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Research Paper

Impact of drought stress and rootstock on growth, compatible osmolytes, and flavonoids of Daphnis tomato

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Abstract
Greenhouse vegetable production faces challenges in regions prone to drought and water shortages. Grafting offers opportunities to enhance performance under stress conditions. This study evaluated the growth and biochemical responses of Daphnis tomato grafted onto different rootstocks under different irrigation levels. In a greenhouse experiment, seven Solanaceous rootstocks were used and the plants were subjected to three irrigation regimes (3-day interval as control, and 6-day and 9-day intervals as moderate and severe drought stresses) for four months. Results showed significant effects of irrigation intervals and rootstocks on growth and biochemical characteristics. Increasing irrigation interval led to the reduction in shoot fresh weight (SHFW), root length (RL), and yield. Certain rootstocks (*Solanum cheesmaniae*, *S. lycopersicum* var. cerasiforme) outperformed others in SHFW, RL, and yield. Also, rootstocks influenced the accumulation of total phenolic compounds (TPC), total soluble carbohydrates (TSC), and total flavonoid content (TFC). *S. lycopersicum* var. cerasiforme and *S. cheesmaniae* showed the lowest levels of these compounds. The interaction of irrigation intervals with rootstocks was significant for root fresh weight, shoot-to-root ratio, and leaf proline content. *S. lycopersicum* var. cerasiforme and *S. cheesmaniae* maintained root biomass under severe drought stress, while *S. nigrum* exhibited efficient resource allocation to the shoots under severe drought stress. Leaf proline content increased under severe drought stress in specific rootstocks. In conclusion, the type of rootstock influenced the growth and biochemical characteristics of the Daphnis tomato under water-deficit stress conditions. *S. cheesmaniae*, and *S. lycopersicum* var. cerasiforme demonstrated better growth, while certain rootstocks exhibited higher levels of biochemical compounds. These findings emphasize the importance of rootstock selection for enhancing drought tolerance in tomato cultivation and show the significance of some biochemical compounds in determining the water status of the greenhouse tomato.

Keywords: drought stress, flavonoids, osmoregulation, total phenolic compounds, total soluble carbohydrates

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Introduction

Tomato (*Solanum lycopersicum* L.) is a widely cultivated vegetable crop that is highly susceptible to drought stress conditions. Drought stress negatively affects tomato plant growth, development, and productivity, making it crucial to understand the physiological and biochemical responses of tomato plants to water scarcity. Numerous studies have investigated the impact of drought on the growth and biochemical changes in the tomato. Drought stress induces a series of morphological, physiological, and biochemical changes in tomato plants. Under water-limited conditions, tomato often exhibits reduced shoot and root growth (Chaves *et al.* 2009). Kusvuran *et al.* (2019) reported that drought stress led to decreased shoot fresh weight (SHFW) and root length (RL) in tomato plants. These limitations can be attributed to the decreased availability of water for cell expansion and nutrient uptake, as well as the disruption of various metabolic processes in the plant (Chaves *et al.* 2009).

At the biochemical level, tomato plants respond to drought stress through the accumulation of osmoprotectants and antioxidant compounds. Proline, a compatible solute, plays a crucial role in osmoregulation and protecting cellular structures during drought stress. Several studies have reported increased proline content in drought-stressed plants (Vurukonda *et al.* 2016; Khan *et al.* 2018). It accumulates in tomato plants in response to water scarcity (Rai *et al.* 2012). Proline acts as an osmolyte, maintaining cell turgor and stabilizing proteins and membranes under water-limited conditions. Furthermore, the antioxidant defense system of tomato plants undergoes modifications in response to drought stress. Reactive oxygen species (ROS) increase under drought conditions, leading to oxidative damage in plant cells. To counteract this, tomato plants activate enzymatic and non-enzymatic antioxidant mechanisms (Zhou *et al.* 2019). Antioxidant enzymes such as superoxide dismutase, catalase, and peroxidase scavenge ROS and minimize oxidative stress (Aftab *et al.* 2011). Additionally, non-enzymatic antioxidants, including phenolic compounds and flavonoids, accumulate in drought-stressed tomato plants (Sánchez-Rodríguez *et al.* 2011). These antioxidants play a vital role in scavenging ROS and protecting cellular components from oxidative damage. By unraveling the physiological and biochemical changes in response to drought, researchers can develop strategies for improving drought tolerance and water use efficiency in tomato cultivation.

