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Effect of Water Deficit on Flowering and Growth Characteristics of *Zinnia elegans*

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Abstract

Water resources have been decreasing in recent years due to global warming, thereby requiring more studies to determine the effect of limited water on plants. This study aimed to determine the effect of different irrigation levels on the flowering and growth characteristics of zinnia plant (*Zinnia elegans*). The research was carried out in the Plant Production Research Center of the Faculty of Agriculture at Çanakkale Onsekiz Mart University, Turkey. For the study, zinnia plants were grown in pots under field conditions and 4 different irrigation treatments were created where 100% (I-100 / control), 75% (I-75), 50% (I-50) and 25% (I-25) decreasing moisture was applied and the soil moisture was monitored by sensors. Data were subjected to variance and PCB-Biplot analyses. Results showed significant differences among irrigation treatments according to measured traits. At the end of the study, irrigation water amount and plant water consumption values were found to be 28.1-142.8 mm and 33.9-144.4 mm, respectively. Water stress was found to have a negative effect on the growth and agronomic characteristics of zinnia. However, it was observed that the quality of flowers is not affected even if plant growth is negatively affected by a 25% water shortage.

Keywords: Irrigation, Ornamental plant, Seasonal flowers, Water stress.

INTRODUCTION

Global warming threatens the existence of water everywhere in the world and this accelerates the need for efficient use of water resources in every aspect. In recent years, research on the response of plants to water constraints in agricultural areas has gained momentum, while studies on outdoor ornamental plants used in landscape areas remain inadequate (Demirel *et al.,* 2018; Demirel *et al.,* 2020). The physiological and morphological changes in ornamentals to be grown under limited irrigation conditions with decreasing water resources are still not clearly known. It is not desirable for these plants to be exposed to water stress as more attention is paid to the visual quality of the landscape plants commonly used in recreation areas. Possible climate change scenarios indicate that many living things will be affected by global warming in the future. Considering that cultivation will be very difficult under conditions where water availability is limited, studies on plants resistant to environmental stress factors, and especially on those that are drought tolerant, will become more important.

When different ecological factors are considered, it is known that seasonal flower species are more resistant than others. *Zinnia elegans*, a member of Asteraceae family, is one of these species. Zinnia is an annual species that naturally occurs in Central America and Mexico. There are some varieties with different colors of layered (early) and small flowers. It is easy to grow, requires effortless cultural maintenance of the plant, is disease resistant and has a long vase life; therefore, it is also considered as a cut flower (Dole, 1999). The plant can grow in any kind of soil which is rich in calcareous soil or organic matter.

Twumasi *et al.* (2005), who performed a study on different varieties of zinnia, examined the effects of water stress on plant growth characteristics as well as its xylem anatomy and vase life, reported that varieties with low water content had a longer vase life. Niu *et al.* (2012) demonstrated that flower size decreased in zinnia plants exposed to high salt stress, and Bizhani *et al.* (2013) stated that high salt concentrations lead to the drying of plants. On the other hand, some researchers have reported that irrigation and plant nutrition practices are among the factors that positively affect quality in zinnia species (Nazarideljou and Heidari, 2014; Sardoei *et al.,* 2014; Elhindi *et al.,* 2015).

While studies carried out so far on zinnia have mostly concentrated on cultivation techniques, research on the physiological effects of environmental stress factors is inadequate. This research therefore aimed to determine the physiological responses of the plant using limited cultivation techniques, to show how the plant morphology changes at different irrigation levels, to determine the relationship between flower quality and plant development characteristics with different amounts of irrigation water applied to the plant, and to determine the plant water consumption values for zinnia.

MATERIALS AND METHODS

Study area and experimental design

The study was carried out in pots under field conditions at the Faculty of Agriculture Research Center in Dardanos Campus of Çanakkale Onsekiz Mart University in 2018. Zinnia flower (*Zinnia elegans*) was used as the plant material. The study was conducted between June 20, 2018 and August 13, 2018. Zinnia flower was planted as a seedling in a pot (70 x 20 x 20 cm), with 4 plants at 15 cm intervals. 1: 1 peat + perlite was used as the growing medium. Zinnia flower was planted in pots in the growing environment prepared in the field on 20 June 2018.

