

The Effect of Hazelnut Husk on Drought Resistance in the 'Hayward' Kiwi (*Actinidia deliciosa*) Variety

Mert İLHAN ^{1*}, Selim KARAGÖL ¹, Ali İSLAM ¹

¹Ordu University, Faculty of Agriculture, Horticulture Department, Ordu/TÜRKİYE

Received: April 27, 2026, Accepted: July 29, 2026

Corresponding author: Mert İLHAN, e-mail: ilhanmert6@gmail.com

Abstract

Objective: This study aimed to evaluate the potential and effectiveness of hazelnut husks in reducing drought stress in 'Hayward' kiwi (*Actinidia deliciosa*) plants.

Materials and Methods: In this study, drought stress was induced in 'Hayward' kiwi plants by subjecting them to four different water restriction levels (0%, 25%, 50% and 75%). Water restrictions were tested in standard peat-perlite (PP) and peat, perlite and hazelnut husk (HPP) supplemented media. After the experiment, the basic physiological parameters as well as shoot and leaf development parameters were analyzed in the plants.

Results: The experiment concluded that drought stress severely negatively affected overall plant development. However, kiwis grown in hazelnut husk-enriched medium performed better than those grown in the standard peat-perlite medium. Accordingly, hazelnut husks successfully conserved relative water content, reduced cellular damage, and maintained total chlorophyll content, making it more successful than the standard growing medium.

Conclusion: The addition of hazelnut husks to the growing medium acted as a buffer in plants under drought stress conditions, mitigating adverse conditions. This new approach is considered a potential sustainable strategy to increase plant resilience to water scarcity caused by climate change.

Keywords: Drought stress, Hazelnut husk, Kiwifruit

'Hayward' Kivi (*Actinidia deliciosa*) Çeşidinde Fındık Zurufunun Kuraklığa Dayanıklılık Üzerindeki Etkisi

Öz

Amaç: Bu çalışma, fındık zurufunun 'Hayward' kivi (*Actinidia deliciosa*) bitkisinde kuraklık stresini azaltmadaki potansiyelini ve etkinliğini değerlendirmek amacıyla yürütülmüştür.

Materyal ve Yöntem: Çalışmada 'Hayward' kivi bitkileri dört farklı su kısıtlaması seviyesine (%0, %25, %50, %75) tabii tutularak kuraklık stresi sağlanmıştır. Su kısıtlamaları denemede standart torf perlit (PP) ve torf, perlit ve fındık zurufu katkılı ortamlarda denenmiştir. Deneme sonrasında bitkilerde temel fizyolojik parametrelerle beraber sürgün ve yaprak gelişim parametreleri analiz edilmiştir.

Araştırma Bulguları: Deneme sonunda kuraklık stresinin bitkinin genel gelişimini ciddi oranda olumsuz etkilediği belirlenmiştir. Bununla beraber fındık zurufu katkılı ortamda yetiştirilen kiviler, standart torf perlit ortamında yetişen bitkilere göre daha üstün performans göstermiştir. Buna göre fındık zurufu bitkilerde yaprak su potansiyelini koruyarak, hücresel düzeydeki hasarları azaltmayı başarmıştır. Ayrıca toplam klorofil içeriğini koruyarak, standart yetiştirme ortamına göre daha başarılı bulunmuştur.

Sonuç: Fındık zurufunun yetiştirme ortamına ilavesi kuraklık stresi şartlarında bitkilerde tampon görevi görerek olumsuz şartları hafiflettiği belirlenmiştir. Bu yeni yaklaşım ile iklim değişikliği sebebiyle oluşan su kıtlığına karşı bitkilerin dayanıklılığını artırmak için sürdürülebilir strateji olabileceği düşünülmektedir.

Anahtar kelimeler: Fındık zurufu, Kivi, Kuraklık stresi

Introduction

The kiwi plant (*Actinidia deliciosa*), originally native to China, was first cultivated in New Zealand in the 1940s. Since the 1970s, the production of this species has rapidly expanded, particularly in Mediterranean countries (Gökbayrak et al., 2007). Kiwi, which is an important agricultural activity, especially in humid climate regions such as the Black Sea Region, ranked worldwide in 2024 as follows: China (2,153,479 tons), New Zealand (667,791 tons), Italy (463,910 tons), Greece (342,330 tons), and Iran (294,658 tons). Turkey ranks 7th globally with 92,249 tons (FAO, 2024). At the provincial level in Turkey, production ranks as follows: Bursa (18,639 tons), Yalova (14,384 tons), Samsun (13,599 tons), Mersin (11,993 tons), and Ordu (8,560 tons) (TÜİK, 2024). These regions possess climatic and soil conditions suitable for kiwi cultivation and make significant contributions to Turkey's kiwi production capacity. Considering the topography and limited agricultural land of the Black Sea region, the ecological adaptation and sustainable cultivation strategies of crops such as kiwi, which can provide economic returns on small plots, are of great importance (Zenginbal et al., 2005). However, in recent years, increasing temperatures, irregular rainfall patterns, and other environmental stress factors caused by global warming have adversely affected kiwi production. These negative conditions associated with climate change, particularly drought, salinity, alkalinity, and extreme temperatures, limit plant growth and development and hinder root access to available water. This leads to a decline in the yield and quality of kiwifruit plants and poses a serious threat to sustainable production (Rajan et al., 2024). Kiwi, whose economic value is rapidly increasing, has a superficial fibrous root system and a very large leaf area owing to its morphological characteristics. These anatomical features make kiwifruit a fruit species with high transpiration rates and consequently very high water consumption (Prendergast et al., 1987). In horticultural crops, salinity, drought, alkalinity, and extreme temperatures adversely affect growth and development. Owing to global warming, natural events such as floods are now observed on over 1,700 mega hectares of land worldwide (Rehman et al., 2015). In addition to the destructive effects of stress on the aboveground parts of plants, such floods can also create hypoxia and anoxia around the roots, which can lead to plant death (Ashraf, 2012). The