Various studies have highlighted the importance of genetic and physiological factors involved in the drought tolerance of tomato plants (Bai and Lindhout 2007). Breeders and researchers have focused on identifying and utilizing drought-tolerant tomato cultivars or wild relatives as potential genetic resources. Also, agronomic practices such as deficit irrigation and irrigation scheduling techniques have been investigated to optimize water use efficiency and mitigate the negative effects of drought on tomato plants. Techniques such as regulated deficit irrigation and partial root-zone drying have shown promising results in conserving water while maintaining tomato yield and fruit quality (Sobeih *et al.* 2004). These strategies involve controlled water deficit during specific growth stages, allowing plants to adapt and allocate resources more efficiently.

While it is feasible to develop a desired cultivar, fixing a specific characteristic in novel cultivars using breeding techniques poses inherent challenges (Araus *et al.* 2002; Bai and Lindhout 2007). Grafting has emerged as an alternative method to harness the advantages of resistant genotypes (as rootstock) to enhance the performance of susceptible commercial cultivars (as scion) in the face of biotic or abiotic challenges (Lopez and Mendonca 2016; Kumar *et al.* 2017). Notably, grafting stands out as a widely employed technique for mitigating water loss and enhancing water use efficiency in vegetable crops. Rootstocks play a crucial role in improving plant adaptation to drought stress by influencing various physiological and biochemical mechanisms. They possess traits that help mitigate the negative effects of water deficit, including enhanced water uptake efficiency, deep root systems, and improved water transport capacity. Grafting tomato scions onto drought-tolerant rootstocks has shown promising results in alleviating drought-induced growth inhibition and improving plant performance under water-limited conditions. Several studies have demonstrated the positive impact of grafting onto drought-tolerant rootstocks on tomato plant growth and physiological characteristics under drought stress. In addition to improved water use efficiency and antioxidant defense system, grafting onto drought-tolerant rootstocks have been found to influence osmotic adjustment. Grafted tomato plants has been shown to exhibit increased accumulation of compatible solutes, such as proline and soluble sugars, which act as osmoprotectants and maintain cellular water potential under drought conditions (Al Hassan *et al.* 2015). The use of drought-tolerant rootstocks in grafting tomato plants offers a promising approach to enhancing drought tolerance and improving plant performance under water-limited conditions. The selection of appropriate rootstocks with desirable traits, including deep root systems, enhanced osmotic adjustment, antioxidant defense mechanisms, and hormonal regulation, can significantly enhance the drought tolerance of grafted tomato plants.

This study aimed to evaluate the growth responses of Daphnis tomato scion grafted on different rootstocks under deficit irrigation and to identify drought-stress indicators among measured biochemical compounds in the grafted Daphnis tomato.

Materials and Methods

The experiment was conducted from 15 January 2020 until 5 July 2021. The soil used in the greenhouse was clay loam (72.4% sand, 12.8% silt, and 14.8% clay). Organic matter content, pH, and EC of the soil were 3.45%, 7.2, and 1.6% respectively.

Plant material and grafting

In this experiment, "Daphnis", an indeterminate commercial cultivar, underwent various grafting treatments detailed in Table 1. Seeds of "Daphnis" and rootstocks were germinated in late January 2020 in polystyrene trays filled with a cocopeat-perlite-based substrate in a greenhouse. Non-grafted "Daphnis" plants were intentionally germinated two weeks later than those designated for grafting, ensuring similar plant sizes at transplantation. The cleft grafting method was conducted 30 days after germination when plants initiated their third true leaf. Following grafting, all plants were immediately placed in a growth chamber with complete darkness, a relative humidity near 90%, and a temperature of 25±2 °C for three days. After primary acclimatization (accompanied by reduced relative humidity and increased light intensity), grafted plants were transferred to the greenhouse for an additional two weeks, exposed to full sunlight, and maintained at a temperature of 28±2 °C. During this stage, grafted plants displaying a notably smaller growth habit- possibly attributed to delayed or inadequate recovery from the grafting process- were excluded, allowing only the most representative ones to remain. Fifty days after germination, the plants were transplanted into a polyethylene greenhouse (8.0 m wide, 30 m long, 4 m height) with a spacing of 30 × 60 cm. Daily irrigation was administered using Hoagland's solution diluted with distilled water in a 1:1 ratio. At this stage, grafted plants exhibiting significant stunted growth, likely due to delayed or insufficient recovery from the grafting process, were removed, and only the most representative ones were retained.

Table 1. Different rootstocks used in this experiment with their abbreviations.