The experiment was carried out with 4 different irrigation treatments and 4 pots for each treatment according to the randomized blocks experiment design. I-100 is the control treatment in which all the consumed part of the usable moisture in the pot is met. In the I-75, I-50 and I-25 treatments, 75 %, 50 % and 25 % of the water applied to the I-100 treatment is applied. A caisson well was used as the water source in the study area. The EC value of the irrigation water was measured as 1.15 ds m^{-1} and the pH value as 7.14. All pots were irrigated equally until the first measurement day (June 25, 2018) and the transition to irrigation treatments.

Forty ml of liquid fertilizer (MF Botanik Tropical, Turkey) containing 18 % N, 18 % P_2O_5, 18 % K_2O, 2 % MgO and micro elements were applied to the pots on June 29, 2018 and July 13, 2018, and 10 g leaf fertilizer (Sherill) was applied on August 03, 2018. No chemicals were applied for weeds in the pots. Weeds were plucked by hand and removed from the pots.

Measurements and calculations

Determination of irrigation water amount and plant water consumption

Soil moisture sensors working according to the dielectric principle (DECAGON 10HS) were used to monitor the pot moisture. One sensor was placed for each pot. The calibration process of the sensors started 15 days before planting. Regression equations were created between the moisture and the sensor values were decreased by calculating the weight of each pot, thus the calibration equations were obtained. Irrigation was made according to the treatments using the results obtained according to the equations. All pots were irrigated equally before starting the irrigation treatments. Irrigations were planned to be made when 30 ± 5% of the usable water holding capacity of S100 was consumed. However, because the air temperature was too high and therefore exceeded the rate given above, irrigation was set to be given one day after July 04, 2018.

Plant water consumption (ET) was determined according to Equation 1 (James, 1988):

$$\text{Equation 1: } ET=I+P-D\pm R\pm \Delta S$$

In equality; ET: Plant water consumption (mm), I: Irrigation water amount (mm), P: Precipitation (mm), D: Deep infiltration (mm), R: Runoff (mm), ΔS: The change of soil water content (mm) between any consecutive irrigations in the pot.

Since the experiment was conducted in a pot, deep infiltration and runoff were ignored.

Physiological measurements

Leaf relative water content

Leaf relative water content measurements were determined at 4–5 day intervals. Before irrigation, 3 leaf samples were taken three times from the zinnia flower in each pot. The samples were weighed with the help of a precision scale and the wet weight (WW), the turgor weight (TW) by keeping them in pure water for 24 hours and then keeping them in the oven at 70 °C for 24 hours, the dry weight (DW) values were obtained. Using these values, the leaf relative water content (LRWC) was calculated with Equation 2 (Bowman, 1989).

$$\text{Equation 2: } \mathbf{LRWC} = \frac{(\mathbf{WW}-\mathbf{DW})}{(\mathbf{TW}-\mathbf{DW})}\mathbf{X100}$$

Stomatal conductivity

Stomatal conductivity was measured by a diffusion leaf porometer (Decagon SC-1) before irrigation. These measurements were made between 11.00 a.m.-14.00 a.m., on a sunny leaf of 3 plants to be selected randomly in each time.

Chlorophyll readings

Chlorophyll readings were measured with a chlorophyll meter (Fieldscout CM 1000) before irrigation. These measurements were made between 11.00 a.m. -14.00 a.m., on one leaf of 3 plants that were randomly selected each time.

Normalized Difference Vegetation Index (NDVI) and Photochemical Reflectance Index (PRI)

Normalized difference vegetation index and photochemical reflectance index measurements were determined by SRS-NDVI and SRS-PRI sensors (Decagon SRS-Nr NDVI, SRS-Nr PRI). The device directly gives the values of NDVI values using Equation 3 (Penuelas *et al.,* 1997) and PRI values using Equation 4 (Gamon *et al.,* 1992*;* Penuelas *et al.,* 1995) by measuring the reflections in the NIR, RED and VIS regions. Measurements were made on non-cloudy days and between 11:00 a.m. and 14:00 a.m. when the angle of incidence of the sun changes the least. NDVI and PRI values were determined for each plant at 4-5 days interval. Values from the sensors were recorded with the help of a datalogger (Decagon M50).

