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Effect of Deficit and Partial Root Zone Drying Irrigation Techniques on Water-Yield Relations of Cotton Under Aydin Plain Conditions

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Abstract This study was carried out to determine seed cotton yield, yield components and water use efficiency of the May 505 cotton cultivar under traditional deficit irrigation and partial root zone drying (PRD) under Aydın conditions in year 2021 at the Research and Application Farm of the Agriculture Faculty of Aydın Adnan Menderes University. The trial was designated in randomized complete block design with two factors and three replications. In the study, three different irrigation levels (100, 67 and 33%) and two different (traditional deficit irrigation (DI) and partial root zone drying (PRD)) applications were investigated. Irrigation water quantity based on cumulative evaporation from class A pan at 8-day irrigation interval was applied through drip system to full irrigation (TS-100), deficit irrigation (DI-67 and DI-33) and partial root zone drying (PRD)- PRD-100, PRD-67 and PRD-33. A total of 575 mm irrigation water was applied to TS-100 treatment, while DI-67 and DI-33 treatment plots received 383 and 189 mm; PRD-100 treatment plots received 290 mm, PRD-67 received 193 mm and PRD-33 treatment received 97 mm of irrigation water. The highest seed cotton yield was obtained from the TS-100 treatments as 511 kg/da, while DI-67 and PRD-100 treatments resulted in yields of 445 kg/ da ve 415 kg/da respectively. There was significant difference among the treatment with respect to seed cotton yields. Average water use efficiency (WUE) values varied between 0.76-1.29 kg/m^3. Yield response factor (k_y) was found to be 0.59 for traditional deficit irrigation and 0.67 partial root zone drying-PRD). It may be concluded that the treatment which gave the best performance was treatment TS-100 (traditional deficit irrigation) when the water was abundant. In the case of water scarcity DI-67 and PRD-67 (traditional deficit irrigation and partial root zone drying-PRD) treatments resulted in reasonable yield and WUE.

Keywords Aydın, partial root zone drying, cotton, drip irrigation, yield response factor

1. Introduction

Water scarcity and drought are the major factors constraining agricultural crop production in arid and semi-arid zones of the world. Irrigation is today the primary consumer of fresh water on earth (Shiklomanov 1998), and thus agriculture has the greatest potential for solving the problem of global water scarcity. Consequently, improvements in management of agricultural water continue to be called for to conserve water, energy and soil while satisfying society's increasing demand for crops for food and fiber [1].

Irrigation water availability is a major concern in cotton production during the hot and dry summer period like Aegean region. Water shortage, increasing production cost and low water use efficiency (WUE) made the economical profit marginal and challenging to the end users. Thus new irrigation strategies must be established to use the limited water resource more efficiently. One of the new irrigation strategies is the deficit irrigation (DI) scheduling, which is a valuable and sustainable production strategy for dry regions [2]. In other words, conventional deficit irrigation (DI) is one approach that can reduce water use without causing significant yield reduction [3]. Partial root zone drying (PRD) is a further development of deficit irrigation (DI). PRD is commonly applied as part of a deficit irrigation program because it does not require the application of more than 50–70% of the water used in a fully irrigated program. PRD is an irrigation technique based on alternately wetting and drying opposite parts of the surface soil under which the plant root system is thought to be located [4]. However, the use of drip irrigation techniques is inevitable in the near feature because of the salinity problem caused by traditional irrigation methods [5]. Also, drip irrigation have been suggested as a means of supplying most types of crops with frequent and uniform applications of water, adaptable over a wide range of topographic and soil conditions [6]. Under good management practices, deficit irrigation can result in substantial water savings with little impact on the quality and quantity of the harvested yield.

Cotton is one of the most important crops in the Aegean Region of western Turkey. Common irrigation methods used for cotton production in this region are wild flooding, basin strip and furrow surface irrigation methods. In recent years, drip irrigation has gained popularity among cotton producers due to incentives provided by the government. In general, the farmers over irrigate, resulting in high water losses and low irrigation efficiencies, thus creating drainage and salinity problems [7].

