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Effect of Different Irrigation Levels on Some Lettuce (*Lactuca sativa*) Varieties Grown in Kocaeli Conditions[A]

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Abstract: The effects of varying irrigation levels on some lettuce cultivars were examined in this study. The research was conducted in Kocaeli province during the 2020-2021 growing season in a greenhouse. A split-plot design was employed in the experiment. Five irrigation levels (0.25 E, 0.50 E, 0.75 E, 1.00 E, and 1.25 E) were established by using the amount of water evaporated (E) from a 100 mm glass petri dish as a reference in the sub-plots. The main plots contained the varieties Carteganas, Concorde, and Melina. Head weight, diameter, length, root length, and leaf number values showed statistically significant ($P<0.01$) differences according to variety (V), irrigation level (IL), and V x IL interactions. The highest average head weight was obtained as 516.9 g in the Melina variety, followed by the Concorde and Carteganas varieties. The highest average head weight was obtained from 0.75 E at 581.2 g, while the lowest was obtained from 0.25 E at 224.8 g. The highest values in all yield components were obtained from the 0.75 E irrigation level. Relatively low values were obtained at 0.25 E and 0.50 E irrigation levels. According to the results obtained, the appropriate lettuce variety can be selected by considering the market value, and Melina, which has a higher unit mass, can be preferred. In addition, it was concluded that small petri dishes could be used in planning the irrigation time for lettuce grown in unheated greenhouse conditions in Kocaeli, and it can be recommended to use a value of 0.75 as the crop-pan coefficient**.**

Keywords: Curly lettuce, deficit irrigation, evaporation, head lettuce, yield.

[A] Produced from a master's thesis. This study does not require ethics committee permission. The article has been prepared in accordance with research and publication ethics.

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Farklı Sulama Seviyelerinin Kocaeli Koşullarında Yetiştirilen Bazı Salata (*Lactuca sativa*) Çeşitleri Üzerine Etkisi

Öz: Bu çalışmada, farklı sulama seviyelerinin bazı salata çeşitleri üzerindeki etkileri araştırılmıştır. Araştırma, Kocaeli ilinde sera koşullarında 2020-2021 yetiştiricilik mevsiminde yürütülmüştür. Denemede, tesadüf bloklarında bölünmüş parseller deneme deseni kullanılmıştır. Ana parsellerde çeşitler (Carteganas, Concorde ve Melina) ve alt parsellerde ise 100 mm'lik cam petri kabından buharlaşan su miktarı (E) referans alınarak oluşturulan beş sulama seviyesi (0.25 E, 0.50 E, 0.75 E, 1.00 E ve 1.25 E) yer almıştır. Baş ağırlığı, çapı, boyu, kök uzunluğu ve yaprak sayısı değerleri çeşit (V), sulama seviyesi (IL) ve V x IL interaksiyonlarına göre istatistiksel olarak önemli ($P<0.01$) farklılıklar göstermiştir. En yüksek ortalama baş ağırlığı Melina çeşidinde 516.9 g olarak elde edilirken onu sırasıyla Concorde ve Carteganas çeşitleri izlemiştir. En yüksek ortalama baş ağırlığı 0.75 E konusundan 581.2 g olarak elde edilirken en düşük ise 224.8 g ile 0.25 E konusundan elde edilmiştir. Verim bileşenlerinin tümünde en yüksek değerler 0.75 E sulama seviyesinden elde edilmiştir. 0.25 E ve 0.50 E sulama seviyelerinde göreceli olarak düşük değerler elde edilmiştir. Elde edilen sonuçlara göre, pazar değeri de dikkate alınarak uygun salata çeşidi seçimi yapılabileceği gibi birim kütlesi daha yüksek olan Melina tercih edilebilir. Bunun yanında, Kocaeli'de ısıtmasız sera koşullarında yetiştirilen salata için sulama zamanının planlanmasında küçük petri kaplarının kullanılabileceği sonucuna ulaşılmış olup ve bitki-kap katsayısı olarak 0.75 değerinin kullanılması önerilebilir.

Anahtar Kelimeler: Kıvırcık salata, kısıntılı sulama, buharlaşma, baş salata, verim.

Introduction

Although the origin of the lettuce and salad plant is shown as the Mediterranean and the Middle East, it has become an indispensable element of all cuisines today. While it is usually raw, it can also be consumed as pickles or cooked in Far-Eastern countries. Lettuce, indispensable for tables, is usually consumed raw in Turkey. It is in the group of appetizing vegetables with its minerals. It is a good diet vegetable with 94-95% water content in its leaves (Yağmur and Aydın, 2021).