Equation 3: $$NDVI = \frac{(R800 - R680)}{(R800 + R680)} X100$$

Equation 4: $$PRI = \frac{(R531 - R570)}{(R531 + R570)} X100$$

Morphological measurements

Plant height, plant diameter, leaf length and flower stem length were measured with the help of a ruler. Flower stem diameter, flower diameter, petal length, petal width, leaf width and leaf thickness were measured with calipers. The number of flowers and number of petals were obtained by counting (Demirel *et al.,* 2020).

Post-harvest measurements

The number of tillers was obtained by counting the new tiller plants formed next to the mother plant after the plants were removed. Root length was measured with a ruler from the exit point of the roots to the farthest point, after which the plants were removed. Fresh root and plant weights were obtained by weighing the roots and plants, respectively. Dry Root and plant weights were kept at 70 °C in the oven until the root and plant were completely dry and their weight was determined, respectively.

Statistical analysis

One-Way ANOVA was used to test whether the difference ($P < 0.05$) between irrigation treatments was significant or not for continuous variables. If the difference was significant, the Duncan test was performed to determine which treatment was different from others. Friedman test (Friedman, 1937) was made in the analysis of discrete variables such as flower number, petal number and number of siblings. For these traits, Bonferroni multiple comparison test (Dunnett, 1964) was used to determine the difference between groups. Variance analyses and multiple comparison tests were made with the help of SPSS 20.0 package program.

PCA-Biplot analysis was performed to visualize the variation of the investigated traits due to irrigation treatments. In the PCA-Biplot analyses, three different graphics were created for the morphological, physiological, and post-harvest measurements. Irrigation treatments were assigned as factor variable and graphical outputs evaluated based on the explained variance of dimensions in the graphics, the position of ellipses of the factors (irrigation treatments), and length/angles of vectors for the measured traits. The Biplot graphics were created under R software environment.

RESULTS AND DISCUSSION

Irrigation water and plant water consumption

The study was conducted between June 20, 2018 and August 13, 2018 for 55 days. During the experiment, 11 measurements were made. I-25 treatment was terminated as flowers were drying on the 31th day after planting (DAP_{31}). In other irrigation treatments, measurements were made until the end of the experiment. Until the irrigation treatments were started, 5000 mL of irrigation water was applied to all pots. Between the planting date of June 20, 2018 and July 6, 2018, approximately 1000 mL of irrigation water was applied daily on I-100, while the irrigation water applied as of July 7, 2018 increased almost twice (data not shown). It can be said that the reason for this is the intense flowering and plant growth.

The amount of irrigation water applied to the treatments and the values of plant water consumption are presented in table 1. The total amount of irrigation water applied according to the treatments and the plant water consumption (ETc) values during the development period were calculated to be between 28.1-142.8 mm and 33.9-144.4 mm, respectively. While the highest plant water consumption was obtained from I-100 treatment, the lowest was obtained from I-25 treatment.

Table 1. Total irrigation water and plant water consumption values applied to the treatments.

Irrigation treatments	Total irrigation water(mm)	Plant water consumption (ETc)(mm)
I-100	142.8	144.4
I-75	109.7	113.5
I-50	76.7	81.4
I-25	28.1	33.9

Physiological measurements

Average values of leaf relative water content (LRWC), stomatal conductivity, chlorophyll values, NDVI and PRI values according to irrigation treatments of the physiological characteristics measured during the experiment are presented in table 2. These values were obtained between 51-78%, 160-323 mmol m^{-2} s^{-1}, 135-191, 0.360-0.580 and 0.019-0.055 according to the treatments, respectively. When examining these results, it is seen that as the irrigation level decreases, or in other words, as the water stress increases in the zinnia plant, the measured physiological characteristics begin to decrease. In addition, in all measured characteristics, the differences between irrigation treatments were found to be statistically significant (Table 2). As a result of the study, it was determined that the effect of water on the zinnia plant was significant and it was concluded that physiological characteristics would be negatively affected in the case of water restriction in zinnia.

Table 2. LRWC, stomatal conductivity, chlorophyll readings, NDVI and PRI values to treatments.