In previous cotton studies, tested drip and furrow methods for cotton irrigation were tested and there were no yield differences between both methods were found [8]. On the other hand, furrow and drip irrigation methods were compared and water use efficiencies (WUE) were determined to be 2.23 and 1.89 kg/m^3 for drip and furrow irrigation methods, respectively [9]. Water use efficiency was 30% higher in the drip irrigation treatments, indicating a definitive advantage of this method under limited water supply was reported in another research [10]. Water use efficiency (WUE) and irrigation water use efficiency (IWUE) varied from 0.58 to 0.62 kg/da/mm and 0.75 to 0.94 kg/da/mm, respectively in cotton irrigated by drip system [11]. According to the findings of a research, it was reported that deficit drip irrigation of cotton at 75% of full irrigation requirements did not decrease seed cotton yield and yield components for two growing seasons [12]. However, irrigation of cotton with four different rates (full irrigation and three deficit rates) for two seasons, the total irrigation depth ranged from 176 to 710 mm, and the highest yield obtained with the highest irrigation level [13]. In a different research using three irrigation levels and two irrigation intervals on drip irrigated cotton, significant difference in yields among crop pan coefficients of 0.33, 0.67 and 1.00 for a screened evaporation pan were determined [14].

The dependence of crop yields on water supply is a critical issue due to the increasingly limited water resources for irrigation in the Aegean region and its semi-arid climate of western Turkey. However, little attempt has been made to assess together deficit irrigation (DI) and partial root zone drying (PRD) techniques for cotton under drip irrigation in the Aegean region. Therefore, this research was conducted to evaluate the water use efficiency and seed yield of cotton under different deficit drip irrigation regimes and techniques.

2. Materials and Methods

This study were conducted during the growing seasons of 2021 at the Agricultural Research Station of Aydın Adnan Menderes University, Aydin-Turkey at 37° 51’ N latitude, 27°51’ E longitude. There was no waterlogging problem and the average annual rainfall was 644.7 mm with a mean monthly temperature of 17.8 ºC according to long-term meteorological data (1983-2020) in the experimental area. Total rainfall during the growing periods was 105,9 mm in 2021.

The soil type of the experiental area was loam and sandy loam in texture. For the cotton experiment area, water content at field capacity varied from 18.4 to 23.1 % and wilting point varied from 7.2 to 10,1 % on dry weight basis. The dry soil bulk densities ranged from 1.35 to 1.52 g/ cm^3 throughout the 1.2 m deep profile. The total available soil water contents within the top 1.2 m of the soil profile was 221 mm.

The May 505 cotton variety was planted on 27 May 2021, with 0.70 × 0.20 m spacing. Before starting the field experiment, 60 kg/ha compound fertilizer (containing 15% pure N, 15% P, and 15% K) was applied to the planting area The required remaining portion of nitrogen was followed by 82 kg/ha as ammonium nitrate 33% before first irrigation.

The trial was designated in randomized complete block design with two factors and three replications. In the study, three different irrigation levels (100, 67 and 33%) and two different (traditional deficit irrigation (DI) and partial root zone drying (PRD)) applications were investigated. Irrigation management treatments consist of one full (TS-100), and two traditional deficit (DI-67, DI-33), and three partial root zone irrigation (PRD-100, PRD-67, and PRD-33). Irrigation water quantity based on cumulative evaporation from class A pan at 8-day irrigation interval was applied through drip system. Full (TS-100) and traditional deficit irrigation (DI-67, DI-33) treatments received 100, 67 and 50% of 8-day cumulative evaporation from Class A pan located at the experimental station, respectively. PRD-100, PRD-67 and PRD-33 received 100, 67 and 33% cumulative pan evaporation value, respectively, on one half of the plot area (Fig. 1). A wetting percentage of 100% in TS-100 and DI treatments, and 50% in PRD treatments was used in this study [15, 16, 17].

Figure 1: Application of partial root zone irrigation (PRD) plot

Equation (1) was used to calculate the irrigation water amount for two approaches;

$$V = P \times A \times E_{pan} \times WL \quad (1)$$

Where V is the volume of irrigation water (L), P wetting percentage (taken as 100 % for row crops), A is plot area (m^2), E_{pan} is the amount of cumulative evaporation during a 8-day irrigation interval (mm), WL represents irrigation levels (0.33, 0.67 and 1.00).