Rootstock name	Common name	Abbreviation
Ungrafted Daphnis	-	Con
Self-grafted Daphnis	-	SG
Solanum pimpinellifolium	Pmp	Pimp
Solanum melongene cv. Thai yellow	Thai Yellow Egg	TY
Solanum lycopersicum cv. Emperador	Emperador	Emp
Solanum melongene cv. Mohalli Yazd	Mohalli Yazd Egg	MY
Solanum cheesmaniae	Galapagus	Gal
Solanum lycopersicum var. *cerasiforme*	Cherry tomato	Ch.T
Solanum nigrum	Black nightshade	BN

Irrigation

A drip irrigation system, employing AzudPro drip irrigation tapes with 0.33 m emitter spacing, 1 mm thickness, and a flow rate of 2.15 L h^{-1} at 100 kPa, was utilized to fulfill fertilizer and irrigation water requirements. These tapes were placed along both sides of the tomato rows in each plot. The operational pressure and applied water of the irrigation system were meticulously regulated through a pressure gauge and a water meter. To prevent lateral water flow between irrigation treatments, polycarbonate sheets were positioned within the plot interface, extending to a depth of 60 cm. Post-transplantation, each plot underwent daily full irrigation for two weeks, ensuring the 0-40 cm soil water content reached field capacity to promote the survival of tomato seedlings. Subsequently, for each irrigation treatment (3, 6, and 9 days), irrigation water was applied to restore soil water to field capacity. Throughout the growing season, soil moisture was monitored at 0.2 m increments down to 0.6 m (root depth) using a portable TDR soil moisture meter (TRIME-PICO 64-TDR, IMKO, Germany). These measurements were taken before irrigations, and the average of several TDR readings along planting rows in each soil layer was recorded as the soil water content. The total volume of water applied (AW) during irrigation was determined by using

$$AW = \left(\sum_{i=1}^{n} \frac{(\theta_{fc} - \theta_1)_i}{100} \times d_i \right) \times A$$

where θ_{fc} and θ_1 represent field capacity and soil volumetric water content before irrigation, d_i is the thickness of i^{th} soil layer, n is the number of soil layers in the root zone and A is the wetted area (canopy cover).

Growth and yield

Four months after the commencement of irrigation treatments, plants were uprooted and shoot and root fresh matter were measured. RL was measured from the base of the shoot/root junction to the tip of the longest root. Harvest of tomato red ripe fruits was done weekly during the fruiting period and yield (cumulative fruit weight) was measured for each plant at the end of the experiment.

Biochemical compounds

One week before harvesting of the plants, leaf samples were taken according to the related protocol and transferred to the laboratory for some biochemical analyses. The amount of proline was measured based on the method of Bates *et al.* (1973). Total soluble carbohydrates (TSC) was estimated by the anthrone method (Irigoyen *et al.* 1992). Total phenolic content (TPC) were measured by the Folin-Ciocalteu reagent method using gallic acid as the standard (McDonald *et al.* 2001). Total flavonoid content (TFC) was determined using the aluminum chloride colorimetric method (Zhishen *et al.* 1999).

Statistical analysis

The experiment was conducted as the spilt-plot design with three levels of irrigation interval (3-day interval as the control, and 6- day and 9-day intervals) assigned to main plots and nine grafting combinations as subplots.

Analysis of variance was carried out for the studied characteristics. When the treatment effects were found significant, mean differences were tested using Duncan's Multiple Range Test (DMRT) at 5% or 1% levels of probability. The SPSS software was used for the statistical analyses of the data.

Results

The analyses revealed significant effects of both irrigation intervals and rootstocks on the growth, yield, and biochemical characteristics of Daphnis tomato plants (Table 2). Furthermore, the irrigation interval × rootstock interaction was significant for the root fresh weight (RFW), shoot-to-root ratio, and proline content.

Table 2. Summary of the results of the analysis of variance for effects of irrigation interval and rootstock on growth and biochemical compounds of Daphnis tomato.

	Irrigation interval (II)		Rootstock (R)		II × R	
	F	*p-value*	*F*	*p-value*	*F*	*p-value*
Shoot fresh weight	37.4	<0.001	14.3	<0.001	0.78	0.70
Root fresh weight	53.1	<0.001	21.6	<0.001	2.30	0.009
Shoot to root ratio	10.6	<0.001	3.67	<0.001	5.97	<0.001
Root length	36.3	<0.001	14.4	<0.001	1.32	0.22
Yield	43.5	<0.001	17.3	<0.001	1.85	0.31
Proline	34.9	<0.001	18.6	<0.001	2.06	0.03
Total phenolic content	22.8	<0.001	6.30	<0.001	0.85	0.74
Total soluble carbohydrates	24.1	<0.001	8.86	<0.001	0.89	0.89
Total flavonoid content	18.2	<0.001	4.49	<0.001	1.15	0.33