Irrigationtreatments	LRWC (%)	Stomatal conductivity (mmol m^{-2} s^{-1})	Chlorophyll readings	NDVI	PRI
	$\bar{X} \pm S\bar{x}$	$\bar{X} \pm S\bar{x}$	$\bar{X} \pm S\bar{x}$	$\bar{X} \pm S\bar{x}$	$\bar{X} \pm S\bar{x}$
I-100	78±0.0a*	323±7.3a	191±1.3a	0.580±0.006a	0.055±0.001a
I-75	73±0.3b	265±5.8b	169±0.9b	0.493±0.008b	0.040±0.001b
I-50	61±0.0c	184±1.3c	152±1.2c	0.401±0.006c	0.022±0.001c
I-25	51±1.8d	160±3.0d	135±1.4d	0.360±0.011d	0.019±0.001d

* The differences between the averages shown in different lowercase letters in the same column are significant and show the difference between treatments (Duncan, $P<0.05$).

According to principal component analysis (PCA) results, all the changes in the five physiological characteristics examined can be explained in 5 different dimensions. The variance explained by the first two dimensions was calculated as 93.3%, and 87.4% of this variation could be explained by the first dimension (Fig. 1). It was seen that the chlorophyll content, leaf water content, stomatal conductivity, NDVI and PRI had a statistically significant positive correlation with the first dimension considering the correlation coefficients of the examined characteristics with dimensions. PRI observations had a positive correlation with the second dimension ($r = 0.49$, $P < 0.01$). Some of the irrigation treatments could be clearly distinguished from each other in the PCA-Biplot graphics. For example, it is observed that I-100 treatment and I25 and I50 treatments can be separated from each other to a great extent and this distinction is realized depending on PRI measurements. In other words, in the measurements taken from the I-75 and I-100 treatments by using PRI measurements, the number of similar samples in terms of PRI measurements is high, so it is understood that it is difficult to distinguish these two applications with PCA-Biplot analysis. In terms of stomatal conductivity, NDVI, chlorophyll readings, and leaf water content, it can be stated that the irrigation restriction reduces these characteristics, since the I-25 treatment is in an area opposite to the vectors belonging to these features (Fig. 1).

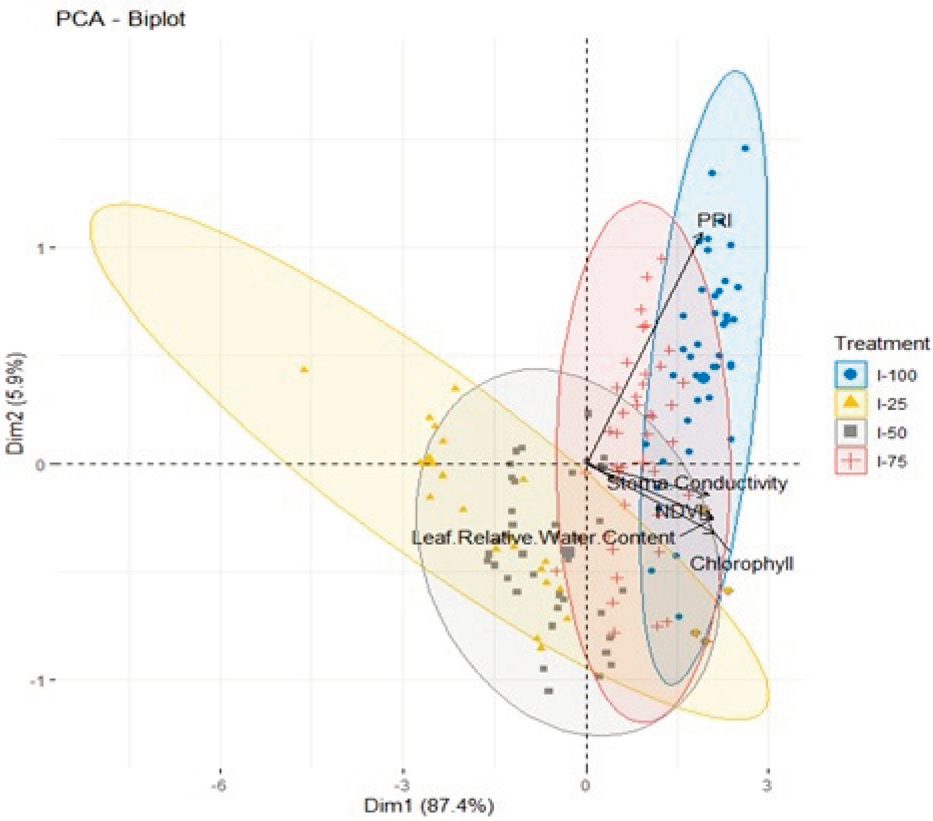

Fig. 1. PCA-Biplot graph for physiological measurements.