responses of plants to abiotic stress are dynamic processes that vary depending on the intensity and duration of the stress, and tolerance development is complex at both the organismal and cellular levels (Korkmaz and Durmaz, 2017). Water deficiency not only negatively affects leaf and stem diameter growth and rooting, but also disrupts water-use efficiency, leading to physiological and biochemical problems (Farooq et al., 2009). Increasing drought conditions due to climate change can cause serious yield losses in kiwifruit production, necessitating the development of new strategies to enhance drought tolerance. In this context, various soil improvement and water management strategies have been developed to increase plant resistance to drought stress (Cowie et al., 2018). One such strategy is to enrich the soil organic matter content and increase the water retention capacity using agricultural waste products (Demir and Işık, 2019). The use of local agricultural by-products, such as hazelnut husks, is thought to improve the physical and chemical properties of the soil, increase water-use efficiency, and thereby enhance the resistance of kiwifruit plants to drought stress (Çiçek and Yücedağ, 2021). In fact, after the harvest of the hazelnut plant in which we are the world leader in production an average of 20% of waste material is generated. It has been observed that these waste materials are generally not utilized economically. However, studies have reported that hazelnut husks, which are rich in organic matter, increase water retention capacity, encourage root development by preventing soil compaction, and improve pH values (İslam, 2016; Güneş et al., 2021). Additionally, it has been stated that the composition of hazelnut husks is similar to or even richer than farm manure, and that in addition to improving the physical properties of the soil, it also provides nutrient supplementation for plants (Zeytin and Baran, 2003; Bender Özenç, 2004). In this context, the effects of hazelnut husk on the physiological and morphological responses of the 'Hayward' kiwi variety to drought stress are of great importance for sustainable agricultural practices. Therefore, in this study, we investigated the effects of hazelnut husk on the 'Hayward' kiwi variety under drought stress conditions, with the aim of sustainability and waste management in agriculture.

Materials and Methods

This study was conducted in unheated polycarbonate greenhouses located on the experimental land of the Department of Horticulture at the Faculty of Agricul-

ture, Ordu University, Turkey. The cuttings used in the study were obtained during winter pruning of the kiwi plot in the experimental area and stored at +4 °C in humidity and temperature controlled warehouses until the trial period began.

As the experimental medium in the study, peat+perlite (PP/1:1) and peat+perlite+hazelnut husk (HPP/1:1:1) were used. The hazelnut husks used in this study were supplied by a producer in the Giresun province after an average preparation period of 8 months. After preparing the media, the field capacities of the 14 liter pots were determined by watering until leakage occurred from the drainage channel, and their weights were recorded.

The hardwood cuttings were planted with their basal buds rendered dormant, leaving two buds per cutting, and were watered weekly. In this way, homogeneous results were obtained from a single shoot for each plant. Watering was performed as needed for each treatment until the shoots reached the 3-4 leaf stage. The hardwood cuttings used in the experiment were carefully selected from successfully rooted plants. To ensure homogeneity across all treatments and replications, only cuttings exhibiting uniform root development and similar initial shoot thickness were included in the study.

For drought stress application, watering was performed at levels corresponding to field capacity (100%) and deficits of 25%, 50%, and 75% of field capacity, thereby inducing drought stress. Throughout the experiment, the amount of water lost by the pots was monitored daily by weighing them using a scale, and the missing water was replenished daily. The trial lasted for eight weeks. During the 8-week experimental period in the greenhouse, the daytime temperatures generally ranged between 30 and 35 °C, while the nighttime temperatures were maintained between 20 and 22 °C. The average relative humidity within the greenhouse was observed to be approximately 75–80%.

At the end of the experiment, the following parameters were examined: plant viability (%), shoot length (cm), fresh and dry shoot weight (g), number of leaves (pcs), shoot tolerance ratio (STR), turgor weight (g), chlorophyll content (SPAD), leaf relative water content (%), leaf area (cm²), ion leakage (%), cell membrane damage rate (%), and degree of damage (1-4). Fresh and dry shoot weights were measured using a scale with ±0.001 g sensitivity (Radwag WTB200). Shoot lengths were determined using a ruler, and the number of leaves was

determined by counting the leaves on each shoot. To determine shoot dry weight, after measuring the fresh weight, shoots were placed on drying papers and dried in an oven (Memmert UN55) at 65°C for 72 h. For each shoot, after measuring the fresh weight of the leaves, the leaves were placed in distilled water for 6 h, after which their turgid weights were recorded. For the determination of leaf dry weight, the leaves were dried in an oven at 80°C for 24 h. Accordingly, the following formula was used to determine the relative water content (RWC, %): $[(FW-DW)/(TW-DW) \times 100]$ (Yamasaki and Dillenburg, 1999), where FW is fresh weight, DW is dry weight, and TW is turgid weight.

The plant survival rate should be calculated as: $\text{Surviving plants} / \text{Total plants} \times 100$. To determine the shoot tolerance ratio, the formula by Turhan et al., (2005) was used in a modified way: $STR = T_x/T_o$, where T_x is the shoot weight (g) of plants subjected to a certain concentration of stress, and T_o is the shoot weight (g) of the control plants. The degree of damage in plants was evaluated according to the scale developed by Sivritepe et al., (2008): plants without any symptoms of drought damage were graded as '1', plants with burns and drying detected on shoot tips and leaf edges as '2', plants with necrosis appearing on the entire leaf and certain parts of the stem as '3', and completely dried and dead plants as '4.'