Compared to the control (3-day interval), the moderate drought stress (6-day interval) resulted in a significant decrease in SHFW by approximately 37.0% and RL by approximately 29.7%. Furthermore, severe drought stress (9-day interval) led to a substantial reduction in SHFW by approximately 72.9% and RL by 62.6% (Figure 1). These findings indicate that as the irrigation interval increased, the plants experienced progressively greater limitations in the shoot and root growth. The effect of irrigation levels on the tomato yield is shown in Figure 1. The increase in the irrigation interval had a significant impact on tomato yield so from the 3-day to 6-day interval, there was a 34% decrease in yield, and from the 3-day to 9-day interval, the yield reduction reached 65%. The biochemical compounds (TPC, TSC, and TFC) were also influenced by irrigation intervals. For TPC, the 3-day irrigation interval resulted in the lowest value of 0.67 mg/g, while the 6-day and 9-day intervals showed an increase of 37% and 67%, respectively compared to the 3-day interval (Figure 1). TSC exhibited a similar pattern with the 3-day interval resulting in the lowest value of 17.7 mg/g. The TSC increased by 76% and 143% with 6-day and 9-day intervals, respectively (Figure 1). TFC also showed the lowest value of

0.12 mg/g at the 3-day interval. The TFC increased by 51% and 104% with 6-day and 9-day intervals, respectively (Figure 1). Figure 2 illustrates the impact of various rootstocks on the growth, yield, and biochemical characteristics of Daphnis tomato plants. The Ch.T rootstock exhibited the highest SHFW of 2239g, followed by Gal, and Emp (2092g and 1883g) showing an increase of 72%, 61%, and 44%, respectively compared with the un-grafted Daphnis control (Figure 2). Ch.T also demonstrated the longest roots, followed by Gal and Emp which were 45%, 35%, and 35% greater than that in the control (Figure 2). All graft combinations increased the yield of the Daphnis cultivar compared to the control, except for the BN rootstock. The maximum increase in yield compared to the control was observed in Ch.T by about 84%, followed by Gal and Emp by about 81% and 63%, respectively (Figure 2).