Drip laterals were placed at the center of adjacent crop rows 0.70 m apart in the experimental plots. Experimental plots were 5 m long and 5 crop rows wide (3.5 m). Irrigation water was used from a deep well located near the experimental site. The control unit consisted of screen filter with 10 L/s capacity, control valves, manometers mounted on the inlet and outlet of each unit. Distribution lines consisted of PVC pipe manifolds for each plot. The diameters of the laterals were 16 mm PE and each lateral irrigated one plant row. The inline emitters were used with a discharge rate of 4 L/h above 10 m operating pressure. In the system, emitter and the lateral spacing were chosen as 0.20 and 0.70 m, respectively.

Crop water consumption under varying irrigation regimes was calculated using the soil water balance equation [18] as;

$$ET = R + I - D \pm \Delta W \quad (2)$$

Where, ET is the water use (mm), *R* is the rainfall (mm), *I* is the depth of irrigation (mm), *D* is the depth of drainage (mm), and ΔW is the change of soil water storage in the measured soil depth.

WUE was calculated as yield (kg/da) divided by seasonal water use (mm). IWUE was determined as yield (kg da) per unit irrigation water applied (mm) [19]. Regression analysis was used to evaluate the water use-yield relationships derived from seasonal crop water use and yield data obtained from the experiment. Seasonal values of the yield response factor (k_y), which represent the relationship between relative yield reduction [1-(*Ya*/*Ym*)] and relative evapotranspiration deficit [1-(*ETa*/*ETm*)], were determined using equation 3 given by Doorenbos and Kassam [20]:

$$1-(Ya/Ym)=k_y(1-ETa/ETm) \quad (3)$$

Where, *ETa* and *ETm* are the actual and maximum seasonal crop water use values (mm), respectively, and *Ya* and *Ym* are the corresponding actual and maximum yields (kg/da).

Seed cotton yield was determined by hand harvesting in the three center rows of each plot on November 16, 2021.

In order to determine the differences between irrigation treatments, the data relating to seed cotton yield was subjected to variance analysis. The Least Significant Differences (LSD) test was used for comparing and ranking the treatments. Differences were declared significant at $p < 0.05$. Variance analysis and LSD tests were carried out with the use of the TARİST program, which was developed for this purpose [21].

3. Results & Discussion

The total irrigation water amounts applied, seasonal water use and water use efficiency values (WUE, IWUE) were presented in Table 1. Altogether 7 treatment irrigations varying from 59 to 165 mm in TS-100 plots were practiced. The first irrigation was applied on July 29 and irrigations were lasted on September 11, in 2021, respectively. Treatments received irrigation water varying from low of 97 mm in PRD-33 plots to high 575 mm in full irrigation plots (TS-100). A total of 290 mm was applied to PRD-100 treatment plots.

Table 1: Seasonal irrigation water, water use, average seed cotton yield, WUE and IWUE data for different treatments

Irrigation treatment	**Seasonal irrigation water (mm)**	**Seasonal water use (mm)**	**Average seed cotton yield (kg/da)**	**Water use efficiency (kg/m^3)**	**Irrigation water use efficiency (kg/m^3)**
TS-100	575	666	511	0.76	0.88
DI-67	383	528	445	0.84	1.16
DI-33	189	344	365	1.06	1.93
PRD-100	290	426	415	0.97	1.43
PRD-67	193	385	345	1.02	1.78
PRD-33	97	220	285	1.29	2.93