One of the 38 vegetable species currently grown in Turkey is lettuce. 6.2% of total vegetable production is in the vegetables with edible leaves group. Lettuce species are grouped according to leaf characteristics. They are grouped as curly-leaf lettuce (*Lactuca sativa* var. Crispa), head lettuce (*Lactuca sativa* var. Capitata), and lettuces (*Lactuca sativa* var. Longfolia) (Sarıyer and Akbudak, 2022). The production period occurs in a short period of 2-3 months. Turkey produces it in open or greenhouse conditions every month and according to the season. Especially in the Marmara, Aegean, and Mediterranean regions, production continues with high commercial returns in every season of the year except June-August. In order to obtain the highest income in our

country, producers produce in open field conditions in the Aegean and Mediterranean regions and greenhouse conditions in other regions in December-February (Vural et al., 2000). Producers generally grow lettuce plants as a second or third crop. Producers prefer to grow cucumbers, tomatoes, and beans in spring and summer, while they prefer lettuce plants in winter. Despite relatively high initial establishment costs, greenhouse plant production is an agricultural method with high economic returns due to early product introduction, no gaps in the market, high product quality, and higher yields (Yıldırım et al., 2015).

Kocaeli province is important in greenhouse cultivation, especially in the winter months. Since natural rainfall cannot be used in greenhouse cultivation, irrigation is the most important input. Effective use of irrigation water, labor savings, the ability to provide plant nutrients with irrigation water, and the advantage it provides in combating weeds and diseases cause the drip irrigation method to be preferred in greenhouse cultivation (Yıldırım et al., 2015). A limited number of studies have been conducted in our country on the irrigation of different lettuce varieties under open field or greenhouse conditions (Turhan et al., 2014; Abd-Elrahman et al., 2022; Yavuz et al., 2023). In these studies, it is seen that irrigation programs based on soil moisture, as well as irrigation programs in which the amount of water evaporated from the Class A evaporation pan is taken as a reference, are widely used (Öneş et al., 1995; Yazgan et al., 2006; Acar et al., 2008; Bozkurt et al., 2009; Çebi et al., 2014; Yıldırım et al., 2015; Kaya et al., 2016). However, it is seen that producers in our country do not adopt these methods much when planning the irrigation schedule, especially in protected plant production. In addition, previous studies have shown that the response of irrigation applications to yield and quality may differ according to the irrigation method, plant species and variety, and climate and soil characteristics. The literature reviews found no study on planning irrigation schedules for different lettuce varieties grown under protected plant conditions in Kocaeli.

This study aims to prepare an appropriate irrigation program by revealing the response of different lettuce varieties grown in greenhouses in the ecological conditions of the Karamürsel district of Kocaeli province to different irrigation levels in terms of yield and quality, using the amount of water evaporated from a small petri dish as a reference, for the winter months.

Material and Method

Research area

The research was carried out in an unheated greenhouse environment (40°39' North, 29°36' East, 410 m above sea level) with an area of 300 m^2 in the Karapınar neighborhood of the Karamürsel district of Kocaeli province during the winter months of the 2020-2021 production season. The treatmets were carried out between December and April. The ridge height of the greenhouse is 3.5 m, and it is constructed from stainless galvanized pipes. The greenhouse cover material is polyethylene and has properties such as ultraviolet additive, infrared ray absorber, dust prevention, and fog prevention. Soil samples taken from the experimental area were analyzed in

the Soil and Water Resources Laboratory of the Atatürk Horticulture Central Research Institute of the Ministry of Agriculture and Forestry of the Republic of Turkey (Table 1). According to the results of the analysis, the soil, which has a loamy texture, is slightly salty. It was evaluated that the experimental area was suitable for vegetable cultivation based on previous cultivation experiences. In Kocaeli-Karamürsel, located in the southeast of the Marmara Region, summer months are generally hot and rainy with little rainfall, and winter months are rainy and cool. The district's annual average temperature is around 14.5 °C. The coldest days are January and February, and the hottest are July and August. Karamürsel district receives an annual average of 705 mm of rainfall. While most rainfall falls in December and January, the lowest values are recorded in July and August. Annually, 112 days of rainfall occur in the district. The average relative humidity of the district is 67%, and the dominant wind direction is generally southeast. (Anonymous, 2021). During the experimental period, the ambient temperature inside the greenhouse varied between 17-35 ºC, and the average relative humidity was 68%.