The chlorophyll content of the plants was measured using an SPAD meter (SPAD-502, Konica Minolta Sensing). For leaf area calculation, the leaves at the middle sections of each shoot were collected and scanned, and the area was calculated in cm² using the 'Digimizer 4.0' software. To determine ion leakage, 0.3 g leaf samples taken from the plants were divided into equal parts, placed into 25 mm × 150 mm glass tubes, to which 15 ml of distilled water was added and then shaken at 100 rpm for 24 h. After shaking, the EC value was measured using an EC meter (HANNA HI 99300) and was recorded as EC₁. The samples were autoclaved at 115°C for 10 min. After being left at room temperature for 24 h, the EC₂ value was recorded. Ion leakage was calculated using the formula $EC_1/EC_2 \times 100$ (Ozden et al., 2009). The cell membrane damage rate was calculated using the following formula based on the plants' EC values: $CMDR (\%) = [(L_t - L_c) / (100 - L_c) \times 100]$, where L_t is the EC value of the treated leaf before autoclaving (EC₁) or after autoclaving (EC₂), and L_c is the EC value of the control leaf before autoclaving (EC₁) or after autoclaving (EC₂) (Arora et al., 1998).

Statistical Analysis

The experiment was designed using a randomized block design with three replicates and ten plants per replicate. The data obtained from the study were evaluated using the JUMP 13.0 statistical software package and analyzed using the LSD test at a significance level of $p < 0.05$. The groups were formed at different significance levels.

Result and Discussion

Effects on Shoot Development

The data on shoot development are in Table 1. Results showed shoot lengths varied statistically with water restriction. As irrigation restriction severity increased, shoot length significantly reduced. For instance, average shoot length in control plants was 5.75 cm, decreasing to 4.05 cm under severe restriction. Differences between media were significant at certain restriction levels. The PP medium showed higher or similar average shoot lengths compared to the HPP medium. Evaluating medium and treatment interaction, both mediums performed the same under severe drought, but PP yielded better results under mild drought. Shoot length data showed plant growth was significantly limited with increased water restriction, consistent with literature stating kiwifruit (*Actinidia deliciosa*) is sensitive to water stress and needs regular water (Pratima et al., 2018; Boini et al., 2024). Kiwifruit plants have high transpiration rates due to large leaf surface area and shallow roots, making them vulnerable to water deficiency (Şahin, 2019).

Comparing mediums, PP medium's higher average shoot lengths under low drought suggest peat's initial aeration and water-holding capacity offer an ideal balance for plant development (Michel and Cannavo, 2013). However, as stress severity increased, HPP medium's performance became more notable. Hazelnut husks, as a soil conditioner, increase soil's water-holding capacity due to high organic matter and porous structure (Demir, 2016).

Differences in shoot fresh and dry weights between media were statistically insignificant. Increasing drought stress negatively affected plant development for both parameters. For example, shoot fresh weight averaged 2.21 g and dry weight 0.48 g in control plants, decreasing to 0.87 g and 0.30 g, respectively, under severe drought. In application medium interactions, as drought severity increased, both mediums showed similar performance in shoot fresh and dry weights. Lowest values were recorded under high drought, with differences under other restrictions not statistically significant. In kiwifruit plants, water deficiency inhibits cell enlargement and growth by reducing turgor pressure, directly reducing shoot length (Pratima et al., 2016). The dramatic decrease in shoot fresh and dry weights shows drought stress's negative impact on biomass accumulation. These decreases in shoot weight indicate that droughts, especially those occurring in summer, can significantly suppress vegetative development in kiwifruit cultivation (Peng et al., 2011).

Table 1. Effects of drought stress and hazelnut husk applications on shoot parameters

Restriction	SL (cm)			SFW (g)			SDW (g)			STR		
	PP	HPP	Avg.	PP	HPP	Avg.	PP	HPP	Avg.	PP	HPP	Avg.
Control (%0)	5.95 a	5.56 ab	5.75 A	2.33 a	2.09 a	2.21 a	0.49 a	0.48 a	0.48 A	1.00 ab	1.00 ab	1.00 A
%25	5.75 a	3.52 d	4.65 B	2.43 a	1.99 a	2.21 a	0.51 a	0.44 ab	0.48 A	1.04 a	0.92 bc	0.98 A
%50	4.88 abc	4.43 bcd	4.64 B	2.21 a	2.18 a	2.20 a	0.45 ab	0.49 a	0.47 A	0.91 c	1.02 a	0.96 A
%75	4.07 cd	4.03 cd	4.05 B	0.94 b	0.81 b	0.88 b	0.27 c	0.33 bc	0.30 B	0.55 e	0.69 d	0.62 B
Avg.	5.16 A	4.38 B		1.98	1.76		0.43	0.44		0.87	0.90	
T _{LSD 5%}			0.92			0.36			0.09			0.06
M _{LSD 5%}			0.65			N.S			N.S			N.S
T × M _{LSD 5%}			1.31			0.51			0.13			0.08

Avg.: Average, N.S: Not significant, T: Treatment, M: Medium, T × M: Treatment × Medium, SL: Shoot length SFW: Shoot fresh weight, SDW: Shoot dry weight, STR: Shoot tolerance ratio

When the tolerance rate parameter, an important indicator of drought stress in plants, was examined, the HPP medium reached higher values than the PP medium, but the differences were not statistically significant. In contrast, the differences observed in the restriction treatments were significant. For instance, the control, 25%, and 50% restriction groups had the highest tolerance rates, whereas

plants subjected to 75% restriction showed a tolerance rate as low as 0.62. Examining the relationship between treatment and medium, the HPP medium was found to be more successful under restricted irrigation. In particular, under 50% restriction, plants grown in HPP performed better than those grown in the PP. Under severe drought stress, the HPP medium was more effective than the

PP medium. Thus, while the tolerance rate in the severely restricted PP medium was determined to be 0.55, it increased to 0.69 in plants grown in the HPP medium. The higher tolerance rate of the HPP medium compared to that of PP under severe drought conditions indicates that the hazelnut husks acts as a protective buffer against plant stress. This can be explained by the high organic matter content and water-holding capacity of the hazelnut husk (Aşkın and Aygün, 2018). The literature also indicates that using hazelnut husks as mulch or soil conditioners preserves soil moisture and reduces water loss by up to 19% (Demir, 2016). Furthermore, organic materials such as hazelnut husks are known to have positive effects on yield and plant health in kiwifruit cultivation (Ozyazıcı et al., 2010). In this study, the superior performance of plants in the HPP medium under 50% restricted irrigation confirmed that the hazelnut husk serves as a buffer under moderate and severe drought conditions.