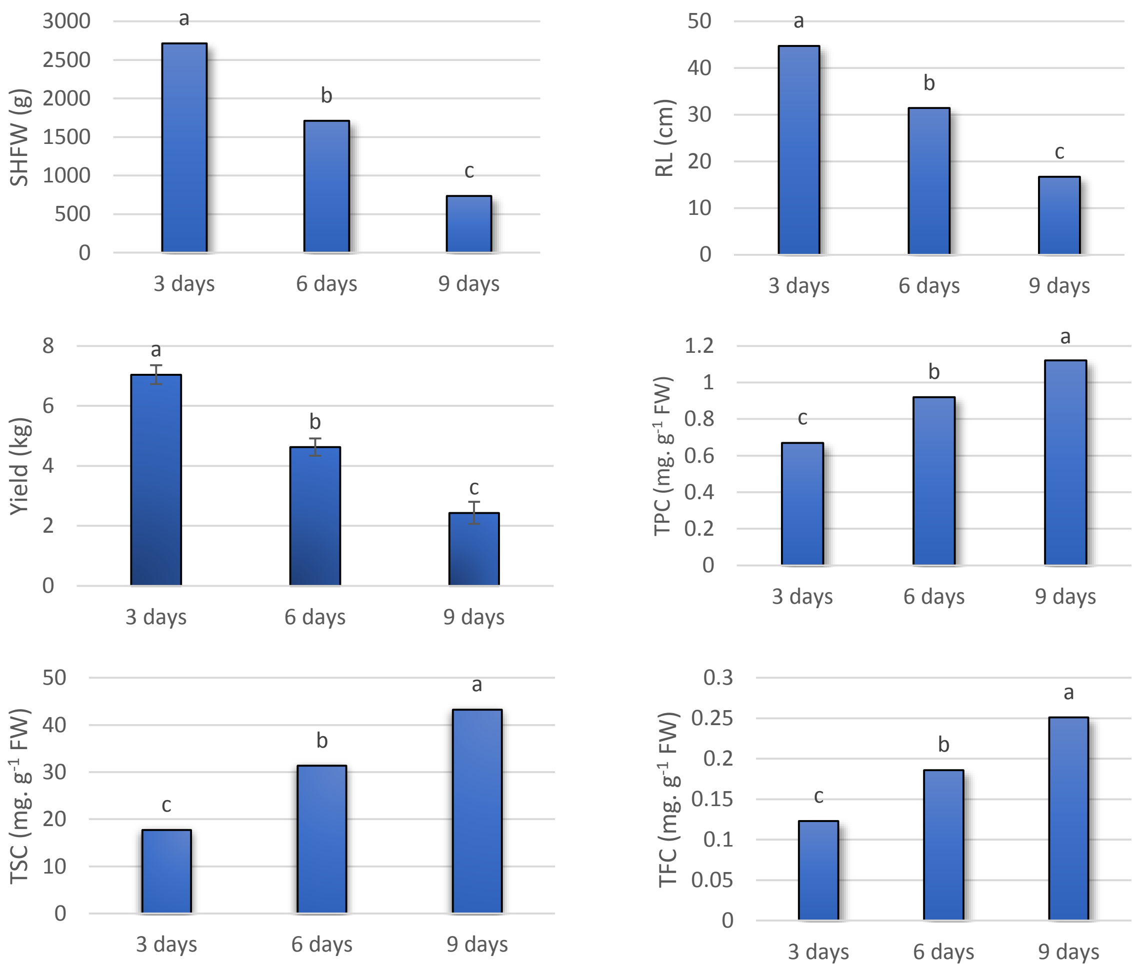

Figure 1. Effect of different irrigation intervals (3 days as the control, 6 days as the moderate, and 9 days as the severe drought stress) on shoot fresh weight (SHFW), root length (RL), yield, leaf total phenolic compounds (TPC), total soluble carbohydrates (TSC), and total flavonoid content (TFC) of the Daphnis tomato. Different letters indicate significant differences at the five percent probability level based on Duncan's multiple range test.

