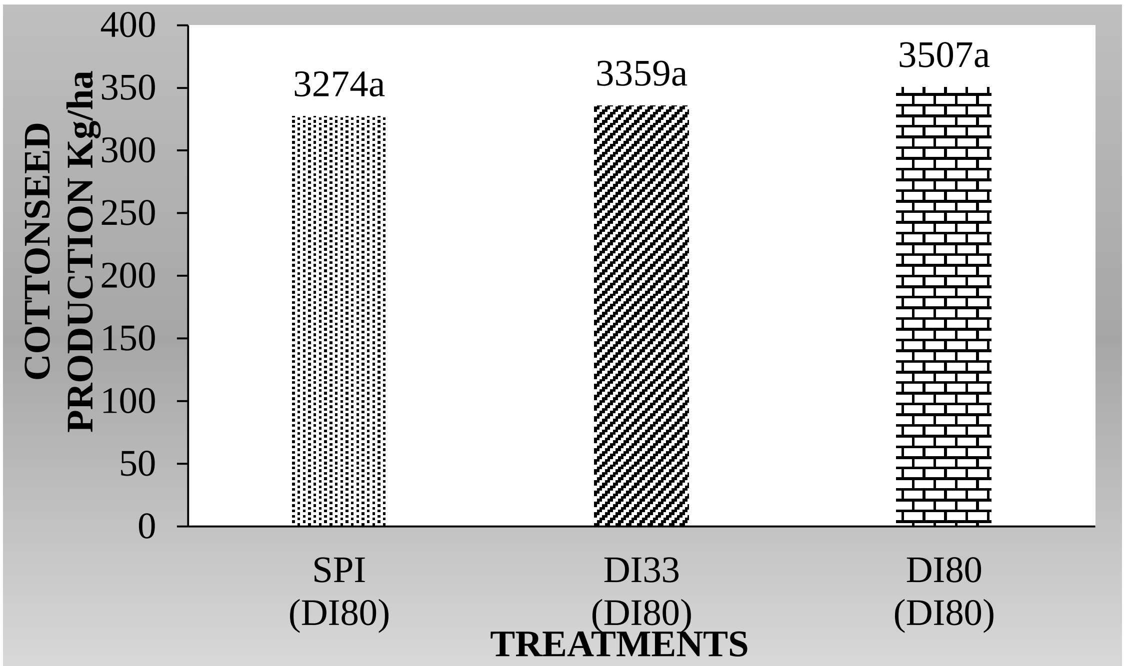

Figure 4. The total seed cotton production during 2015.

Figure 4 shows the total seed cotton production. The DI33 treatment tends to produce higher number of bolls than the other two ones. The difference between the SPI and DI33 treatments was 13.85% while between DI33 and DI80 ones it was 7.69% and between the SPI and DI80 ones it was 8.80%.

According to the plant height, someone could expect higher plants to produce higher yield, because higher plants produce higher number of flowers and the higher number of flowers give higher number of bolls. However, cotton plants did not follow this pattern of production. More flowers consume more nutrients while the mean weight of the matured bolls is lower. This was expected because no fertilization was used.

The results showed that the DI80 produced higher yield than the other two treatments. The seed cotton yield reached at 3507 Kg/ha while the DI33 one produced 3359Kg/ha and the SPI 3274Kg/ha. The difference between the DI33 and DI80 treatments was 4.22% while between the DI33 and SPI treatments it was 2.53kg/ha and between the DI80 and SPI it was 6.64%. It must be noticed that the production was unexpectedly high, taking into account the late season sowing and the absence of any fertilization. This could be explained by the dry conditions during October and possibly by the existence of nitrates in the irrigation water.

3.4. Irrigation water use efficiency

The water use efficiency (WUE) is one of the major indices which describes how effective was the irrigation program and the irrigation method. It is the division between the produced yield and the total amount of the used irrigation water (Howell *et al*., 1990).

In the current research, the WUE was:

- For the treatment SPI:

$WUE_A = \frac{Yield}{Total\ amount\ of\ irrigation} = \frac{3274}{3564+428+2550} = 0.50$ Kg/ha/mm.

- For the treatment DI33:

$WUE_B = \frac{Yield}{Total\ amount\ of\ irrigation} = \frac{3359}{3866+420+2550} = 0.49$ Kg/ha/mm.

- For the treatment DI80:

$WUE_C = \frac{Yield}{Total\ amount\ of\ irrigation} = \frac{3507}{3719+429+2550} = 0.52$ Kg/ha/mm.

The mean value of the irrigation water that applied to each treatment was calculated from the mean values of water that recorded by the flowmeters in each plot. In Table 1 is presented the amount of water which was applied in the three treatments. The amount of irrigation water during the germination period was 428m^3/ha, 420m^3/ha and 429m^3/ha for the treatments SPI, DI33 and DI80 respectively while the rest irrigation period the amount of water was 3564m^3/ha, 3866m^3/ha and 3719m^3/ha for the treatments SPI, DI33 and DI80 respectively.