Seasonal plant water use values varied in connection with the irrigation water applied to the treatments and the amount of moisture at planting and harvest. At the same time, although it has a great effect on plant water consumption, there was 105,9 mm rain on the experimental area during the growing season. Plant water use was higher at full irrigation level (TS-100) than in the deficit (DI) and PRD irrigation plots. Water use values increased with increasing irrigation levels in each irrigation approaches. Seasonal water use varied from 220 to 666 mm among the different treatments. The highest water use was observed in TS-100 treatment as 666 mm, and the lowest water use was measured in PRD-33 treatment as 220 mm. This was followed by PRD-67 and DI-67 treatments, 385 and 528 mm in the growing season, respectively (Table 1). The seasonal water use values was obtained from treatments PRD-100 as 426 mm. Seasonal water use in the full irrigation treatment S_1, was in agreement with results obtained by [18] in the Aydın plain with the drip system and who determined water use values as 800 mm. Seasonal water use of cotton under the same region has been reported as 899 mm by [22]; as 855-882 mm by [23] under furrow irrigation system; as 265-753 mm by [13] and as 268-754 mm by [12] under drip irrigation system. Once the results of this study are compared with those of furrow irrigation studies at the same region, it is clear that drip irrigation systems are able to save substantial amount of water. Under drip irrigation applications, seasonal water use of cotton was obtained by [24] as 287-584 mm in Adana conditions; as 410-725 mm by [25] in the High Texas Plains. On the other hand, [26] found that seasonal water use in cotton varied between 432 and 739 mm depending on irrigation regimes in Uzbekistan conditions by using drip and furrow irrigation methods. In another study, [27] applied a total of 738 mm irrigation water amount to drip irrigated cotton in the Bekaa Valley of Lebanon. The results observed in this research were in agreement with the others given above.

Seed cotton yields varied from 285 to 511 kg/da among the treatments (Table 1). The highest average seed cotton yield was observed in TS-100 treatment as 511 kg/da and the lowest yields were found in PRD-33 treatment as 285 kg/da. PRD-100 and DI-67 treatments resulted in nearly the same cotton yields (415 and 445 kg/da, respectively). On the other hand, the response of seed cotton yield to different irrigation treatments (variance analyze) are given in Table 2. Data obtained from study showed that seed cotton yield was significantly affected by irrigation levels and irrigation application methods ($p < 0.01$). There was no interactions between irrigation application methods (App.) and irrigation levels (IL) were observed for any investigated parameters in year. Traditional full and deficit irrigation (TS-100; DI) methods resulted in higher yield than partial root zone drying (PRD) applications. Seed cotton yield was found to increase with irrigation water levels. Examining these results from the point of view of irrigation levels (IL), three groups formed in year. The first group consisted of the 100% treatments where no water restriction had been applied in the whole growing season, treatments in which water had been applied at the 67 % level were second, and treatments which had received water at the 33 % level formed the third group. Especially, as the irrigation level increased, seed cotton yield were increased in all applications. The highest average yield was obtained from IL-100 treatment as 463.1kg/da, followed by IL-67 treatment as 395.0 kg/da. The lowest yield was obtained from IL-33 treatment as 325.0 kg/da.

Table 2: Seed cotton yield (kg/da) as influenced by irrigation applications and irrigation levels

Irrigation application methods (App.)	**Traditional full and deficit irrigation (TS-100; DI)**	**440.4a**
	Partial root zone drying (PRD)	**348.3b**
F value (App.)		**
LSD %5		13.632
Irrigation levels (IL)	IL-100%	463.1a
	IL-67%	395.0b
	IL-33%	325.0c
F value (IL)		**
LSD %5		16.696
App. x IL		ns

*P< 0.05; **P< 0.01; ns: not significant

In a column values with a common letter are not significantly differ from one another using LSD%5

A significant decline in seed cotton yield under deficit irrigation treatment is reported in many previous researches.

According to the results of a study conducted on drip irrigated cotton in Aydın area, the highest cotton yield was achieved from a treatment in which 100 % of the amount of evaporation from a class A-pan was applied at 8-day irrigation interval [28]. On the other hand, the highest seed cotton yield (5870 kg/ha) was reported in the Harran plain from the full irrigation treatment (100%) with 6-day irrigation interval using drip irrigation method [7]. The average seed cotton yield was obtained as 5760 kg/ha under drip irrigated treatment in western Turkey [12]. Another Aydın plain conditions the highest average raw cotton yield was obtained from S_1 treatment (Carisma-V1) as averaging 6300 kg/ha. It was determined Carisma (V1) cultivar performed higher yields than Candia (V2) and Gloria (V3) [29]. Similar results were obtained by [18] as 5985 kg/ha at the same conditions. The results observed in this research were in agreement with the others given above. In evaluations conducted previously, it has been found that irrigation level have significant effect on seed cotton yield. It has been concluded that the most proper irrigation programme suggested for achieving highest cotton yield would be using the delinted seed applications under water abundant conditions in which the crop water requirements were fully met by IL-100 treatment (treatment D_1).