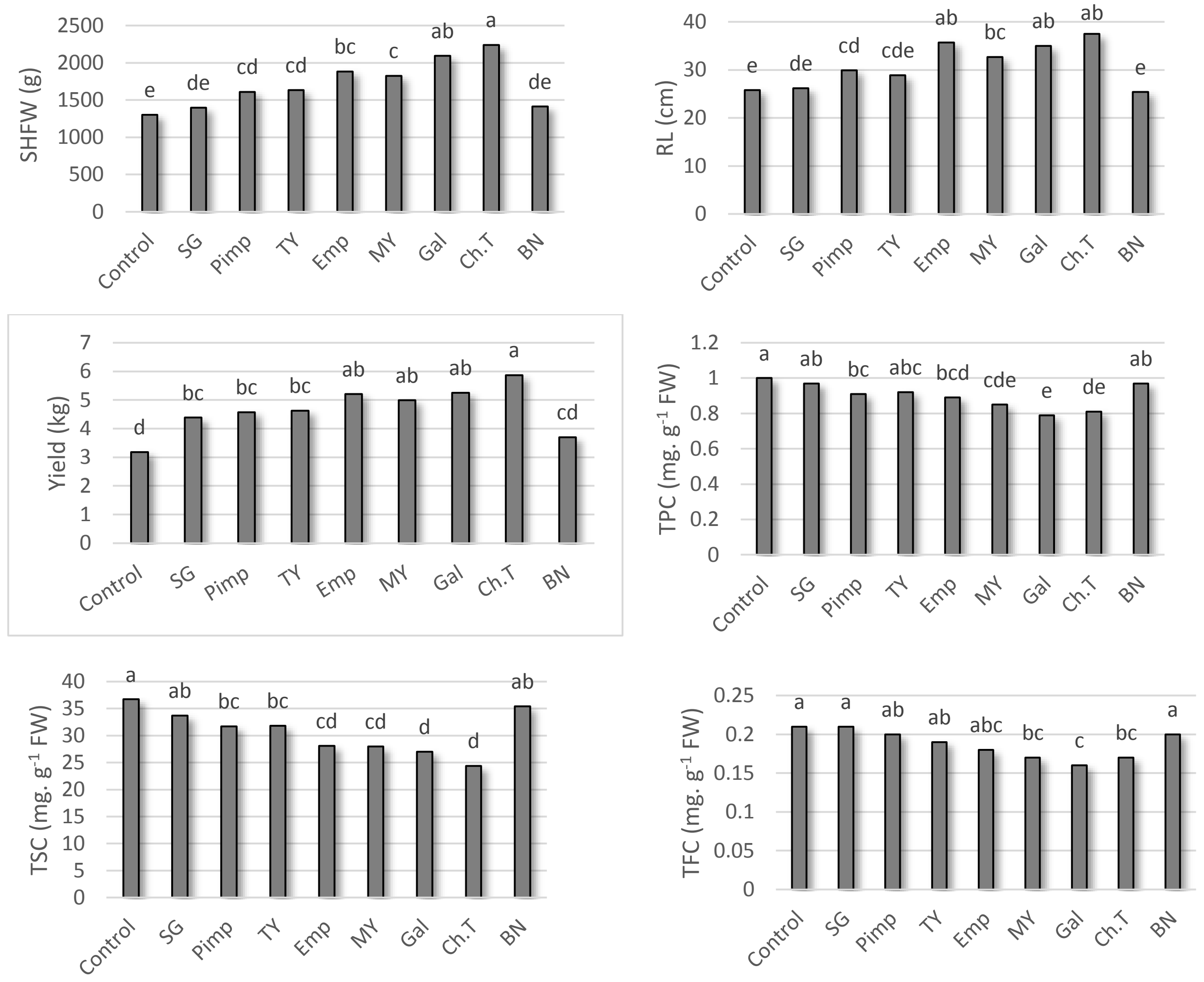

Figure 2. Effect of different rootstocks on shoot fresh weight (SHFW), root length (RL), yield, leaf total phenolic content (TPC), total soluble carbohydrates (TSC), and total flavonoid content (TFC) of the Daphnis tomato. Different letters indicate significant differences at the five percent probability level based on Duncan's multiple range test.

The highest TPC values were observed in the un-grafted Daphnis (control), SG, and BN rootstocks, while the lowest values were recorded in Gal and Ch.T (Figure 2). Reduction of the TPC in GAL and Ch.T compared to the control were 21% and 19% respectively. Similarly, TSC and TFC were highest in the control, SG, and BN rootstocks, with the lowest levels found in Ch.T, Gal, and MY (Figure 2). The irrigation interval × rootstock interaction about RFW, shoot-to-root ratio, and leaf proline content are presented in Figure 3. When the un-grafted Daphnis (control) was subjected to a 3-day irrigation interval, the RFW was 139.9 g. However, as the irrigation interval increased to 9 days, the RFW significantly decreased to 48.42 g. A similar trend can be observed for the most rootstock and irrigation interval combinations, indicating that longer irrigation