Table 1. Some properties of the experimental area soils

Depth (cm)	Soil texture	pH (sat.)	EC25 (sat.) (µmhos cm^{-1})	Lime (%)	Organic matter (%)	Available phosphorus (P_2O_5, ppm)	Available potassium (ppm)
0-30	50	6.81	507	0.20	2.46	53	118
	Loamy	Neutral	Lightly salted	Very little	Middle	High	Low

Agricultural applications and experimental treatments

The experiment was set up in a randomized block split-plot design with four replications. Lettuce (*Lactuca sativa*) varieties were in the main plots, and irrigation levels were in the subplots (Table 2). The plant to plant spacing of in each plot was 33 cm, and the row spacing was 40 cm; 16 plants were planted in one plot, and 48 seedlings were planted in one replication. In the trial, 60 plots were created with three varieties, five irrigation levels, and four replications (3×5×4), and 960 lettuce seedlings were planted. The plot area represents the area of each sub-plot (6.336 m^2). A head lettuce variety known as Iceberg, "Carteganas," a variety known as Mediterranean lettuce, "Concorde," and a variety known as curly lettuce, "Melina," were used as crop material. Carteganas is a head lettuce variety with a very slow stemming characteristic in hot weather conditions and is highly resistant to Nasonovia Ribisnigri (aphid). It has a medium-sized, attractive head structure and is resistant to leaf tip burn (Rijkzwaan, 2021). The Concorde variety has high yield, deep curly leaves with very slow stemming, large and open head structure, and long shelf life after harvest (Rijkzwaan, 2021). The Melina variety has a circular head and frilled leaf shape; its leaves are thick, juicy, and crisp. It is a commercial variety suitable for fresh consumption. The variety has a late stemming feature and is suitable for autumn, winter, spring, and early summer cultivation in temperate regions. It is resistant to some races of lettuce downy mildew, aphids, and lettuce mosaic virus (Melina, 2021).

Table 2. Experimental treatments

Main plots (Lettuce varieties)	
Variety 1	Cartagena
Variety 2	Concorde
Variety 3	Melina
Submain plots (Irrigation levels)	
25% E	Application of irrigation water at the level of 25% evaporated water from the pan
50% E	Application of irrigation water at the level of 50% evaporated water from the pan
75% E	Application of irrigation water at the level of 75% evaporated water from the pan
100% E	Application of irrigation water at the level of 100% evaporated water from the pan
125% E	Application of irrigation water at 125% evaporated water from the pan

Fermented barnyard manure was spread on the soil during soil preparation. No other fertilization was done. A drip irrigation system was established after the experimental area was plowed and hoed with a hoeing machine. The seedlings were planted on 28.12.2020. The first water was given on the same day. Hoeing was done on January 20, 2021, and February 15, 2021, to ensure soil aeration and weed control. Irrigation water was given to the plants with a drip irrigation system.

The irrigation system control unit used in the experimental consists of central, side, and lateral pipes. Lateral pipes have inline drippers with a diameter of 16 mm and 33 cm intervals. The flow rate of the drippers on the laterals was measured as 1.9 L h^{-1} under 1 atm constant pressure in the tests conducted before the trial. The diameter of the central and side pipes was arranged as 32 mm. Mini valves were used to transition from side pipes to laterals, and ball valves were used from the main pipe to the side pipes. The distance between the laterals is arranged to equal the row spacing (40 cm).

Determination of the amount of irrigation water to be applied and the irrigation program

In determining the amount of irrigation water to be applied, evaporation data obtained from a glass petri dish (diameter: 100 mm and high: 20 mm), which is practical to use in greenhouses, were used. Cemek et al. (2004) found a linear relationship between the glass dishes placed on the soil surface and the A-class evaporation dish in their study conducted with Petri dishes so that farmers could obtain more practical and easy results as an alternative to the daily evaporation amounts from the A-class evaporation dish in determining the amount and time of irrigation in their production in greenhouses. In this study, the amount of irrigation water was determined by using the evaporation values of the Petri dishes placed in the greenhouse according to the instructions given by Cemek et al. (2004) with the following equality.

