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Determination of the yield response to water for two different globe artichoke cultivars (*Cynara scolymus* L. cv. Bayrampaşa and Starline F1) in greenhouse conditions

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Abstract: *Determination of the yield response to water for two different globe artichoke cultivars (*Cynara scolymus *L. cv. Bayrampaşa and Starline F1) in greenhouse conditions.* In the research, the response of the artichoke plant to various amounts of irrigation water was determined, and efforts were made towards developing the optimum irrigation schedule and water-yield-production factors. The trial was conducted in a split plot design, with regard to three different levels of irrigation and two different artichoke cultivars (*Cynara scolymus* L. cv. Bayrampaşa and Starline F1), with three replications. Irrigation water was applied, based on the principal of monitoring the soil, so that irrigation would start when 40% of the available water holding capacity was exhausted and 100, 70 and 40% of the moisture deficit would be applied. Seasonal evapotranspiration values reached the highest in the fully irrigated (100%) treatment, calculated as 797 and 811 mm for the cultivars Bayrampaşa and Starline F1 respectively. The highest artichoke yield was obtained for a 100% irrigation level as 20.33 $t \cdot ha^{-1}$ for the Bayrampaşa cultivar and as 33.69 $t \cdot ha^{-1}$ for the Starline F1 cultivar. In general, it was seen that various irrigation applications have statistically significant effects on yield. The highest values of irrigation water use efficiency (*IWUE*) were obtained from the irrigation level in which 70% of the irrigation need was met. Also, the water–yield relation factor (k_y) was determined to be 1.37 for the total growing season.

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Key words: Irrigation scheduling, drip irrigation system, water–yield production, evapotranspiration

INTRODUCTION

Irrigation programming involves studies about determining when and how much irrigation to apply to a plant during its growing period. Within this scope; it is first needed to choose an irrigation method which is consistent with the climatic, soil, topographical and botanical conditions of the area, which allows efficient use of available water and will not cause yield decrease. Among irrigation methods, the drip irrigation method stands out in terms of uniform use of water, high efficiency, irrigation water saving and ease of operating, especially in the irrigation of vegetable and fruit trees. Today, all of Israel's irrigated farming lands, 95% of those in France, 62% of those in Egypt and 50% of those in the U.S.A. are irrigated using pressured irrigation methods, including the drip irrigation method (www.icid.org). Although its use is assumed to be roughly around 10% in Turkey, it is increasingly becoming more widely used.

Both domestically and worldwide, a great deal of research has been conducted which will shed light on irrigation programming for various climatic and plant conditions. In some of this research, irrigation programming of plants has been carried out in a manner which monitors the moisture content of the soil, crop and atmospheric conditions. A lot of research has been completed on vegetable and fruit groups which were irrigated using the drip irrigation method and evaluated by taking plant-soil-atmosphere relations into consideration, such as broccoli, carrot, zucchini, radish [Imtiyaz et al., 2000]; zucchini [Eliades, 1988, Randall and Locascio, 1988]; tomato [Locascio and Smajstrla, 1996]; potato [Panigrahi et al. 2001; Ferreria and Carr, 2002; Ünlü et al., 2006]; strawberry [Yuan et al., 2004] and artichoke [Boari et al., 2012] and it has been demonstrated that this method yields quick and practical results.

As artichoke, cultivated in large areas in Mediterranean countries and consumed in considerable amounts, is a very good diet vegetable which is rich in protein, vitamins and nutrients, demand for this vegetable type is rapidly growing. Since it is beneficial for human health, artichoke is commonly used in the pharmaceutical industry as well. It has been stated that artichoke has positive effects against heart disease, cancer and liver disease [Krauss et al., 1996].

In artichoke cultivation, water-production functions must be known very well in order for a high yield and quality. As it is necessary to develop a favorable irrigation program for artichoke in order to be able to generate alternative production, the applicability of existing artichoke production to regional conditions has been researched, and the resulting data can be used as a basis for further research.

MATERIAL AND METHODS

The research was conducted during the 2013/2014 cultivation season in the city of Tekirdağ, in Namık Kemal University, Faculty of Agriculture Research Greenhouse. Each trial parcel, sized 4 × × 3 m, covers a total of 12 m^2 and consists of four plant rows. The inter-row and above-row is 1 m. The soil type is deep, heavy textured, well-drained and the available water holding capacity within 0.9 m of the soil profile is approximately 0.17 m. The electrical conductivity (*EC*) of the irrigation water was classified as C_1S_1 according to U.S. Salinity Lab. (U.S. Salinity Laboratory Staff, 1954).