Morphological measurements

Within the scope of the study, the morphological characteristics were measured in parallel with the physiological ones. During the experiment, a total of 12 parameters were measured, including plant height, plant diameter, flower stem length, flower stem diameter, flower diameter, flower number, petal length, petal width, petal number, leaf thickness, leaf length and leaf width.

6 measurements were made in I-25, which is the treatment with the highest water constraint, and 11 measurements were made in all other treatments. The statistical analysis results regarding the averages of these measurements are shown in Table 3.

Table 3. Change of morphological characteristics according to irrigation treatments.

Irrigation treatments	Plant height (cm)	Plant diameter (cm)	Flower stem length (cm)	Flower stem diameter (mm)	Flower diameter (mm)	Number of flowers
	$\bar{X} \pm S\bar{x}$	$\bar{X} \pm S\bar{x}$	$\bar{X} \pm S\bar{x}$	$\bar{X} \pm S\bar{x}$	$\bar{X} \pm S\bar{x}$	$\bar{X} \pm S\bar{x}$
I-100	27.9±0.3a*	24.5±0.6a*	34.2±1.5a*	7.3±0.3a*	81.4±1.1a*	5±0.3a**
I-75	24.9±0.4b	22.7±0.4b	31.3±1.1ab	6.2±0.2b	78.2±1.5a	4±0.0a
I-50	23.2±0.4c	19.9±0.4c	26.2±0.6c	6.2±0.2b	68.4±2.2b	4±0.4a
I-25	21.3±0.4d	16.4±0.0d	28.4±2.3bc	5.5±0.2c	58.7±2.6c	2±0.4b

Irrigation treatments	Petal length (mm)	Petalwidth (mm)	Number of petals(piece)	Leaf thickness (mm)	Leaf length (mm)	Leafwidth (mm)
	$\bar{X} \pm S\bar{x}$	$\bar{X} \pm S\bar{x}$	$\bar{X} \pm S\bar{x}$	$\bar{X} \pm S\bar{x}$	$\bar{X} \pm S\bar{x}$	$\bar{X} \pm S\bar{x}$
I-100	23.2±0.4a*	8.3±0.1a*	136±3.2a**	0.55±0.02a*	69.9±2.9a*	42.6±2.6ns*
I-75	22.7±0.2a	7.8±0.2ab	113±8.1ab	0.52±0.02a	64.4±1.2b	41.4±2.0ns
I-50	19.1±0.4b	6.7±0.1c	106±6.5b	0.41±0.01b	59.7±1.3b	36.4±1.0ns
I-25	17.4±0.8c	7.6±0.2b	71±3.9c	0.34±0.03b	62.9±1.0b	37.4±1.3ns

The differences between the averages shown in different lowercase letters in the same column are significant and show the difference between subjects *(Duncan, $P<0.05$), ** (Bonferroni, $P<0.05$).

In the study, it was determined that different irrigation levels have a significant ($P<0.05$) effect on the morphological characteristics of zinnia. The average highest plant height value was realized in I-100 (27.9 cm) irrigation; followed by I-75 (24.9 cm), I-50 (23.2 cm) and I-25 (21.3 cm) irrigation treatments, respectively. Considering the values obtained in terms of plant diameter, flower stem length and flower stem diameter, it was seen that the I-100 irrigation issue came to the fore, while the effect of I-100 and I-75 irrigation treatments for flower stem length and flower diameter was statistically at the same level. Flower diameter has the lowest value in I-25 (58.7 mm) irrigation, which has the highest water constraint. There is a decrease according to the decrease in the amount of irrigation applied throughout the flower. Heidari *et al.* (2016) pointed out that the flower diameter decreased despite the increasing drought stress in zinnia. While the average number of flowers per plant reaches its highest value in irrigation I-100 (5 pcs), there is no statistical difference in terms of the effect of I-100, I-75 and I-50 irrigation issues on the number of flowers (Table 3). In their studies conducted by different researchers on different ornamentals, they stated that as the amount of irrigation increases, the number of flowers on the stem increases (Karagüzel *et al.,* 2011).