$$I = E \times kpc \times A \times P \quad (1)$$

In the equation, I is the amount of irrigation water (L), E is the cumulative evaporation amount in two irrigation intervals (mm), kpc is the pan-crop coefficient, A is the plot area (m^2), and P is the wetted area ratio. In this study, E (pan) values were determined by taking into account the daily value read from a 100 mm glass petri dish, and irrigation was carried out when every 7.5 mm cumulative evaporation amount was reached as a result of preliminary experiments. Since the winter season was within seasonal norms, the irrigation interval changed between 5-12 days according to the determined evaporation amount. In the study where the pan and crop coefficients were considered together, the kpc values were taken as 0.25, 0.50, 0.75, 1.00, and 1.25 according to irrigation treatments. The wetted area ratio was taken as 1 in this study. Since the drip irrigation method was used for the irrigation of lettucevarieties, the amount of irrigation water determined in terms of volume was converted to minutes by taking into account the number of drippers and flow rate in each sub-plot, and irrigation water was applied for the specified time for each experimental treatment. Valves were used to provide water to the plots for the specified time.

Statistical analysis

The data obtained from the experiment was analyzed using the SPSS-23 package program with the analysis of variance (ANOVA) technique. According to the F test, when statistically significant differences were observed between the experimental treatments, Duncan's Multiple Range Test was performed to determine the differences between the means.

Results and Discussion

Amounts of irrigation water applied

Immediately after planting the plants, equal amounts of water (10 mm) were applied to all subplots. Subsequent irrigations were applied according to the experimental treatments. Irrigation dates and the amounts of irrigation water applied in each irrigation are given in Table 3. A total of 12 irrigations were carried out, excluding the irrigation water. According to the experimental treatments, the total amount of seasonal irrigation water applied to lettuce plants varied between 30.9 mm and 113.4 mm.

Table 3. Amounts of irrigation water applied to sub-plots according to irrigation tretments (mm)

Date	Irrigation treatments				
	25% E	50% E	75% E	100% E	125% E
28.12.2020	10.0	10.0	10.0	10.0	10.0
05.01.2021	1.9	3.8	5.6	7.5	9.4
13.01.2021	1.9	3.8	5.6	7.5	9.4
22.01.2021	1.9	3.8	5.6	7.5	9.4
05.02.2021	1.9	3.8	5.6	7.5	9.4
10.02.2021	1.9	3.8	5.6	7.5	9.4
22.02.2021	1.9	3.8	5.6	7.5	9.4
04.03.2021	1.9	3.8	5.6	7.5	9.4
09.03.2021	1.9	3.8	5.6	7.5	9.4
14.03.2021	1.9	3.8	5.6	7.5	9.4
19.02.2021	1.9	3.8	5.6	7.5	9.4
24.03.2021	1.9	3.8	5.6	7.5	9.4
Total	**30.9**	**51.8**	**71.6**	**92.5**	**113.4**

Head weight

The effect of variety and irrigation levels on lettuce head weight was statistically significant at the 1% probability level (Table 4). According to the average data, the highest head weight was seen in the Melina variety, also known as curly lettuce, followed by the Concorde variety, also known as red lettuce, and the lowest lettuce weight was obtained in the Cartegenas variety, also known as Iceberg lettuce. According to the evaluation of different irrigation levels, the highest head weight was obtained from the 75% E irrigation level. In comparison, the lowest was determined from the 25% E irrigation application. In the case of 100% E, where 100% of the water evaporated from the petri dish was taken as a reference, the average head weight was in the second group according to the Duncan test. It was followed by 125% E and 50% E irrigation treatments. The effects of different irrigation levels on head weight by varieties are given in Figure 1. The highest head weight was obtained in the Melina variety with 75% E irrigation, while the lowest head weight was obtained in the Cartegenas variety with 25% E treatment. Yıldırım et al. (2015) determined that yield increased with increasing irrigation water in a study they conducted on lettuce plants under deficit irrigation conditions in unheated glass greenhouse conditions in Çanakkale province. In a study conducted by Al-Bayati and Şahin (2018) in open field conditions in Konya province, the highest average marketable head weight was determined as 865.85 g in I_{120} treatment. The lowest average marketable head weight was 475.68 g in the I_{60} treatment. Kuslu et al. (2008) reported in their study carried out under greenhouse conditions that the increase in irrigation water salinity caused a decrease in yield in curly lettuce, and the highest yield was obtained at low salinity levels (0.3-1.2 dS m^{-1}) as 245-248 g $plant^{-1}$. Çerez (2020) reported that in the production of curly lettuce with limited water application in two different periods, autumn and spring, the highest average head weight was obtained from the

S_{120} treatment with 1130.8 g for the autumn period and from the S_{100} treatment with 1170.8 g for the spring period. It is thought that these differences in lettuce head weight values are due to the variety, irrigation water level, water quality, and other different agricultural practices.