Effects on Leaf Development

The effects of drought stress levels and medium differences on leaf development as a result of the experiment are shown in Table 2. When the data related to turgor weight in plants at the end of the experiment were examined, the differences observed in both treatments and the treatment $\times$ medium interaction were significant. The data showed that as the restricted irrigation increased, the turgor weight of the plants decreased significantly. The average turgor weight in control plants with no restrictions

was 0.97 g, whereas this value decreased to 0.52 g in plants subjected to 75% restriction. The differences between the media were not statistically significant. Additionally, when application and medium relationships were considered, the highest turgor weight (1.03 g) was observed in the control plants grown in the HPP medium. Conversely, the lowest turgor weight was found in plants grown in the HPP medium subjected to a 75% restriction. The results showed that an increase in drought severity caused a significant reduction in plant turgor weight. The decrease in turgor weight from 0.97 g in control plants to 0.52 g under 75% restriction in the experiment demonstrates the severity of the effect of drought stress on plant water status (Bartlett et al., 2012). Gucci et al., (1996) reported that when the leaf water potential in kiwifruit plants fell below the threshold of -0.3 MPa, stomatal conductance quickly decreased, thereby limiting transpiration. Similarly, Mills et al., (2009) reported that restrictive irrigation negatively affected leaf water potential, photosynthetic rate, and stomatal conductance by reducing soil water content. In the present study, the highest turgor weight (1.03 g) was reached by control plants grown in the HPP medium, showing that the hazelnut husk increases the water-holding capacity and improves plant water status. Previous studies have shown that hazelnut husk compost significantly increases soil water holding capacity and improves the physical properties of the soil (Özenç and Özenç, 2008; Aşkın and Aygün, 2018).

Table 2. Effects of drought stress and hazelnut husk applications on leaf development

Restriction	TW (g)			RWC (%)			LA (cm ²)			LN (pieces)		
	PP	HPP	Avg.	PP	HPP	Avg.	PP	HPP	Avg.	PP	HPP	Avg.
Control (%0)	0.91 ab	1.03 a	0.97 A	61.34 a	59.12 ab	60.23 A	28.29 a	25.30 ab	26.79 A	4.03 ab	4.5 a	4.29 A
%25	0.77 bc	0.61 cd	0.69 B	60.46 ab	62.55 a	61.51 A	20.72 bc	18.48 c	19.60 B	3.75 bc	4.19 ab	3.97 AB
%50	0.70 bcd	0.72 bcd	0.71 B	55.52 ab	62.08 a	58.80 A	18.77 c	20.11 bc	19.44 B	3.26 c	4.01 ab	3.64 B
%75	0.55 cd	0.49 d	0.52 C	32.19 c	52.14 b	42.16 B	11.26 d	11.71 d	11.48 C	2.21 d	3.25 c	2.73 C
Avg.	0.73	0.71		52.38 B	58.97 A		19.76	18.90		3.31 B	4.00 A	
T _{LSD 5%}			0.16			5.95			3.87			0.48
M _{LSD 5%}			N.S			4.20			N.S			0.34
T $\times$ M _{LSD 5%}			0.23			8.41			5.48			0.68

Avg.: Average, N.S: Not significant, T: Treatment, M: Medium, T $\times$ M: Treatment $\times$ Medium, TW: Turgor weight, RWC: Relative water content, LA: Leaf area, LN: Leaf number

When plants were evaluated in terms of leaf relative water content, the main effect of the growing medium was found to be statistically significant. Accordingly, the average relative water content (RWC) of plants grown in the HPP medium was approximately 58.97%, whereas this rate decreased to 52.38% in plants grown in the PP medium. Furthermore, unlike mild stress levels, severe restricted irrigation had a

statistically significant negative effect on leaf RWC. The overall average RWC remained stable between 58.80% and 61.51% up to the 50% restriction level but dropped significantly to 42.16% under 75% restricted irrigation. When the treatment $\times$ medium interaction was examined, the RWC decreased drastically to 32.19% in the PP medium under severe drought stress (75%), indicating considerable water loss. In contrast, in the HPP medium at the same

stress level, the RWC was recorded at 52.14%. Although this value decreased compared to the control plants, it was significantly higher than that of the PP medium under the exact same severe stress conditions. These values indicate that the hazelnut husk serves as a significant buffer for maintaining relative water content in plants under drought stress. These findings can be explained by the increased water-holding capacity of the hazelnut husk, which allows water in the root zone to be retained for longer periods of time. It has been reported that hazelnut husk application increases soil organic carbon content from 1.40% to 3.51%, increases total porosity and field capacity, and reduces soil density by 33% (Gülser et al., 2015). These improved soil properties enable plants to absorb water more effectively, even under water-limited conditions. The literature on stomatal control mechanisms in kiwifruit plants under water stress shows that this species uses a stomatal closure strategy to maintain plant water status (Calabritto et al., 2024).