In the research greenhouse, climatic elements were monitored throughout the cultivating period from the meteorology station that was placed into the greenhouse. The irrigation system was composed of water source, fertilizer tank, screen filter, pipelines and drippers, respectively. The irrigation water needed for the irrigation of research parcels was taken from a nearby city feeder into the system.

In the research, soil moisture change was monitored via tensiometers. For this purpose, SR model tensiometers manufactured by the Irrometer Company were used. For moisture assessments, in conformity with the principles stated in Güngör and Yıldırım [1989], two tensiometers were fixed into the the trial parcels, so as to go 30 and 60 cm deep into the soil. Prior to the initiation of the study, tensiometer calibration was done under field conditions and equations were formulated for each 30 cm layer.

The artichoke cultivars that were used in the research were Bayrampaşa and Starline F1. The cuttings of cv. Bayrampaşa were obtained from the underground stem of dormant plants. The seedlings of cv. Bayrampaşa and cv. Starline F1 were transplanted into the plots in early September. The Starline F1 is an early season cultivar with high yield and strong root and stem structures. The Bayrampaşa cultivar has quite large and flattened heads with brownish-red bracts.

The experimental design was a split plot replicated three times. The experiments consisted of two cultivars (main plots) and three irrigation levels (subplots). These are:

- main plot: V_1 – Bayrampaşa cultivar; V_2 – Hibrit Starline F1 cultivar;
- sub plot: I_{100} – A treatment which was irrigated so much as to increase the level of moisture to match the field capacity when 40% of the available water holding capacity is consumed; I_{70} – A treatment to which 70% of the amount of irrigation water applied to treatment I_1 was applied; I_{40} – A treatment to which 40% of the amount of irrigation water applied to treatment I_1 was applied.

Irrigation water was applied to plots with drip irrigation. The percentage of wetted area was realized as 50%. Effective root depth was 60–90 cm and evapotranspiration rates were calculated with respect to 90 cm soil depth, according to the water budget approach [Walker and Skogerboe, 1987].

Starline F1 seedlings and Bayrampaşa underground buds were planted by hand into the parcels of which the field preparation was completed on 20 September, 2013 (DOY 263). Yield harvest was taken when the crown diameter generally reached approximately 13 cm, between 20–25 March 2014 (DOY 79–84). Produce samples taken from each parcel were taken to the laboratory and physical measurements were completed.

Water–yield functions were determined [Howell et al., 1990] with reference to the relations between applied irrigation water and measured evapotranspiration, and harvest efficiency. Irrigation water use and water use efficiency rates were calculated based on the irrigation water applied to trial treatments, measured evapotranspiration and harvest efficiency values [Zhang et al., 1999].

In addition, the water–yield relation method known as the Stewart model [Doorenbos and Kassam, 1979] was used in order to determine the effects of water deficit on harvest yield.

A variance analysis of the data obtained from the research, the significance control of the variations between the averages, and the correlations between the characters studied were determined according to the principals stated in Yurtsever [1984] and Düzgüneş et al. [1987] using SPSS 8.0.

RESULTS AND DISCUSSION

Throughout the cultivation period, the climatic elements taken from the meteorology station located within the greenhouse are graphed in Figure 1. As can be seen on the figures, in parallel with the increase in the interior temperature of the greenhouse, soil temperature and leaf surface temperatures in the greenhouse showed an increase, whereas relative moisture values showed a decrease. Interior temperature values showed the same tendency as the changes in outer temperature. The maximum interior tem-