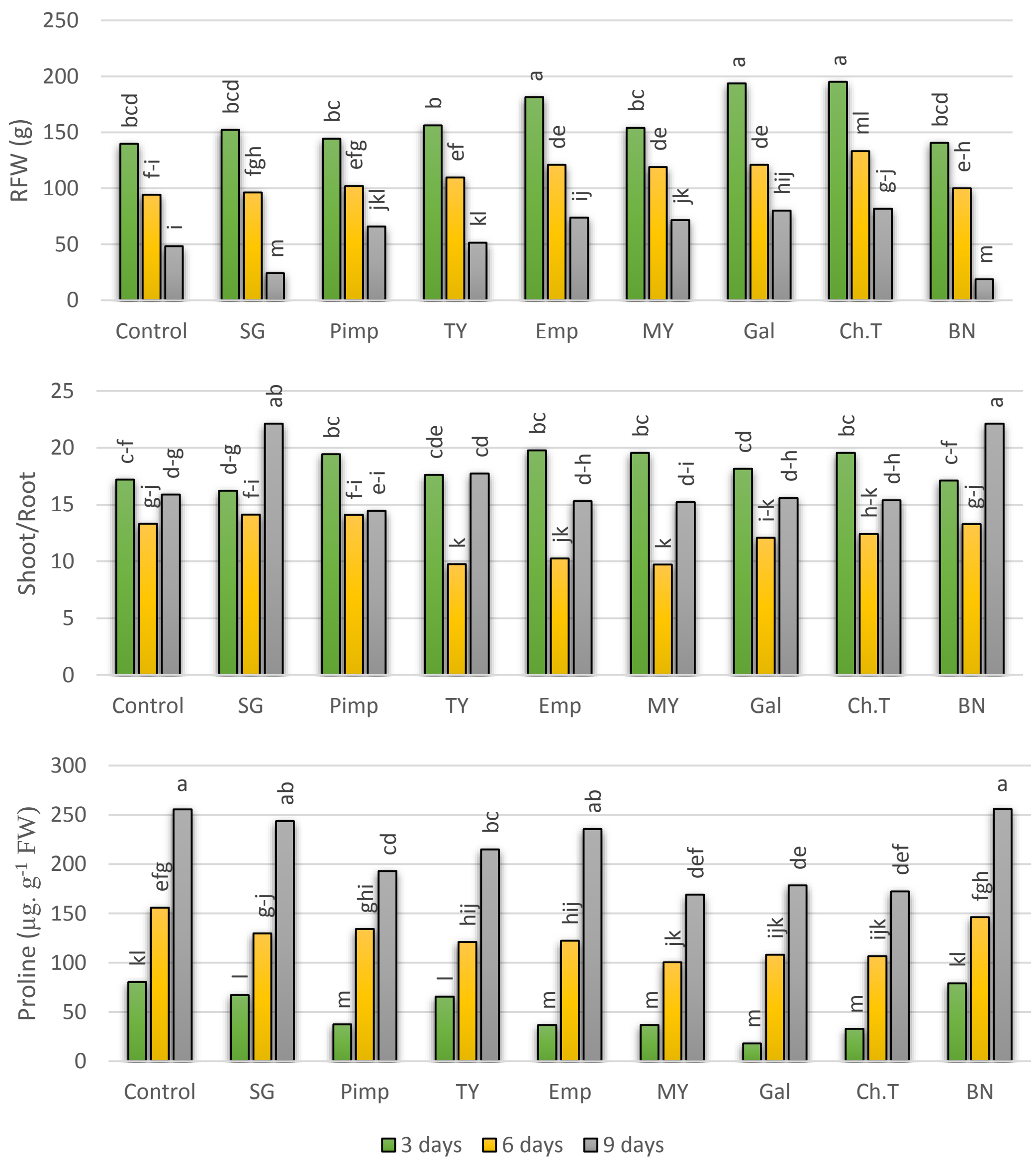

Figure 3. Interaction of irrigation intervals with rootstocks about root fresh weight (RFW), shoot-to-root ratio, and leaf proline content of the tomato plants. Different letters indicate significant differences at the five percent probability level based on Duncan's multiple range test.

intervals tend to result in lower RFW (Figure 3). Under severe drought stress (9-day interval), Ch. T and Gal rootstocks showed the highest RFW, indicating their superior performance in maintaining root biomass under water-limited conditions (Figure 3). The shoot-to-root ratio also displayed variation depending on the specific combination of irrigation intervals and stress and certain rootstocks. Figure 3 shows that SG and BN rootstocks exhibited the highest shoot-to-root ratio under severe drought stress (9-day interval), indicating a more efficient allocation of resources to the above-ground biomass. The leaf proline content, a known indicator of drought stress, showed a significant increase under severe drought and certain rootstock combinations. For instance, the leaf proline content of the un-grafted Daphnis at the 3-day irrigation interval was 80.15 μg/g. However, as the irrigation interval extended to 9 days, the leaf proline content significantly increased to 255.5 μg/g. Similar trend can be observed for other rootstock and irrigation interval combinations, indicating that longer irrigation intervals can lead to a higher leaf proline content, potentially indicating greater stress levels in the plants (Figure 3).

Discussion

The results demonstrated significant effects of both irrigation intervals and rootstocks on various measured characteristics. The reduction in SHFW and RL under severe drought stress (9-day interval) is consistent with the previous studies on the impact of drought on tomato plants (Kusvuran *et al.* 2019). This decline indicates the plants' adaptation to limited water availability by reducing biomass production and root expansion. Water scarcity restricts photosynthetic capacity (Kusvuran *et al.* 2019), cell expansion, and nutrient uptake, leading to decreased biomass accumulation (Chaves *et al.* 2009). These findings highlighted the vulnerability of the Daphnis tomato to prolonged drought conditions. Yield of Ch.T, Gal, and Emp rootstocks exhibited increases of approximately 84%, 81%, and 63%, respectively, compared to the control. Even the SG rootstock showed a 37% increase in yield compared to the control, underscoring the positive impact of grafting on yield, irrespective of the applied rootstock. Grafting scion onto rootstock induces the formation of callus tissue at the graft junction, which may or may not undergo differentiation into xylem and phloem. This process can influence the transport rate of materials between the scion and rootstock, potentially leading to reduced water flow to shoots (resulting in decreased hydraulic conductance) and restricting the transport of photoassimilates to roots. The accumulation of photoassimilates above the grafting junction may serve as a catalyst for promoting plant reproductive growth, as evidenced in our experiment.