When the effects of irrigation applications on the zinnia on the morphological characteristics of the flower are examined qualitatively, it was determined that the flower quality has a statistically significant ($P<0.05$) effect on the petal length, petal width and petal number. It was determined that the water stress on the plants increased due to the water constraint, so in the measurements made for the flower quality, the petal length and the petal numbers decreased.

The highest value obtained in terms of leaf thickness was I-100 (0.55 mm) and the lowest value was I-25 (0.34 mm) for irrigation treatments. While I-100 and I-75 irrigation treatments were statistically effective on leaf thickness at the same level, it was found that there was no difference between I-50 and I-25 irrigation treatments. On the other hand, it has been determined that the applications do not have a statistically significant effect on leaf width (Table 3).

The results of the PCA analysis related to the morphological measurements showed that the change in vegetative characteristics can be explained by 11 dimensions. The variance explained by the first two dimensions was found to be 85.1 %, and the first dimension explains 70.6 % of this variation and the second dimension 14.5 % (Fig. 2). It was determined that 12 different vegetative traits have statistically significant positive correlations in the first dimension, considering the relationships between the investigated features and dimensions. It was observed that five of the parameters (number of flowers, number of petals, flower stem diameter, plant diameter) were positively correlated and five of them were negatively correlated. As can be seen in Fig. 2, the highest variation in terms of the investigated parameters was observed in I-25. The fact that the data points of the I-100 treatments are in the upper right part of the graph with respect to these vectors indicates that this application has an increasing effect on these parameters. It can be said that the observations in the intersection area of different irrigation practices have a limiting effect on the differentiation of irrigation practices in terms of the morphological characteristics examined. As a matter of fact, it is understood from the graph that there are similarities in the data obtained from irrigation practices at different dates in terms of leaf thickness, leaf width, petal length and petal width (Fig. 2).