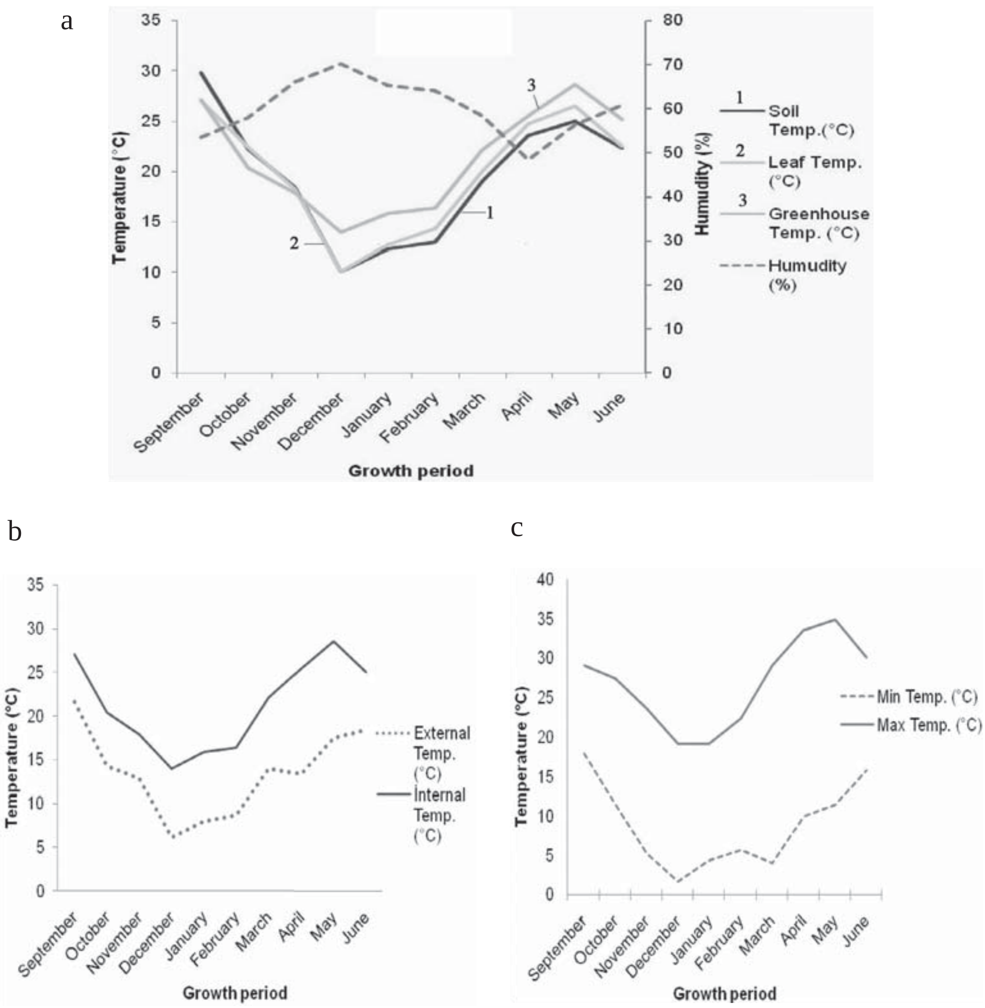

FIGURE 1. Climatic factors inside the greenhouse (a, b, c)

perature value was measured as 35°C in March while the minimum interior temperature value was measured as 1.7°C in the month of December.

The growth periods and growing season lengths for 2013/2014 is shown in Figure 2. As can be followed on the figure, it took the crop approximately 116 days to reach the first harvest maturity in 2014 within the fruit growth period. The whole growing season was completed in 281 days.

In the research, the growth periods of the artichoke plant were defined as early vegetative growth period (1a, leaf growth), late vegetative growth period (1b, leaf growth, sub-branch formation, and flower bud formation), generative growth period (flowering, fruit formation, maturity) and the period of loss in vegetative parts. In research conducted under different regional conditions and with different artichoke types, the growing period is completed in about 270 days and subsequently left to rest for three months [Vural et al., 2000; Prohens ve Nuez, 2008].

Evapotranspiration results

Seasonal total evapotranspiration values, calculated according to water budget approach and with respect to the amounts of applied irrigation water and rates of changes in soil moisture for all treatments during the cultivation periods, are summarized in Table 1.

TABLE 1. Effect of irrigation treatment and years on irrigation characteristics

Variety	Main effect	Soil water depletion (mm·90 cm^{-1})	Irrigation water applied (mm)	Seasonal evapotranspiration (mm)	*IWUE*	*WUE*
Bayrampaşa	I_{100}	22	775	797	2.62 ns	2.55 ns
	I_{70}	87	542	629	2.63	2.26
	I_{40}	126	310	436	2.58	1.83
Starline F1	I_{100}	12	799	811	4.21 ns	4.15 ns
	I_{70}	85	560	645	4.47	3.88
	I_{40}	112	320	431	3.54	2.62

ns – not significant.