With increased restricted irrigation, the marked decrease observed in leaf area was found to be statistically significant. The average leaf area in the control group without water restriction was 26.79 cm², which decreased to 19.60 cm² and 19.44 cm² on average in the 25% and 50% restricted irrigation groups, respectively. Under the most severe drought stress, leaf area shrank to as little as 11.48 cm², more than halving the leaf area that of control plants. The differences between the growing mediums were statistically insignificant, but the differences in the treatment × medium interaction were significant. Accordingly, the best development in both media was observed in the control plants, whereas the lowest leaf area was observed in plants subjected to 75% water restriction. The decline in leaf area from 26.79 cm² in the control to 11.48 cm² under 75% restriction (a 57% decrease) and the reduction in leaf number from 4.29 to 2.73 (a 36% decrease) clearly revealed the suppressive effect of drought stress on morphological development. These reductions directly limit the photosynthetic capacity and carbon gain of plants (Farooq et al., 2009). This dramatic decrease in leaf area can be interpreted as an adaptation strategy adopted by kiwifruit plants to minimize the water loss. A smaller leaf area reduces the transpiration surface, thereby limiting water loss (Waseem et al., 2011). However, this strategy also limits photosynthetic capacity. As drought severity increased, there were statistically significant

reductions in the number of leaves on plants. The average leaf number was 4.29 in control plants, dropping to 2.73 in plants under 75% irrigation restriction. Moreover, when differences in growing mediums were examined, the HPP medium yielded better results even under severe stress conditions compared to the PP medium. In general, the average leaf number in plants grown in the HPP medium was 4.00, whereas this number decreased to 3.31 in the PP medium. When treatment × medium interactions were evaluated in terms of leaf number, plants grown in the PP medium reduced their leaf number under 25% and 50% restricted irrigation due to stress, while those grown in the HPP medium under the same restriction levels remained in the same group as the control plants. Additionally, plants in the HPP medium subjected to 75% restricted irrigation performed on par with those in the PP medium exposed to 50% restriction irrigation. Kiwifruit plants are sensitive to drought because of their broad leaf area and shallow root structure, and they rapidly close their stomata under severe drought, leading to leaf drop if this persists for an extended period (Gucci, 1996; Vurro et al., 2024). It also attempts to increase its chances of survival by reducing its transpiration surface. Following this, it can display a drought avoidance response along with leaf drop (Rahman et al., 2011; Bao et al., 2024).

Effects on Physiological Development

The physiological effects of drought stress and medium differences in this experiment are shown in Table 3. Examining plant vitality, although HPP performed better, differences were not statistically significant. In contrast, increasing drought severity significantly decreased vitality, indicating that medium alone may not strongly affect vitality, but drought stress has a dominant adverse effect (Tiwari et al., 2021). Plants in the control (0%), 25%, and 50% restricted irrigation groups were in the same group, whereas 75% restriction showed a decline in vitality to 70.00%. Evaluating application × medium interactions, all relationships were in the same group up to 75% restricted irrigation. Conversely, although plants in HPP medium had higher vitality at 75% restriction, they, with PP medium plants, showed the lowest vitality. Previous studies indicated drought stress in kiwifruit reduces turgor and relative water content, leading to vitality decline (Mills et al., 2009). Chlorophyll content, a key indicator of photosynthetic capacity, significantly reduced with increasing water restriction. Average chlorophyll content in control

plants was 43.23, decreased to 39.17 and 34.59 in the 50% and 75% restricted irrigation treatments, respectively. The HPP medium mitigated chlorophyll loss better than PP, showing superiority in buffering drought damage to the photosynthetic mechanism. Interaction results showed under control and 25% restricted irrigation, plants in HPP medium

performed better than in PP medium. Literature indicates severe chlorophyll reductions in plants due to degradation from water restriction (Preet Pratima and Sharma, 2017; Kumar et al., 2023; Bao et al., 2024). Furthermore, hazelnut husks may help preserve chlorophyll under stress by increasing water retention capacity (Aşkın and Aygün, 2018).

Table 3. Effects of drought stress and hazelnut husk applications on physiological parameters

Restriction	PV (%)			CC (Spad)			IL (%)			CMDR (%)			DD (1-4)		
	PP	HPP	Avg.	PP	HPP	Avg.	PP	HPP	Avg.	PP	HPP	Avg.	PP	HPP	Avg.
Control (%0)	96.66a	100.00a	98.33A	38.97bc	47.49a	43.23A	46.69bc	47.63bc	47.16	0.00c	0.00c	0.00C	1.55c	1.21c	1.38C
%25	100.00a	100.00a	100.00A	36.26cd	42.92ab	39.59AB	53.85ab	49.13bc	51.49	23.12b	14.17bc	18.64B	2.11b	1.31c	1.71B
%50	96.66a	96.66a	96.66A	37.07cd	41.27bc	39.17B	63.13a	33.03d	48.08	41.56a	8.13bc	24.84AB	2.04b	1.42c	1.73B
%75	66.66b	73.33b	70.00B	36.07cd	33.12d	34.59C	60.46a	44.08c	52.27	54.78a	16.24b	35.60A	3.02a	2.69a	2.86A
Avg.	90.00	92.50		37.09B	41.20A		56.03A	43.46B		29.86A	9.68B		2.18A	1.66B	
T _{LSD} 5%			11.98			3.76			N.S			11.14			0.31
M _{LSD} 5%			N.S			2.66			4.70			7.88			0.21
T × M _{LSD}			16.94			5.32			9.41			15.76			0.43

Avg.: Average, N.S: Not significant, T: Treatment, M: Medium, T × M: Treatment × Medium, PV: Plant vitality, CC: Chlorophyll content, IL: Ion leakage, CMDR: Cell membrane damage rate, DD: Damage degree

Although the values for the ion leakage parameter increased with increasing restriction, the observed differences were not statistically significant. However, when the differences between the media were compared, the ion leakage was determined to be 56.03% for plants grown in the PP medium, whereas this ratio decreased to 43.46% in the HPP medium. In terms of application and medium relationships, only plants in the PP medium under control (0%) conditions reached values similar to those in the HPP medium. In addition, at every level of restricted irrigation, plants grown in the HPP medium exhibited lower ion leakage than those grown in the PP medium. Therefore, the HPP medium was more effective in maintaining ion leakage than the PP medium. This indicates that the lower ion leakage at every restriction level in the HPP medium indicates that the hazelnut husk supports an in situ moisture conservation strategy that increases plant resilience (Pratima et al., 2016). Similar physiological studies have reported that drought resistance and recovery ability in kiwifruit are directly related to the stability of cell membrane (Bao et al., 2024). Thus, hazelnut husks not only provide physical stability but also minimize the destructive effects of drought stress at the cellular level during kiwifruit cultivation.