Table 4. Head weight, diameter, height, root length, and leaf number values of different lettuce varieties under different irrigation levels

Treatment	Head weight (g)	Head diameter (cm)	Head length (cm)	Root length (cm)	Number of leaves (cm)
Variety (V)					
Carteganas	219.8 c	27.8 a	27.9 b	16.9 b	12.2 c
Concorde	335.3 b	26.5 b	29.3 a	17.6 a	26.9 b
Melina	516.9 a	26.9 b	27.2 c	18.0 a	32.1 a
Irrigation level (IL)					
25% E	224.8 e	23.3 d	24.8 d	16.1 c	20.1 e
50% E	298.2 d	26.4 b	27.6 c	18.4 b	22.1 d
75% E	581.2 a	34.8 a	32.4 a	19.0 a	30.0 a
100% E	360.8 b	24.7 c	28.9 b	16.1 c	22.8 c
125% E	321.7 c	26.2 b	26.9 c	17.9 b	23.8 b
Significance					
V	**	*	**	*	**
IL	**	**	**	**	**
V×IL	**	**	**	**	**

Note: Small letters indicate statistically significant differences among experimental treatments. **, * Significant at the 1% and 5%, respectively.

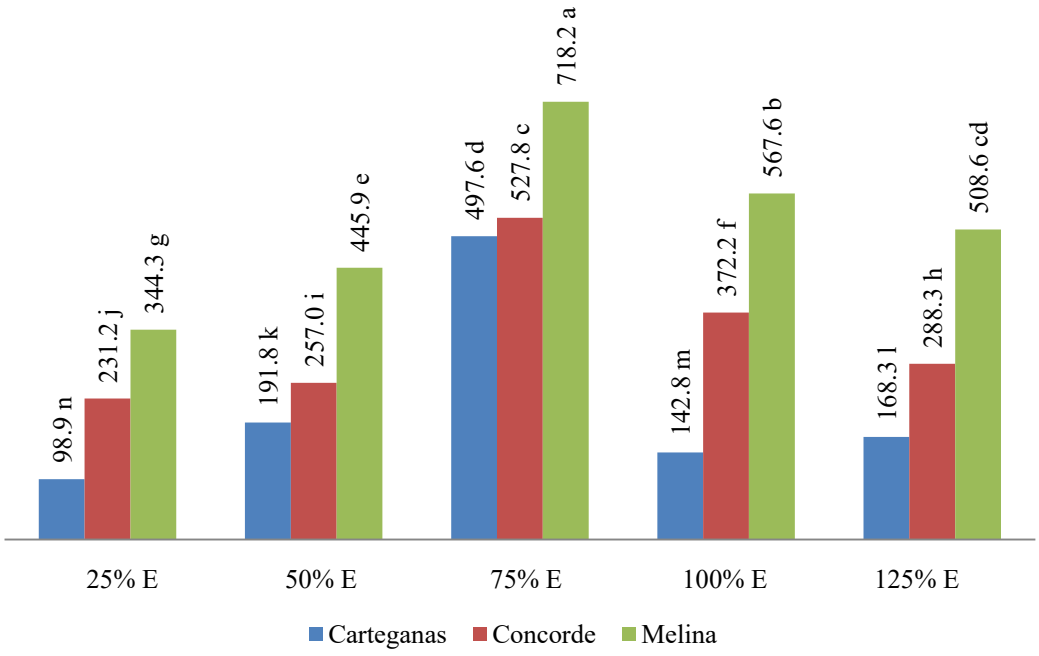

Figure 1. *Head weight (g) values of lettuce varieties under different irrigation levels*

Note: According to the Duncan test for each variety, different letters indicate significant differences at a 5% probability level.

Head diameter

The effect of different varieties and irrigation levels on lettuce head diameter was statistically significant (Table 4). The highest head diameter was obtained in the head lettuce variety Carteganas, followed by Melina, a curly lettuce, and Concorde, a red curly lettuce. According to the evaluation made in terms of different irrigation levels, the highest head diameter was obtained from 75% E irrigation level, while the lowest was determined from 25% E irrigation. The effects of different irrigation levels on head diameter by varieties are given in Figure 2. The highest head diameter in all varieties was obtained from 75% E irrigation, while the lowest head diameter values were determined from 25% E. The highest head diameter was obtained in the Carteganas variety under 75% E irrigation application, followed by the Concorde variety. Mohamoud (2019) reported that curly lettuce reached the highest head diameter in 125% irrigation application. The results of this study show that different varieties and irrigation levels can cause differences in lettuce head diameter.