As the amount of water applied increased, WUE and IWUE decreased. In general, the IWUE values were higher than those of WUE in all treatments. This could be attributed to water used from soil storage. The highest water use efficiency (WUE) averaging 1.29 kg/m^3 was obtained in PRD-33, followed by DI-33 with 1.06 kg/m^3 and the lowest one was found in the TS-100 treatment as 0.76 kg/m^3 (Table 1). Treatment DI-33 and PRD-33 from all applications (traditional, deficit and PRD) used to water more efficiently. The range of WUE reported is very large (1.1–2.7 kg/m^3) and thus offers tremendous opportunities for maintaining or increasing agricultural produc- tion with 20–40% less water resources [30]. [31]. reported that water use as percent of fully irrigated treatment is decreased and irrigation water use efficiency (IWUE) is increased essentially by PRD as reported in a number of species, e.g. cotton, tomato, pear grapevine and hot pepper. On the other hand, in our study both WUE and IWUE values were similar to the findings of other researchers [7, 11, 27, 26, 12, 13, 18, 29, 32].

In order to evaluate the effects of water use on seed cotton yield regression analysis was conducted. There was a significant second order polynomial relationships were found between seasonal water use and seed cotton yield in irrigation treatments (Fig 1). Polynomial relationships of water use and seed cotton yield for drip irrigated cotton were given by [7, 13, 18, 24].

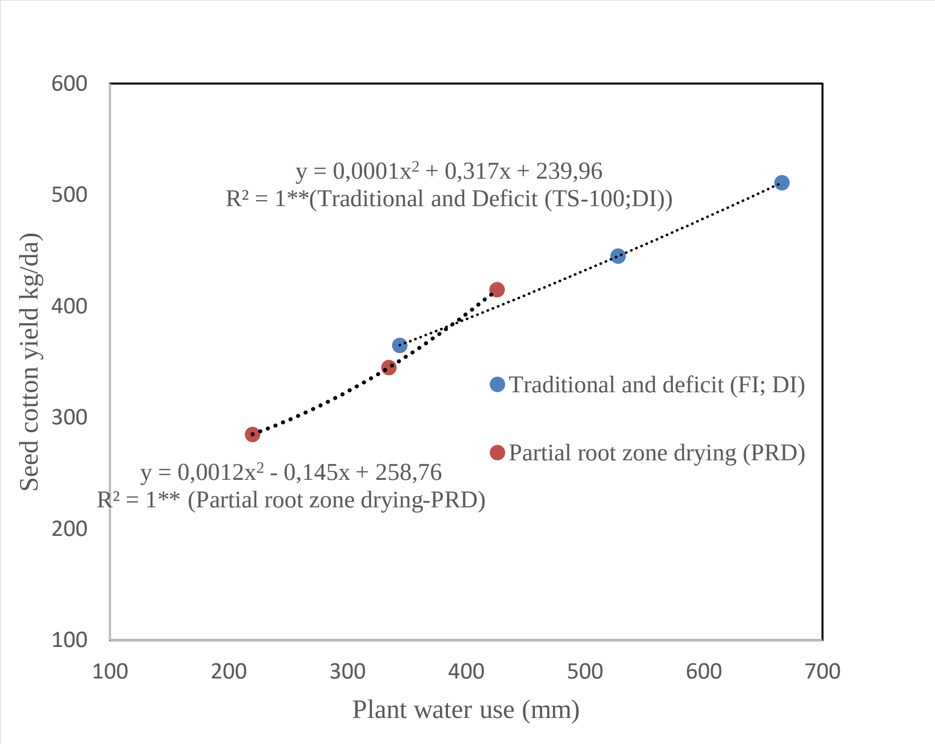

Figure 1: The relationship between plant water use and seed cotton yield

The k_y factor which represents the slope of the relationship between relative ET and relative yield, was determined the methods of [26]. Yield response factor (k_y) was found to be 0.59 for traditional-deficit and 0.67 for partial root zone drying (PRD) applications. The average k_y for the whole growing season were found to be 0.84 by [20], 0.89 by [7] and 0.78 by [13] in Aydın conditions.