Although the effectiveness of restricted irrigation in terms of ion leakage was not statistically significant, the rate of cell membrane damage increased significantly as the severity of restriction increased. For example, while cell membrane damage was 18.64% at 25% restriction, it increased to 35.60% at 75% restriction. The differences between the media

in terms of cell membrane damage were also statistically significant. Accordingly, in plants grown in the HPP medium, the cell membrane damage rate was 9.68%, whereas in the PP medium, this ratio increased to 29.86%. Regarding the interaction relationships, the HPP medium maintained stable stress conditions and managed to keep the cell membrane damage rate low up to a 75% restriction. In contrast, in the PP medium, significant increases in the rate of cell membrane damage were observed after 25% restriction. It is reported that, in plant cells exposed to stress, lipid peroxidation disrupts membrane permeability balance, leading to ion leakage and resulting in cellular damage (Gucci et al., 1996). However, considering the medium differences, it is predicted that hazelnut husks, with their high organic matter and water retention capacity, will increase plant resistance under stress conditions (Aşkın and Aygün, 2018). It has been reported that hazelnut husk applications reduce soil density by 33% and increase porosity and infiltration rate (Gülser et al., 2015). This improved physical structure presumably facilitates plant access to water and minimizes oxidative stress on membranes (Özenç and Özenç, 2008). Thus, data on ion leakage and cell membrane damage prove that hazelnut husks are not only a waste valorization agent in kiwifruit cultivation but also act as a buffer that can alleviate cellular damage caused by drought stress.

Finally, results parallel to the cell damage parameter were observed in terms of the degree of damage. Accordingly, the average damage degree in the control plants was 1.38, whereas plants under severe

drought experienced a score of 2.86. Considering the medium differences, the HPP medium maintained the damage scale at a low level. The data indicated that, in the HPP medium, plants had an average degree of damage of 1.66, whereas in the PP medium, this value rose as high as 2.18. When the application and medium relationships were examined, plants grown in the HPP medium managed to maintain the degree of damage at the same level up to the 75% restricted condition. Conversely, in the PP medium, the degree of damage increased at all levels after the control application. Accordingly, while the degree of damage in plants under 25% and 50% restricted irrigation remained roughly the same, the highest (3.02) damage degree was observed in the 75% restricted irrigation level. The literature states that the Hayward (*A. deliciosa*) cultivar is quite sensitive to drought stress compared to other kiwifruit species and responds morphologically quickly to water restriction (Preet Pratima and Sharma, 2017). In Hayward plants, as the relative water content decreases, the stomatal conductance decreases rapidly, which limits transpiration and causes an increase in leaf temperature (Gucci, 1996). The increase in damage degree in the PP medium starting from 25% restriction can be explained by the rapid stomatal closure of this cultivar at low water potentials, resulting in halted transpiration and subsequent tissue damage (Gucci et al., 1996). In general, these results demonstrate that drought stress significantly disrupts the physiological status of plants, with severity-dependent reductions in vitality, chlorophyll content, and membrane integrity. HPP medium, likely through mechanisms that enhance stress tolerance and cellular stability, provides greater protection against drought induced damage. These findings highlight the critical interaction between medium conditions and drought stress in determining plant resilience and suggest that optimizing growth mediums such as HPP can help mitigate the adverse effects of water restriction.

Conclusion

In conclusion, with increasing drought stress, plant parameters such as shoot length, shoot fresh and dry weight, shoot tolerance rate, turgor weight, leaf relative water content, leaf area, leaf number, plant vitality, and chlorophyll content decreased significantly. Conversely, cell membrane damage rate and damage degree scale increased significantly. Furthermore, the study revealed that hazelnut husk played an important role in mitigating the negative

effects of drought stress in the "Hayward" kiwi variety. Although decreases were observed in growth and physiological parameters such as shoot length, fresh and dry weight, leaf number, turgor weight, leaf area, and chlorophyll content under drought stress, the medium containing hazelnut husks made the plants more resistant to these stress conditions. In particular, for stress indicators such as leaf relative water content, cell membrane damage rate, and damage degree, the HPP medium yielded more positive results than the PP medium. In addition, ion leakage levels were lower and vitality was higher in plants grown in the HPP medium. These findings demonstrate that hazelnut husks are an effective soil conditioner that supports plant growth by conserving water potential in kiwi plants under drought stress conditions. It should be noted that this study was conducted under controlled greenhouse conditions using young rooted hardwood cuttings in pots over an 8-week period. Therefore, the short-term physiological responses observed here may not fully reflect the long-term performance of mature kiwi vines under field conditions. Future long-term field trials are required to validate the effectiveness of hazelnut husk compost applications in established kiwi orchards.

Conflict of interest

There is no conflict of interest among the authors.

Author contrubiton statement

AI conceived the idea and designed the work. MI drafted the manuscript. MI and SK carried out all the experiments. All the authors read and agreed unanimously.

References

- Arora, R., Pitchay, D. S., & Bearce, B. C. (1998). Water-stress-induced heat tolerance in geranium leaf tissues: A possible linkage through stress proteins?. *Physiologia Plantarum*, 103(1), 24-34. <https://doi.org/10.1034/j.1399-3054.1998.1030104.x>
- Ashraf, M. A. (2012). Waterlogging stress in plants: A review. *African Journal of Agricultural Research*, 7(13), 1976-1981. <https://doi.org/10.5897/AJARX11.084>
- Aşkın, T., & Aygün, S. (2018). Does hazelnut husk compost (HHC) effect on soil water holding capacity (WHC)? An environmental approach. *Eurasian Journal of Soil Science*, 7(1), 87-92. <https://doi.org/10.18393/ejss.337222>