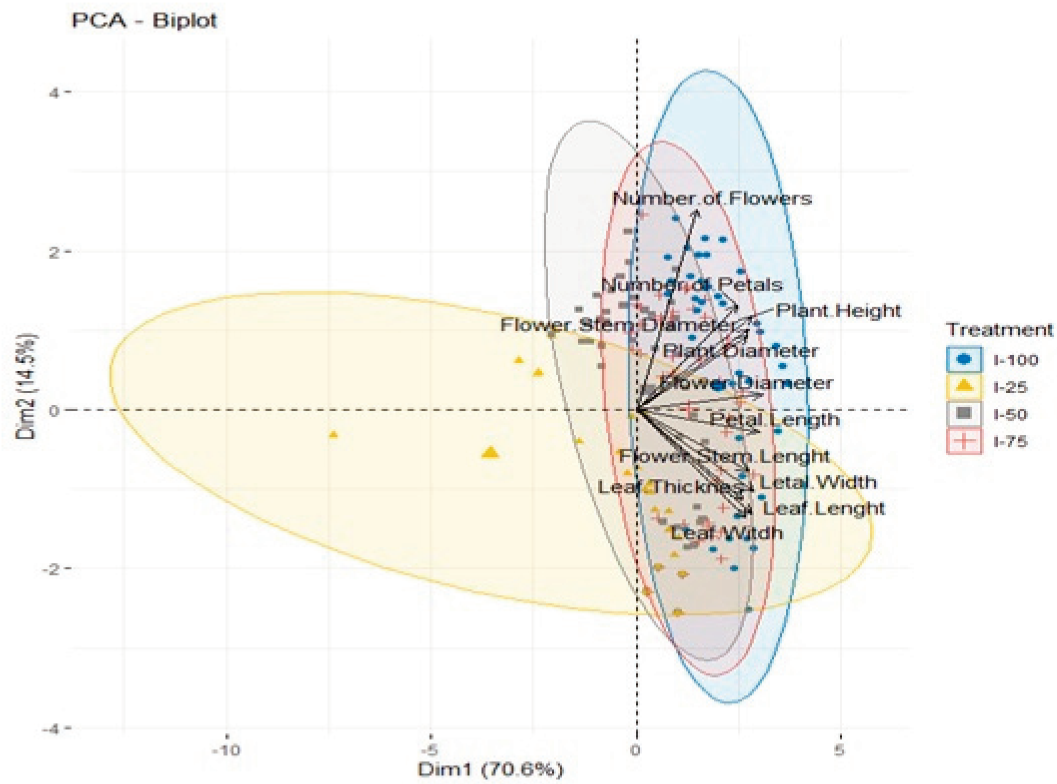

Fig. 2. PCA-Biplot graph for morphological measurements.

Post-harvest measurements

The results regarding the parameters measured after the zinnia is harvested are given in table 4. When the root growth characteristics of zinnia plants harvested were examined, it was determined that the root length decreased according to different irrigation levels. While the highest root length was realized in I-75 irrigation with an average of 36.6 mm, it was followed by I-100 (35.1 mm), I-50 (27.2 mm) and I-25 (24.9 mm) irrigation treatments, respectively. On the other hand, while I-100 and I-75 irrigation treatments have the same effect on root length, it has been determined that there is no significant difference between I-50 and I-25 irrigation treatments. When looking at table 4, it can be said that I-100 irrigation treatment comes to the fore in terms of plant wet and dry weight. Considering the number of tillers occurring in the plant, it has been determined that the I-50 application is one of the stress treatments. I-100 and I-75 irrigation treatments followed this application, respectively.

Table 4. Measurement results at post-harvest of zinnia.

Irrigation treatments	Root length (cm)	Fresh root weight (g)	Fresh plant weight (g)	Dry plant weight (g)	Number of tillers
	$\bar{X} \pm S\bar{x}$	$\bar{X} \pm S\bar{x}$	$\bar{X} \pm S\bar{x}$	$\bar{X} \pm S\bar{x}$	$\bar{X} \pm S\bar{x}$
I-100	35.1±1.1a*	3.5±0.5ns*	66.2±8.7a*	12.8±1.3a*	8±0.5ab**
I-75	36.6±0.8a	3.8±0.4ns	47.7±0.8b	10.2±0.1b	8±0.3ab
I-50	27.2±0.7b	4.0±0.4ns	33.3±2.4c	6.9±0.4c	9±0.4a
I-25	24.9±0.9b	5.7±0.7ns	26.9±1.9c	6.4±0.1c	7±0.4b

The differences between the averages shown in different lowercase letters in the same column are significant and show the difference between subjects *(Duncan, P<0.05), ** (Bonferroni, P<0.05).

In addition to the data given in table 4, the number of flowers, dry root weight and plant height values were also added to the PCA-Biplot analysis. In the PCA-Biplot analysis of harvest measurements, all the total variation could be explained by 8 dimensions. In the first two dimensions, 70.3% of the variation in harvest measurements has been explained, and 53.1% of this is related to the first dimension and 17.2% to the second dimension (Fig. 3). It was observed that the wet root weight and dry root weight of the traits examined during the harvest had a high correlation ($r > 0.75$) with the second dimension, and all other traits were positively correlated with the first dimension. The separation of irrigation treatments in the PCA-Biplot graph and the change of the examined features according to the treatments are presented in Figure 3. It can be said that the largest variation is in the I-100, considering the data distributions and the ellipses of irrigation treatments. As the amount of water decreased according to irrigation practices, the variation in the characteristics examined at the harvest decreased. While the I-100 and I-25 of irrigation treatments show clear differences in terms of the characteristics examined, no significant distinction was observed between I-100 and I-75 and I-50 treatments. Vectors belonging to investigated features and their angles provide information about correlations between parameters. Accordingly, a positive correlation was found between dry and wet root weight, and it was observed that the correlation between these parameters and other investigated characteristics was low. It can be said that there is a high positive correlation between root length, wet plant weight, dry plant weight, root length and flower number. According to the directions of the vectors belonging to these parameters and the positions of the ellipses belonging to the irrigation treatments on the graph, it is seen that the parameters that distinguish the I-100 treatment from the I-25 treatment are root length, wet plant weight, dry plant weight, root length, flower number, number of tillers. To put it more clearly, it has been observed that these characteristics change positively with increasing irrigation water (Fig. 3).