The results showed that there were no significant differences between the treatments as for the WUE. However, the DI80 treatment tends to apply the irrigation water more efficiently than the other two.

4. Results and Discussion

The local cotton producers’ practice, in Greece, is to apply sprinkler irrigation for germination and drip irrigation for growing period. The cost to buy, maintain and use two different irrigation systems is not economically affordable, taking into account the economic crisis and the fact that the majority of Greek farms are small sized.

A research was conducted during the year 2015 in order to study if drip irrigation system can replace the traditional sprinkler one, during the germination of cotton. During germination three treatments in three replications were organized: a) Sprinkler irrigation, b) Drip irrigation with emmiter spacing at 0.33cm (DI33) and c) Drip irrigation with emmiter spacing at 0,.80cm (DI80). After germination and during growing, all treatments were irrigated wit drip irrigation with emmiter spacing at 0.80cm, in order to

Table 1. Total water use efficiency.

Parameters	SPI	DI33	DI80
Total Seed Cotton Yield (Kgr/ha)	3274[a]	3359[a]	3507[a]
Drip Irrigation (m^3/ha)	3564	3866	3719
Sprinkler (m^3/ha)	428	420	429
Precipitation (m^3/ha)	2550	2550	2550
Total Water Inputs (m^3/ha)	6542	6836	6698
WUE (Kgr·$ha^{-1}m^3$)	0.50[a]	0.49[a]	0.52[a]

evaluate the effect of applying drip irrigation system, durng germination, on the final production of cotton.

The statistical analysis showed that:

- There was no statistical significant difference at the total number of germinated cotton plants per m^2. The SPI treatment tends to give a slightly higher number of plants than the other two ones. Between the treatments DI80 and DI33 that the emitter spacing was 80cm and 33cm respectively, there were no statistical differences in the total number of cotton plants that germinated. Furthermore, the DI80 treatment tends to be slightly better than the DI33 which means that the cotton producers could save even more money as the laterals with emitter spacing at 80cm are cheaper than those with emitter spacing at 33cm and they have not to buy and maintain two different drip irrigation systems, one for the germination period and another for the rest of the irrigation period.
- There were no statistical significant differences between the treatments at plant height, final total cotton production and water use efficiency.

To conclude, the results of the study showed that the cotton producers can apply drip irrigation not only during the developing stage of cotton but also during germination period.

References

Allen, G.R., Pereira, S.L., Dirk, R. and Martin, S. (1998), Crop evapotranspiration - Guidelines for computing crop water requirements - FAO Irrigation and drainage paper 56. FAO Irrigation And Drainage. Paper No 56, FAO Rome. pp. 1-194.

Ritchie, L. G., Bednarz, W.G., Jost, H.P. and Brown, M. S. (2004), Cotton Growth and Development, Cooperative Extension Service, University of Georgia, pp. 3-14, http://www.soilcropandmore.info/crops/CottonInformation/B1252/B1252.pdf

Howell, T.A., Cuenca, R.H. and Solomon, K.H. (1990), Crop yield response. In: Hoffman (ED), Management of Farm Irrigation Systems. ASAE. pp. 312s.

Mitsios, J.K., Toulios, M.G., Charoulis, A., Gatsios, F., Floras, St. (2000), Edaphic project and Edaphic chart of experimental field of University of Thessaly in Velestino area. Zymel publications, Athens, (in Greek).

Montgomery, C.D. and Runger, C.G. (2003), Applied Statistics and Probability for Engineers. 3rd Edition. John Wiley and Sons. pp. 372-459.

Papanikolaou, C. and Sakellariou-Makrantonaki, M.. (2012), The effect of an intelligent surface drip irrigation method on sorghum biomass, energy and water savings. Irrigation Science Journal, DOI 10.1007/s00271-012-0344-2.

Papastylianou, T.P. and Argyrokastritis, G.I. (2014), Effect of limited drip irrigation regime on yield, yield components,and fiber quality of cotton under Mediterranean conditions. Agric. Water Manage. 142, 127-134.

Sakellariou-Makrantonaki, M., Vlachos, V. and Papanikolaou, C. (2006), Effect of different drip irrigation methods on development and productivity of cotton. Proceedings of the 10th Panhellenic Conference of the Hellenic Hydrotechnical Association (HHA), Xanthi, pp. 637-644, (in Greek).

Sakellariou-Makrantonaki, M., and Papanikolaou, C. (2008), Water Saving by using modern irrigation methods. Proceedings of AgEng 2008 International Conference on Agricultural Engineering, Hersonissos, Crete, Greece, OP-670 (CD-ROM).

Sakellariou – Makrantonaki, M., C., Papanikolaou, E., Mygdakos, (2009), Fiber sorghum biomass yield, water use efficiency and economic results under different levels of water, using subsurface and surface irrigation systems. Fresenius Environmental Bulletin, vol. 18, No 9, pp. 1624-1632.