- Bao, W. W., Chen, X., Li, R. N., Li, M., Xie, C. J., Dou, M. R., ... & Xu, Y. (2024). Comprehensive assessment of drought resistance and recovery in kiwifruit genotypes using multivariate analysis. *The Plant Journal*, 119(1), 100-114. <https://doi.org/10.1111/tpj.16746>
- Bartlett, M. K., Scoffoni, C., & Sack, L. (2012). The determinants of leaf turgor loss point and prediction of drought tolerance of species and biomes: a global meta-analysis. *Ecology Letters*, 15(5), 393-405. <https://doi.org/10.1111/j.1461-0248.2012.01751.x>
- Bender Özenç, D. (2004). Usage of hazelnut husk compost as a growing medium. In *VI International Congress on Hazelnut* 686 (pp. 309-318). 10.17660/ActaHortic.2005.686.43
- Boini, A., Bortolotti, G., Demetrio Perulli, G., Corelli Grappadelli, L., & Manfrini, L. (2024). *Actinidia chinensis*: physiological and productive performances under different irrigation restitutions. *European Geosciences Union General Assembly EGU24*, 10468. 10.5194/egusphere-egu24-10468
- Calabritto, M., Mininni, A. N., Di Biase, R., Pietrafesa, A., & Dichio, B. (2024). Spatio-temporal dynamics of root water uptake and identification of soil moisture thresholds for precision irrigation in a Mediterranean yellow-fleshed kiwifruit orchard. *Frontiers in Plant Science*, 15, 1472093. <https://doi.org/10.3389/fpls.2024.1472093>
- Cowie, A. L., Orr, B. J., Sanchez, V. M. C., Chasek, P., Crossman, N. D., Erlewein, A., ... & Welton, S. (2018). Land in balance: The scientific conceptual framework for Land Degradation Neutrality. *Environmental Science & Policy*, 79, 25-35. <https://doi.org/10.1016/j.envsci.2017.10.011>
- Çiçek, N., & Yücedağ, C. (2021). Ateş çiçeğinde (*Salvia splendens*) yetiştirme ortamı olarak fındık zurufunun kullanımı. *Artvin Çoruh Üniversitesi Orman Fakültesi Dergisi*, 22(2), 202-208. <https://doi.org/10.17474/artvinofd.950512>
- Demir, Z. (2016). Properties of hazelnut husks as mulching material. *Agriculture and Food*, 4(1), 510-517.
- Demir, Z., & Işık, D. (2019). Effects of cover crop treatments on some soil quality parameters and yield in a kiwifruit orchard in Turkey. *Fresenius Environmental Bulletin*, 28(9), 6988-6997.
- FAO. (2024). *FAOSTAT İstatistik Veritabanı*. Birleşmiş Milletler Gıda ve Tarım Örgütü. Retrieved March 7 2026, from <https://www.fao.org/faostat/en/#data/QCL>
- Farooq, M., Wahid, A., Kobayashi, N. S. M. A., Fujita, D. B. S. M. A., & Basra, S. M. (2009). Plant drought stress: effects, mechanisms and management. In *Sustainable agriculture* (pp. 153-188). Springer. https://doi.org/10.1007/978-90-481-2666-8_12
- Gökbayrak, Z., Dardeniz, A., Engin, H., & Aygün, Ö. (2007). *Hayward kivi (Actinidia deliciosa) çeşidinde gözlenen farklı meyve tiplerine ait çekirdeklerin çimlenme güçlerinin belirlenmesi*. V. Ulusal Bahçe Bitkileri Kongresi, Erzurum, Turkey, 04-07 Eylül 2007, ss. 603-606.
- Gucci, R., Massai, R., Xiloyannis, C., & Flore, J. A. (1996). The effect of drought and vapour pressure deficit on gas exchange of young kiwifruit (*Actinidia deliciosa* var. *deliciosa*) vines. *Annals of Botany*, 77(6), 605-613. <https://doi.org/10.1093/aob/77.6.605>
- Gülser, C., Kızılkaya, R., Askın, T., & Ekberli, I. (2015). Changes in soil quality by compost and hazelnut husk applications in a hazelnut orchard. *Compost Science & Utilization*, 23(3), 135-141. <https://doi.org/10.1080/1065657X.2015.1013584>
- Güneş, H., Boyno, G., Durak, E. D., & Demir, S. (2021). Çeşitli organik atıkların barbunya fasulyesi (*Phaseolus Vulgaris* L. Var. Pinto) bitkisinin gelişimine ve arbusküler mikorhizal funguslar'a etkisi. *Türkiye Tarımsal Araştırmalar Dergisi*, 8(2), 235-247. <https://doi.org/10.19159/tutad.933578>
- İslam, E. (2016). *Fındık zurufu kompostunun toprak mekaniksel özellikleri üzerine etkisi* [Yayımlanmamış yüksek lisans tezi]. Ordu Üniversitesi.
- Korkmaz, H., & Durmaz, A. (2017). Bitkilerin abiyotik stres faktörlerine verdiği cevaplar. *Gümüşhane Üniversitesi Fen Bilimleri Enstitüsü Dergisi*, 7, 192-207.
- Kumar, A., Sharma, N., Wani, T. F., & Sharma, R. (2023). Water productivity of temperate fruits in climate change scenario. In *Advances in water management under climate change* (pp. 210-235). CRC Press. <https://doi.org/10.1201/9781003351672>
- Michel, J. C., & Cannavo, P. (2013). Importance of peat particle size effects on spatial root distribution and changes on aeration properties. In *International Symposium on Growing Media and Soilless Cultivation* 1034 (pp. 347-354).