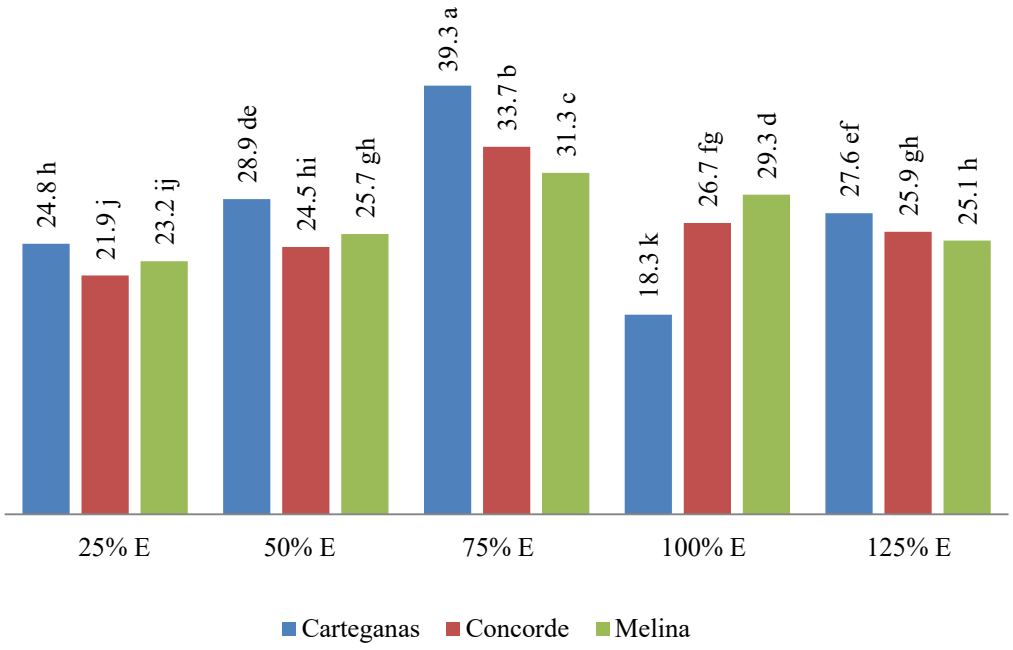

Figure 2. *Head diameter (cm) values of lettuce varieties under different irrigation levels*

Note: According to the Duncan test for each variety, different letters indicate significant differences at the 5% probability level.

Head length

The results of variance analysis for the effect of lettuce varieties grown under different irrigation levels on head length are given in Table 4. The effect of variety (V), irrigation level (IL), and V × IL interaction on lettuce head length was statistically significant at a 1% probability level. According to the average data, the highest head length was seen in the Concorde variety, followed by Carteganas, and the lowest head length was obtained in the

Melina variety. When the average head length values on three lettuce varieties under different irrigation levels were examined, 75% E irrigation level obtained the highest head length. At the same time, the lowest was determined from 25% E irrigation application. In 100% E, where 100% of the evaporated water from the Petri dish was taken as reference, the average head weight was in the second group in the Duncan test, followed by 50% E and 125% E treatments, respectively. The effects of different irrigation levels on head length by varieties are given in Figure 3. The highest head length was obtained from the Concorde variety under 75% E irrigation level according to the interaction between variety and irrigation levels. In comparison, the lowest was obtained from 25% E × Melina. Al-Bayati and Şahin (2018) observed an increase in head length as the amount of irrigation water increased in the limited water application they carried out in open fields in Konya conditions on lettuce, while the highest head length was obtained from I_{120} and I_{100} treatmens. The data show that variety, irrigation level, open field or under cover cultivation systems, and cultural practices can affect head length.