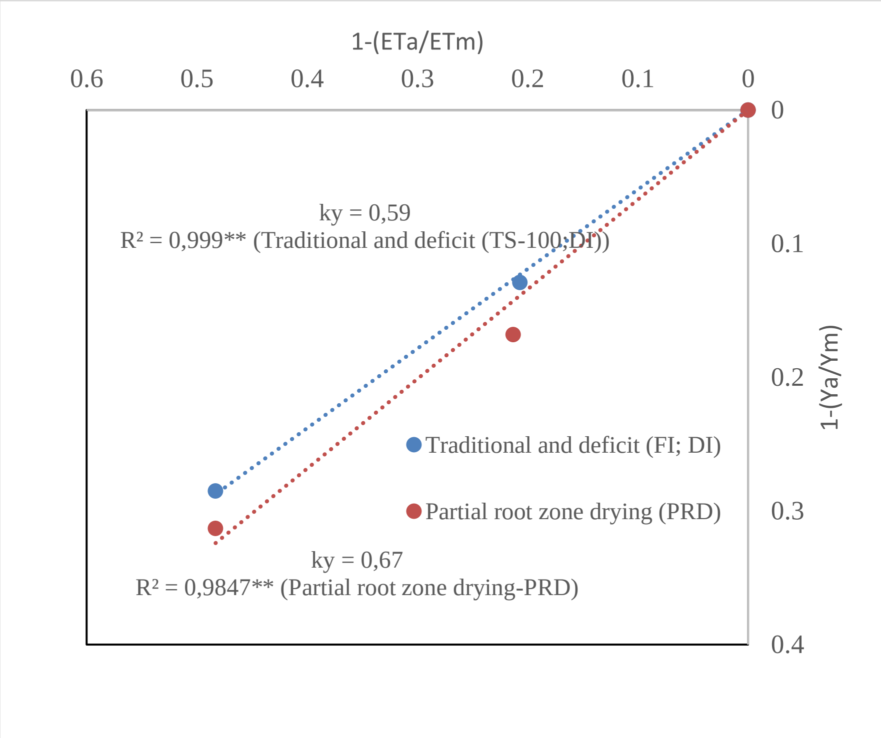

Figure 2: Yield response factor ,k_y, of cotton for different irrigation treatments

4. Conclusion

In this study, we evaluated the effects of partial root zone drying (PRD) and deficit irrigation (DI) strategies on yield and water use efficiency of the drip irrigated cotton crop under Aegean semi-arid climatic conditions in western Turkey in 2021. PRD-100 treatment received about 50% of irrigation water applied to the TS-100 plots in growing sesason. On the other hand, the 50% deficit irrigation techniques (PRD-100) reduced seed cotton yields by 19% compared to TS-100 irrigation. PRD-100 irrigation strategy was effective in saving irrigation water. Overall, the research results revealed that the PRD irrigation practice for cotton did not provide any seed cotton yield benefit as compared to traditional deficit drip irrigation (DI). It may be concluded that the treatment which gave the best performance was treatment TS-100 (traditional deficit irrigation) when the water was abundant. In the case of water scarcity DI-67 and PRD-67 (traditional deficit irrigation and partial root zone drying-PRD) treatments resulted in reasonable yield and WUE.

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References

[1]. Kassam A.H., Molden D., Fereres E., & Doorenbos J. (2007). Water productivity: science and practice – in- troduction. Irrigation Science, 25: 185–188.