- <https://doi.org/10.17660/ActaHortic.2014.1034.43>
- Mills, T. M., Li, J., & Behboudian, M. H. (2009). Physiological responses of gold kiwifruit (*Actinidia chinensis*) to reduced irrigation. *Journal of the American Society for Horticultural Science*, 134(6), 677-683. <https://doi.org/10.21273/JASHS.134.6.677>
- Ozden, M., Demirel, U., & Kahraman, A. (2009). Effects of proline on antioxidant system in leaves of grapevine (*Vitis vinifera* L.) exposed to oxidative stress by H₂O₂. *Scientia Horticulturae*, 119(2), 163-168. <https://doi.org/10.1016/j.scienta.2008.07.031>
- Ozyazıcı, G., Ozdemir, O., & Ozyazıcı, M. A. (2010). Organik kivi üretiminde toprak düzenleyicilerin ve organik materyallerin verim ve bazı meyve özellikleri üzerine etkileri. *Türkiye IV. Organik Tarım Sempozyumu*, 28 Haziran-1 Temmuz 2010, Erzurum, Turkey.
- Özenç, D. B., & Özenç, N. (2008). Short-term effects of hazelnut husk compost and organic amendment applications on clay loam soil. *Compost Science & Utilization*, 16(3), 192-199. <https://doi.org/10.1080/1065657X.2008.10702377>
- Peng, J., Xiao, W., Huang, D., Xiao, R., & Wang, Z. (2010). Effects of ground mulching with rice chaff on soil condition and plant growth of kiwifruit. In *VII International Symposium on Kiwifruit* 913 (pp. 283-288). <https://doi.org/10.17660/ActaHortic.2011.913.36>
- Pratima, P., Sharma, N., & Kaushal, R. (2016). Effect of deficit irrigation and in situ moisture conservation on soil moisture content and frequency of irrigation in kiwifruit cultivar Allison. *Journal of Applied and Natural Science*, 8(4), 2093-2098. <https://doi.org/10.31018/jans.v8i4.1096>
- Pratima, P., Sharma, N., & Sagar, H. (2018). Effect of deficit irrigation on physico-chemical characteristics in various kiwifruit (*Actinidia deliciosa* Chev.) cultivars. *International Journal of Bio-resource and Stress Management*, 9(2), 287-292. <https://doi.org/10.23910/IJBSM/2018.9.2.1851>
- Preet Pratima, P. P., & Sharma, N. (2017). Response of kiwifruit cultivars to deficit irrigation in terms of canopy temperature and water relations. *Indian Journal of Horticulture*, 74(4), 515-519. <https://doi.org/10.5958/0974-0112.2017.00100.1>
- Prendergast, P., McAneney, K. J., Astill, M. S., Wilson, A. D., & Barber, R. F. (1987). Water extraction and fruit expansion by kiwifruit. *New Zealand Journal of Crop and Horticultural Science*, 15(3), 345-350. <https://doi.org/10.1080/03015521.1987.10425580>
- Rahman, M. H., Holmes, A. W., Saunders, S. J., & McCurran, A. G. (2011). Relative contribution of avoidance and tolerance to dehydration resistance in kiwifruit (*Actinidia* species). *Journal of Crop Improvement*, 25(3), 202-218. <https://doi.org/10.1080/15427528.2011.550024>
- Rajan, P., Natraj, P., Kim, M., Lee, M., Jang, Y. J., Lee, Y. J., & Kim, S. C. (2024). Climate change impacts on and response strategies for kiwifruit production: A comprehensive review. *Plants*, 13(17), 2354. <https://doi.org/10.3390/plants13172354>
- Rehman, M. U., Rather, G. H., Gull, Y., Mir, M. R., Mir, M. M., Waida, U. I., & Hakeem, K. R. (2015). Effect of climate change on horticultural crops. In *Crop production and global environmental issues* (pp. 211-239). Springer. https://doi.org/10.1007/978-3-319-23162-4_9
- Sivritepe, N., Erturk, U., Yerlikaya, C., Turkan, I., Bor, M., & Ozdemir, F. (2008). Response of the cherry rootstock to water stress induced in vitro. *Biologia Plantarum*, 52(3), 573-576. <https://doi.org/10.1007/s10535-008-0114-4>
- Şahin, G. (2019). Kivi (*Actinidia deliciosa*) yetiştiriciliği ve Türkiye zirai hayatındaki yeri. *Bartın Üniversitesi Edebiyat Fakültesi Dergisi*, 4(1), 3-32.
- Tiwari, A., Punetha, S., & Kesarvani, K. (2021). Drought stress and its impact on plant mechanism. *International Journal of Plant Sciences*, 16, 95-112. <https://doi.org/10.15740/HAS/IJPS/16.AAEBSSD/95-112>
- Turhan, E., Dardeniz, A., & Müftüoğlu, N. M. (2005). Bazı Amerikan asma anaçlarının tuz stresine toleranslarının belirlenmesi. *Bahçe*, 34(1), 11-20.
- TÜİK. (2024). *Bitkisel Üretim İstatistikleri Veritabanı*. Türkiye İstatistik Kurumu. Retrieved March 2026, <https://biruni.tuik.gov.tr/medas/?kn=92&locale=tr>
- Vurro, F., Manfrini, L., Boini, A., Bettelli, M., Buono, V., Caselli, S., ... & Janni, M. (2024). Kiwi 4.0: in vivo real-time monitoring to improve water use efficiency in yellow flesh *Actinidia Chinensis*. *Biosensors*, 14(5), 226. <https://doi.org/10.3390/bios14050226>

- Waseem, M., Ali, A., Tahir, M., Nadeem, M. A., Ayub, M., Tanveer, A., ... & Hussain, M. (2011). Mechanism of drought tolerance in plant and its management through different methods. *Continental Journal of Agricultural Science*, 5(1), 10-25.
- Yamasaki, S., & Dillenburg, L. R. (1999). Measurements of leaf relative water content in *Araucaria angustifolia*. *Revista Brasileira de Fisiologia Vegetal*, 11(2), 69-75.
- Zenginbal, H., Özcan, M., & Haznedar, A. (2005). Rize ekolojik şartlarında yetiştirilen kivi çeşitlerinde fenolojik gözlem ve pomolojik analizler üzerine bir araştırma. *Derim*, 22(1), 1-9.
- Zeytin, S., & Baran, A. (2003). Influences of composted hazelnut husk on some physical properties of soils. *Bioresource Technology*, 88(3), 241-244. [https://doi.org/10.1016/S0960-8524\(03\)00005-1](https://doi.org/10.1016/S0960-8524(03)00005-1).