As can be seen in the table, the highest amount of irrigation water and the highest evapotranspiration belong to treatment I_{100} in both varieties. The evapotranspiration values measured in the trial treatments throughout the whole growing season ranged between 436 and 797 mm for the Bayrampaşa cultivar, and between 431 and 811 mm for the Starline F1 cultivar. The seasonal evapotranspiration of the artichoke cultivar grown by Cantore et al. [2013] in Bari (Italy) under lysimeter conditions was 967 mm for the first year and 911 mm for the second year.

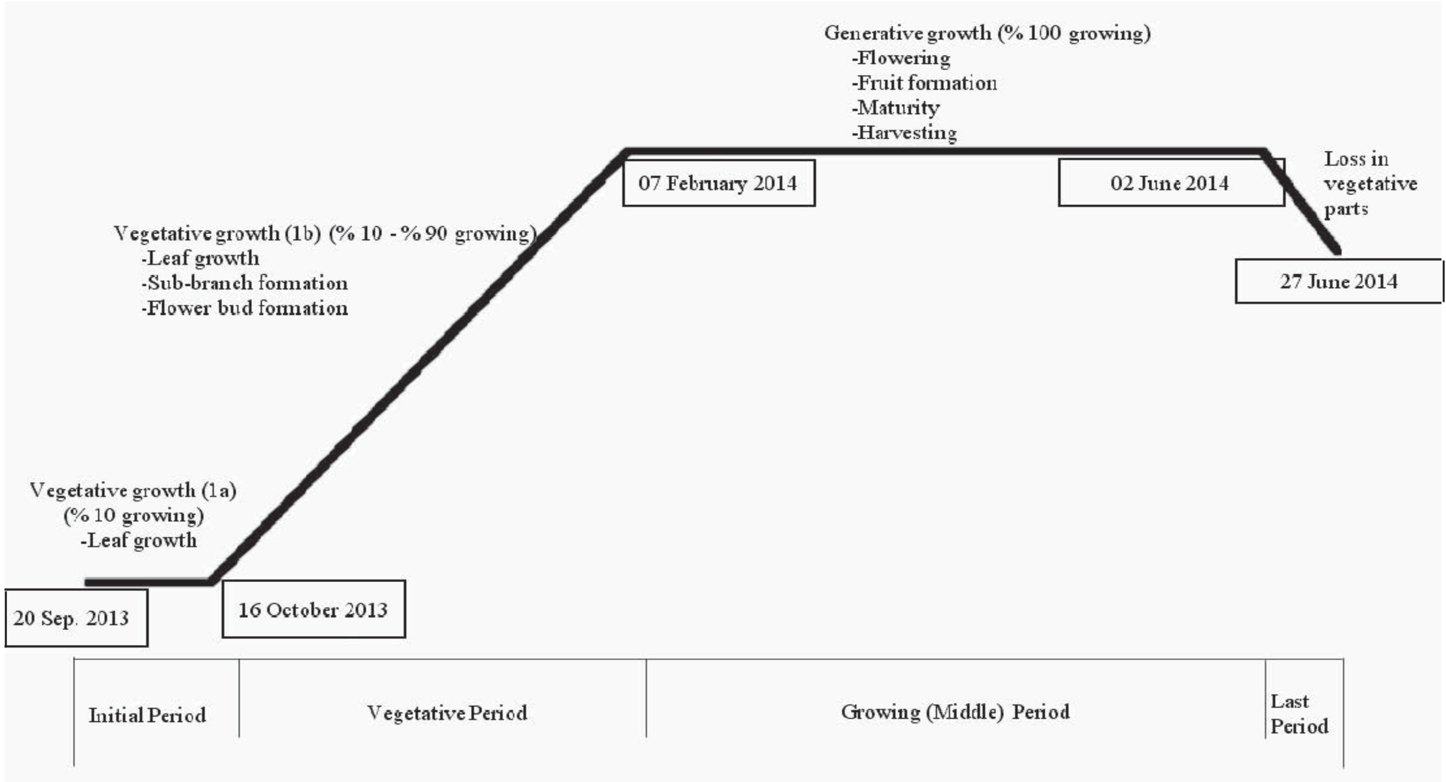

FIGURE 2. Growth periods of artichoke

Results concerning yield and yield components

Artichoke yield and some physical yield parameters and results of variance analyses on the parameters are presented in Table 2 for each treatment and varieties. statistically showed a significance of 0.05 and cultivar × irrigation level interaction was found to be insignificant. According to the Duncan test results, which is performed in order to determine the level of variance, each cultivar and irrigation level constituted a different group