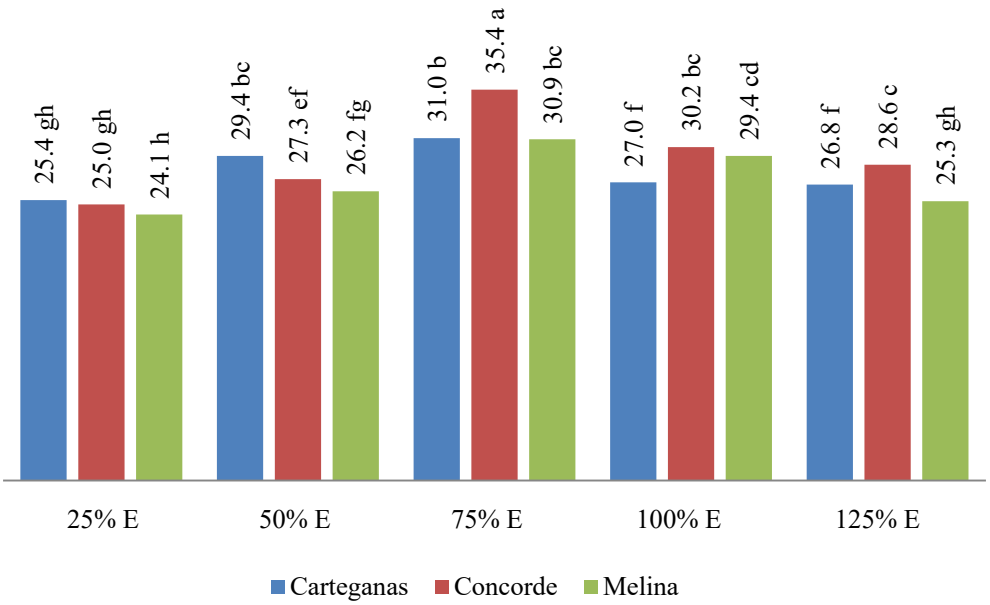

Figure 3. *Head length (cm) values of lettuce varieties under different irrigation levels*

Note: According to the Duncan test for each variety, different letters indicate significant differences at a 5% probability level.

Root length

The highest root length was obtained in curly lettuce Melina and red lettuce Concorde varieties, while the lowest root length was obtained in the Iceberg lettuce Cartegenas variety (Table 4). The effect of irrigation levels on root length was significant at a 1% probability level. The highest root length was obtained from 75% E irrigation level, followed by 50% E and 125% E treatments. The 100% E, where 100% of the evaporated water from the

pan was taken as reference, and the lowest irrigation level, 25% E treatment, were in the last group according to the Duncan test in average root length. The effects of different irrigation levels on root length by varieties are shown in Figure 4. The longest roots were measured in Melina variety 75% E and 125% E irrigation levels, followed by Cartegenas × 75% E and Concorde × 50% E interactions, respectively. Çerez (2020), Acar et al. (2008), and Al-Bayati and Şahin (2018) reported that different irrigation levels did not affect root length in limited water application in lettuce (*Lactuca sativa* L. var. Longifolia).

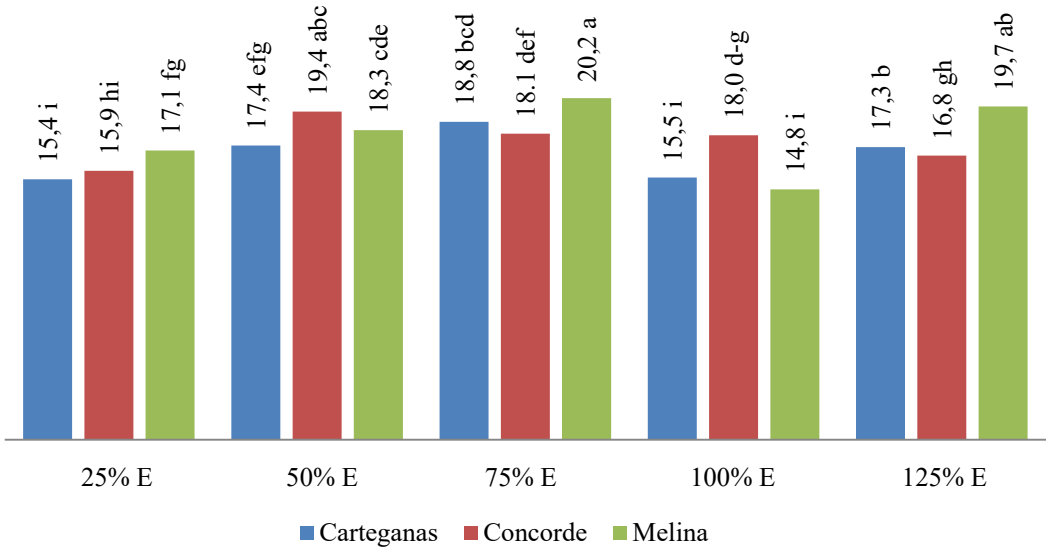

Figure 4. *Root length (cm) values of lettuce varieties at different irrigation levels*

Note: According to the Duncan test for each variety, different letters indicate significant differences at a 5% probability level.