[2]. Topak, R., Süheri, S., & Acar, B. (2010). Effect of different drip irrigation regimes on sugar beet (Beta vulgaris L.) yield, quality and water use efficiency in Middle Anatolian, Turkey. Irrig Sci. Published online 27 May 2010, doi: 10.1007/s00271-010-0219-3.

[3]. Kirda C., Topcu S., Kaman H., Ulger A.C., Yazici A., Cetin M., & Derici M.R. (2005). Grain yield response and N-fertiliser recovery of maize under deficit ir- rigation. Field Crops Research, 93: 132–141.

[4]. Marsal J., Mata M., del Campo J., Arbones A., Vallverdú X., Girona J., & Olivo N. (2008). Evaluation of partial root-zone drying for potential field use as a deficit irrigation technique in commercial vineyards according to two different pipeline layouts. Irrigation Science, 26: 347–356.

[5]. Simsek, M., Kacıra, M., & Tonkaz, T. (2004). The Effects of Different Drip Irrigation Regimes on Watermelon (Citrullus lanatus) Yield and Yield Components Under Semi-Arid Climatic Conditions. J. Agric. Res, 55: 1149-1157.

[6]. Çetin, Ö., & Bilgel, L. (2002). Effects of Different Irrigation Methods on Shedding and Yield of Cotton. Agricultural Water Management, 54: 1-15.

[7]. Yazar, A., Sezen, S.M., & Sesveren, S. (2002). LEPA and Trickle Irrigation of Cotton in the Southeast Anatolia Project (GAP) Area in Turkey. Agricultural Water Management, 54(3):189-203.

[8]. Howell, T.A., Meron, M., Davis, K.R., Phene, C.J., & Yamada, H., (1989). Water management of trickle and furrow irrigated narrow row cotton in the San Joaquin Valley. Soils and Fertilizers 52, 4.

[9]. Hodgson, A. S., G. A. Constable, G. R. Duddy, & I. G. Danieles, (1990). A comparison of drip and furrow irrigated cotton on a cracking clay soil. II. Water-use efficiency water logging, root distribution and soil structure. Irr. Sci. 11, 143-148.

[10]. Mateos, l., Berengena, J., Orgaz, F. & Fereres, E. (1991). A Comparison Between Drip and Furrow Irrigation in Cotton at Two Levels of Water Supply. Agric. Water Manag., 19: 313-324.

[11]. Ertek, A., & Kanber, R. (2001). Effects of Different Irrigation Programs on the Growth of Cotton Under Drip Irrigation. Turkish Journal of Agriculture and Forestry, 25: 415-425 (in Turkish with English abstract).

[12]. Basal, H., Dağdelen, N., Ünay, A., & Yılmaz, E. (2009). Effects of Deficit Drip Irrigation Ratios on Cotton (Gossypium hirsutum L.) Yield and Fiber Quality. Journal of Agronomy & Crop Science, 195(1): 19-29.

[13]. Dağdelen, N., Basal, H., Yılmaz, E., Gürbüz, T., & Akçay, S. (2009). Different Drip Irrigation Regimes Affect Cotton Yield, Water Use Efficiency and Fiber Quality in Western Turkey. Agricultural Water Management, 96(1): 111-120.

[14]. Dağdelen, N., F. Sezgin, T. Gürbüz, E. Yılmaz, S. Akçay, & E, Yeşilırmak. (2009). "Yield and Water Use Efficiency of Drip Irrigated Cotton (Gossypium hirsutum L.) at Different Irrigation Intervals and Watering Regimes" Philippine Agricultural Scientist, Vol: 92(2), pp. 193-200.

[15]. Howell T.A., Schneider A.D., & Evett S.D. (1997). Sub-surface and surface microirrigation of corn-Southern High Plains. Transactions of the ASAE, 40: 635– 641.

[16]. Bozkurt Y., Yazar A., Gencel B., Sezen S.M. (2006): Optimum lateral spacing for drip-irrigated corn in the Mediterranean Region of Turkey. Agricultural Water Management, 85: 113–120.

[17]. Yazar, A., Gökçel, F., & Sezen, M.S. (2009). Corn yield response to partial rootzone drying and deficit irrigation strategies applied with drip system. Plant Soil Environ., 55, (11): 494–503.