TABLE 2. Yield and yield parameters of artichoke

Variation source	Variety	Main treatment	Marketable yield ($t \cdot ha^{-1}$)	Total head number	Head weight (g)	Head diameter (cm)	Receptacle diameter (cm)	Receptacle weight (g)	Stem thickness (cm)
Cultivars	Bayrampaşa		14.19a	2.9a	434.23a	12.36	7.69	63.07	2.27
	Starline F1		23.33b	4.3b	472.88b	12.43	7.57	61.90	2.38
	×		*	*	*	ns	ns	ns	ns
Irrigation levels		I_{100}	27.01a	5.0a	478.48a	12.57	8.09	70.22	2.29
		I_{70}	19.62b	3.7b	467.29b	12.35	7.21	53.81	2.37
		I_{40}	10.19c	2.1c	414.88c	12.26	7.60	63.56	2.33
			*	*	*	ns	ns	ns	ns
Cultivar × Irrigation level	Bayrampaşa	I_{100}	20.33	4.0	466.71	12.69	8.51	78.57	2.01
		I_{70}	14.25	2.8	446.88	12.09	7.27	54.64	2.21
		I_{40}	8.00	1.9	389.08	12.29	7.31	56.02	2.60
	Starline F1	I_{100}	33.69	6.0	490.26	12.46	7.68	61.88	2.58
		I_{70}	24.99	4.5	487.71	12.61	7.14	52.99	2.53
		I_{40}	11.32	1.3	440.69	12.22	7.89	71.12	2.05
	×		ns	ns	ns	ns	ns	ns	*

[*] Significant at the $p < 0.05$; ns – not significant. Means marked with the different letter differ significantly.

The highest average yields for the cultivars Bayrampaşa and Starline F1 were obtained as respectively 20.33 and 33.69 $t \cdot ha^{-1}$ in treatment I_{100}. Whereas the lowest average yields for both cultivars were seen to take place in treatment I_{40} to which 40% irrigation was applied, as 8.00 and 11.32 $t \cdot ha^{-1}$ respectively.

According to the variance analysis results; variance among difference irrigation application levels and cultivars where the fully irrigated treatment I_{100} formed the first group and treatment I_{40} formed the last one with the lowest yield. Also, some yield parameters such as total head number and head weight showed a significance of 5% among the irrigation levels and also cultivars while the differences were not significant among the cultivars × irrigation level interactions.

When the world average yield value of artichoke is assessed on the basis of countries, it can be seen that Argentina and Egypt have the highest yields with 23 t·ha^{-1}, followed by Uzbekistan, Cyprus and Peru with approximately 20 t·ha^{-1}. The yield values obtained in the artichoke study conducted by Munich Technical University [Saleh, 2003] in Germany ranged between 14.64–21.07 t·ha^{-1}, while they ranged between 11.9–19.9 t·ha^{-1} in the study conducted by Garnica et al. [2004] in Spain and between 10–11.4 t·ha^{-1} in the study conducted in Italy by Boari et al. [2012]. The yield average in Turkey is around 12 t·ha^{-1} [Anonymous, 2013; Bektaş and Saner, 2013].

Seasonal water–yield relation is graphed in Figure 3. The water–yield relation factor (k_y) of the artichoke plant was found to be 1.37 for the cultivars Bayrampasa and Starline F1. According to these results, it is clear that, as explained in theory in Doorenbos and Kassam [1979], water limitation implemented throughout the entire growing season, or in other words, artichoke cultivation under dry conditions, will face yield loss. As shown in the aforementioned graph, it can be said that when 25% of proportional water consumption deficit is generated throughout the total growing season a 34% yield decrease will be seen, while this would increase to 69% when the proportional water consumption deficit is 50%.