Number of leaves

The average leaf number values of lettuce varieties under different irrigation levels are given in Table 4. According to the average data, the highest leaf number was obtained in the Melina variety, followed by the Concorde and Cartegenas varieties. When the average leaf number values of different irrigation levels on three lettuce varieties were examined, the highest leaf number was obtained from a 75% E irrigation level. At the same time, the lowest was determined from a 25% E irrigation application. The effects of different irrigation levels on leaf numbers by variety are given in Figure 5. The highest leaf number was obtained in the Melina variety under 75% E irrigation, while the lowest leaf number was determined from 25% E application in the Cartegenas variety.

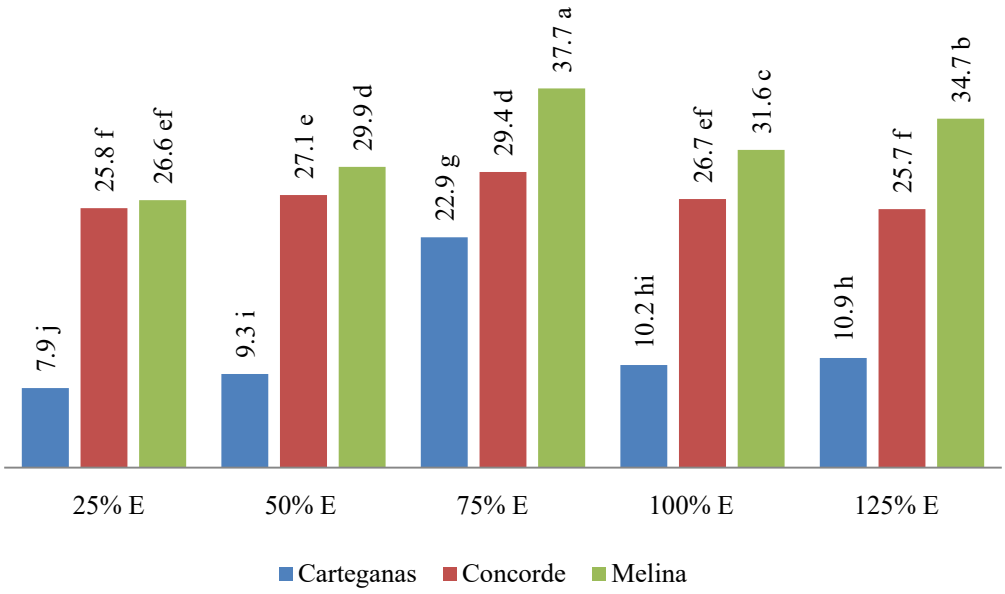

Figure 5. *Leaf count values of lettuce varieties at different irrigation levels*

Explanation: According to the Duncan test for each variety, different letters indicate significant differences at the 5% probability level.

Conclusion

This study investigated the effects of the amount of water evaporated from Petri dishes on head yield and some yield components of three different lettuce varieties under different irrigation levels. In the study conducted under unheated greenhouse conditions in Kocaeli, the pan-crop coefficients (Kpc) were taken as 0.25, 0.50, 0.75, 1.00, and 1.25, and irrigation treatments were formed as 0.25 E, 0.50 E, 0.75 E, 1.00 E, and 1.25 E. As a result of the study, it was determined that all the parameters examined according to the varieties and different irrigation levels showed statistically significant ($P<0.01$) differences. The highest yield was obtained from the Melina variety, followed by the Concorde and Cartegenas varieties. The highest values in yield and yield components were obtained from 75%E, treatment to which irrigation water was applied as 75% evaporated from the Petri dish. According to the study results, it is not recommended since the yield and yield component values are relatively lower under 25% E and 50% E irrigation treatments. Depending on the variety preference, it may be recommended to take 75% of the evaporated water as a reference by using 100 mm glass Petri dishes in the irrigation program for lettuce grown in greenhouses in Kocaeli.

Acknowledgments

This study does not require approval from the ethics committee. The article was prepared using research and publication ethics. The first author contributed 60%, and the second contributed 40% to the publication. There is no conflict of interest between the authors.

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