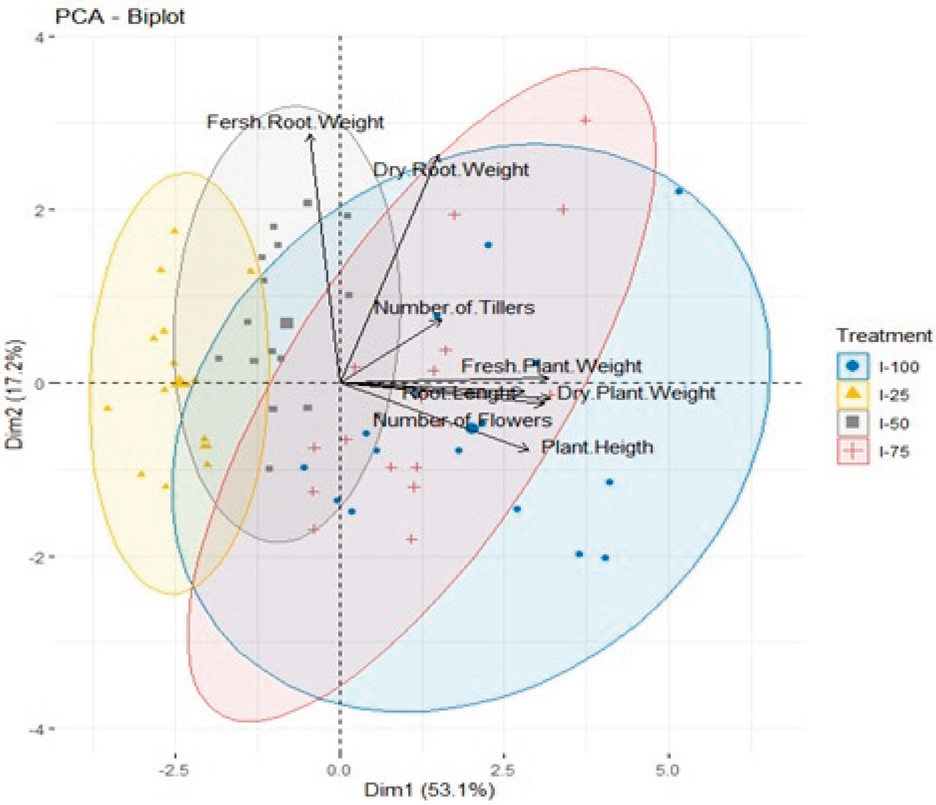

Fig. 3. PCA-Biplot graph for measurements at post-harvest.

CONCLUSION

Water restriction was applied to the plants in this study conducted on the ornamental zinnia (*Zinnia elegans*), which belongs to Asteraceae family and is one of the species with the magnificent flowers of seasonal flower groups. According to the results of the research, it was determined that irrigation applications at different levels have a statistically significant effect on the plant growth performance and flowering characteristics of zinnia. The changes seen in the morphological characteristics of the zinnia flower are one of the most important indicators that the plant is responding differently to variable irrigation levels. On the other hand, there was no significant difference between the I-100, I-75 and I-50 irrigation treatments in the number of flowers that occur on the plant during the growing period. In I-25 irrigation treatment, there is a significant decrease in the number of flowers compared to other treatments.

One of the results of the study is that the water stress increases in the zinnia plant due to the decrease in the irrigation level. The most prominent signals of this appear in the physiological characteristics. It was determined that in applications with increased water constraints, the plant was subjected to water stress, and all the parameters measured depending on the amount of irrigation water applied to the plants were affected.

This research conducted on *Zinnia elegans*, which is one of the most important seasonal flowers among ornamental plants, showed that a limited irrigation program can be successfully applied on the plant. It was observed that 25% water restriction did not adversely affect the flower quality, which is the most important criterion for ornamental plants.

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