As can be seen on Table 1, *IWUE* and *WUE* values decrease as the irrigation water level decreases. Statistically, the variance between cultivar × irrigation level interactions in terms of *IWUE* and

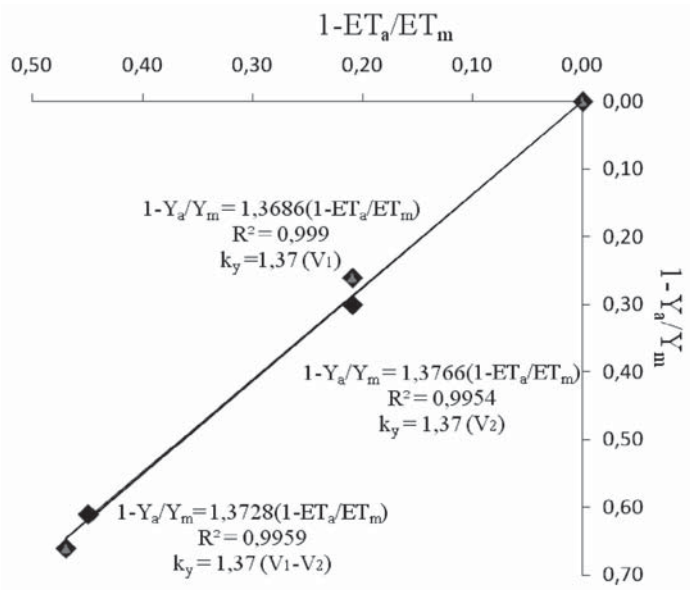

FIGURE 3. Yield response factor (k_y), for total growing period (V1: Bayrampaşa; V2: Starline F1; ETa, ETm: actual and maximum evapotranspiration; Ya, Ym: actual and maximum yield)

WUE values was found to be insignificant. The highest irrigation water use efficiency (*IWUE*) values for the cultivars Bayrampaşa and Starline F1 were obtained from treatment I_{70} as 2.63 kg·m^{-3} and 4.47 kg·m$^{-3,}$ respectively, while the lowest *IWUE* values were obtained from treatment I_{40} as 2.58 and 3.54 kg·m^{-3}, respectively. In the optimum treatment, the *IWUE* values for the cultivars Bayrampaşa and Starline F1 were calculated as 2.62 and 4.21 kg·m^{-3}, respectively; whereas the *WUE* values were found to be 2.55 and 4.15 kg·m^{-3}, respectively.

CONCLUSIONS

The fact that yield values obtained from the fully irrigated treatment I_{100} were considerably greater than those obtained from treatment I_{40}, which was subjected to maximum limitation, clearly exhibits the importance of irrigation for artichoke cultivation. Irrigation water use efficiency and water use efficiency values varied depending on irrigation levels. Generally, as the amounts of applied irrigation water decrease, irrigation water use efficiency and water use efficiency showed a decrease in both varieties.

There is no statistical difference between irrigation levels in terms of efficiency. When yield and efficiency results are taken into consideration together, for obtaining maximum yield in artichoke cultivation, the fully irrigated subject (I_{100}) can be recommended. And in cases where water source capacity is limited, it can be said that the option of limiting irrigation water can be taken for saving purposes, provided that level of this limitation should not exceed 30%.

Consequently, scientific data which will support the water–yield functions and irrigation programming of artichoke was obtained in the study. It is expected that the findings will be useful for researchers and investors who will be working on this subject.

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Streszczenie: *Wpływ nawadniania na plonowanie dwóch odmian karczocha zwyczajnego (*Cynara scolymus *L. cv. Bayrampaşa oraz Starline F1) w warunkach szklarniowych.* Badano wpływ zróżnicowanego nawadniania roślin karczocha w celu określenia optymalnego poziomu nawadniania i innych wskaźników plonowania zależnych od tego czynnika. Doświadczenie zostało założone w trzech powtórzeniach w układzie split-plot. Testowano trzy poziomy nawodnienia

(100, 70 i 40%) u dwóch odmian karczocha zwyczajnego (Bayrampaşa oraz Starline F1). Najwyższą ewapotranspirację odnotowano przy pełnym nawodnieniu (100%) i wynosiła ona 797 mm dla odmiany Bayrampaşa oraz 811 mm dla odmiany Starline F1. Przy tym samym poziomie nawadniania uzyskano największy plon, tj.: 20,33 $t \cdot ha^{-1}$ dla odmiany Bayrampaşa oraz 33,69 $t \cdot ha^{-1}$ dla odmiany Starline. Zróżnicowane warunki nawadniania wywierały istotny statystycznie wpływ na plonowanie. Najwyższy wskaźnik efektywności w wykorzystaniu wody (*IWUE*) otrzymano w przypadku nawadniania na poziomie 70%. Wskaźnik zależności między nawadnianiem a plonowaniem (k_y) wynosił 1,37 dla całego sezonu wegetacyjnego.