[18]. Erten, E., & Dağdelen, N. (2020). Yield and Water Relations of Drip Irrigated Cotton Under Various Irrigation Levels. Journal of Scientific and Engineering Research, 7(2): 204-211.

[19]. Howell, T.A., Cuence, R.H., & Solomon, K.H. (1990). Crop yield response. In: Management of Farm Irrigation Systems. (G.J. Hoffman, et al), ASAE, St. Joseph, MI, 93-122.

[20]. Doorenbos, J., & Kassam, A.H., (1986). Yield response to water, Irrigation and Drainage, FAO, ROME, Paper: 33, pp. 257.

[21]. Açıkgöz, N., Aktas, M.E., Mokhaddam, A.F., & Özcan, K. (1994). Tarist an agrostatistical package programme for personel computer. Ege Üniv. Fac. of Agriculture, Field Crops Symposium, İzmir, Turkey (in Turkish with English abstract).

[22]. Sezgin, F., Yılmaz, E., Dağdelen, N., & Baş, S., (2001). Effect of different irrigation methods and water supply level application on water-yield relations in cotton growing. Third National Hyrology Congress, Univ. of September 9, Izmir, Turkey, June 27-29.

[23]. Dağdelen, N., Yılmaz, E., Sezgin, F. & Gürbüz, T. (2006). Water-Yield Relation and Water Use Efficiency of Cotton (Gossypium hirsutum L.) and Second Crop Corn (Zea mays L.) in Western Turkey. Agricultural Water Management,82: 63-85.

[24]. Ünlü, M., Kanber, R., Koç, D.L., Tekin, S., & Kapur, B. (2011). Effects of Deficit Irrigation on the Yield and Yield Components of Drip Irrigated Cotton in Mediterranean Environment. Agricultural Water Management, 98: 597-605.

[25]. Colaizzi, P.D., Evett, S.R., & Howell, T.A. (2005). Cotton production with SDI, LEPA and spray irrigation in a thermally limited climate. In: Proceedings of the Conference on Emerging Irrigation Technology. 6-8 November 2005, The Irrigation Association, Phoenix, Arizona, (CD ROM), 15-30.

[26]. Ibragimov, N., Evett, S.R., Esanbekov, Y., Kamilov, B.S., Mirzaev, L., & Lamers, J.P.A. (2007). Water use efficiency of irrigated cotton in Uzbekistan under drip and Furrow Irrigation. Agric. Water Manag., 90: 112-120.

[27]. Karam, F., Lahoud, R., Masaad, R., Daccache, A., Mounzer, O. & Rouphael, Y. (2006). Water Use and Lint Yield Response of Drip Irrigated Cotton to Length of Irrigation Season. Agricultural Water Management, 85: 287-295.

[28]. Dağdelen, N., Yılmaz, E., Sezgin, F., Gürbüz, T., & Akçay, S. (2005). Effects of Different Trickle Irrigation Regimes on Cotton (Gossypium hirsutum L.) Yield in Western Turkey. Pakistan of Biological Sciences, 8(10): 1387–1391.

[29]. Dağdelen, N., Gürbüz, T., & Tunalı, S.P. (2019). Response of Different Cotton Cultivars to Water Stress on Water-Yield Relations Under Drip Irrigation Conditions in Aydın Plain. Derim, 36(1): 64-72 (in Turkish with English abstract).

[30]. Zwart S.J., & Bastiaanssen W.G.M. (2004). Review of measured crop water productivity values for irrigated wheat, rice, cotton and maize. Agricultural Water Management, 69: 115–133.

[31]. Kang S.Z., & Zhang J. (2004). Controlled alternate partial root-zone irrigation: its physiological consequences and impact on water use efficiency. Journal of Experimental Botany, 55: 2437–2446.

[32]. Akçay, S., & Dağdelen, N. (2017). Water productivity and fiber quality parameters of Deficit Irrigated Cotton in a Semi-Arid Environment. Fresenius Environmental Bulletin, 26(11): 6500-6507.