The significant increase in TPC and TSC under severe drought stress is consistent with the findings of other studies on plants exposed to water scarcity (Martínez *et al.* 2007; Gharibi *et al.* 2019). Accumulation of TPC and TSC serves as an adaptive mechanism to mitigate the negative effects of drought stress. These compounds contribute to osmotic adjustment, maintaining cell turgor, and enhancing the plant's ability to tolerate water deficit conditions (Kusvuran *et al.* 2019). The increase in TPC and TSC levels indicates the activation of biochemical pathways involved in stress tolerance and resource allocation adjustments. The higher flavonoid content observed in the control and SG, and grafted plants on BN rootstocks is consistent with the findings of studies on the impact of drought stress on flavonoid accumulation in tomato plants (Conti *et al.* 2019). Flavonoids are known for their antioxidant properties and their involvement in stress signaling and defense mechanisms in plants (Li *et al.* 2021). The higher flavonoid content in these plants suggests that these rootstocks may upregulate flavonoid biosynthesis pathways in response to drought stress, leading to enhanced stress tolerance.

The effect of different rootstocks on the measured characteristics provides insights into the role of grafting in enhancing plant tolerance to deficit irrigation. Un-grafted Daphnis showed lower SHFW and RL compared to the most grafted rootstocks, indicating the potential benefits of rootstock selection in improving growth under water-limited conditions. Previous studies have reported similar findings, highlighting the ability of specific rootstocks to confer drought tolerance to the scion through various mechanisms, such as altered water uptake and transport efficiency (Kumar *et al.* 2017). The superior performance of *Solanum cheesmaniae* (Gal) as a tomato wild species and *Solanum lycopersicum* var. cerasiforme (Ch.T) as an intermediate genetic admixture between wild currant-type tomatoes and domesticated tomatoes in terms of SHFW and RL were aligned with the previous studies on the use of wild Solanum species as rootstocks for tomato grafting (Cortez-Madrigal *et al.* 2012; Alves *et al.* 2021; Bharathi *et al.* 2021). These rootstocks likely possess characteristics that confer enhanced drought tolerance to the scion. The improved growth of grafted plants on the Ch.T and Gal rootstocks can be attributed to their ability to maintain higher water uptake and sustain physiological functions under water-limited conditions. These findings highlight the potential of wild Solanum species as rootstocks for enhancing drought tolerance in tomato plants.

The interaction of irrigation intervals with rootstocks about RFW, shoot-to-root ratio, and leaf proline content provide further insights into the responses of the Daphnis tomato under deficit irrigation. The increase in the shoot-to-root ratio under the 9-day interval irrigation for the self-grafted Daphnis and BN rootstock suggests the more efficient allocation of resources to the above-ground biomass. This response is consistent with the studies reporting altered biomass partitioning in plants subjected to water stress (Eziz *et al.* 2017). The higher shoot-to-root ratio indicates a shift in resource allocation, favoring shoot growth to optimize light capture and photosynthetic activity in response to limited water availability.

The increased leaf proline content observed under severe drought stress for certain rootstocks is in line with the findings of studies on plant proline accumulation in response to water stress (Wang *et al.* 2022). Proline serves as an osmoprotectant and a signaling molecule under drought conditions, contributing to osmotic adjustment and the maintenance of cellular integrity (Wang *et al.* 2022). The higher proline content in these treatments indicates the activation of drought-responsive pathways and the plant's attempt to counteract the detrimental effects of water deficit.

Overall, the findings of this experiment align with previous studies on the growth and biochemical responses of tomato plants under drought-stress conditions. The observed reductions in shoot growth and RL, accompanied by the accumulation of osmoprotectants and antioxidant compounds, demonstrate the plant's ability to adapt to water scarcity. The observation that rootstocks with high growth in terms of SHFW, RL, and RFW had the lowest levels of biochemical compounds can be attributed to a trade-off between growth and defense mechanisms in plants. When plants experience favorable growing conditions, such as optimal irrigation and nutrient availability, they tend to allocate more resources towards growth and development. This allocation of resources toward growth often comes at the expense of defense mechanisms, such as the production of biochemical compounds.

Conclusion

Rootstock selection significantly influenced the growth and biochemical responses of Daphnis tomato under deficit irrigation. *Solanum cheesmaniae*, and *Solanum lycopersicum* var. cerasiforme demonstrated superior growth, while exhibiting lower levels of biochemical compounds. This observation suggests that these particular rootstocks may have been less affected by drought stress, possibly owing to their larger root systems. These findings emphasize the importance of rootstock selection for enhancing drought tolerance in tomato cultivation and show the significance of some biochemical compounds in screening of water status of the greenhouse tomato.

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Conflict of interest

The authors declare that they have no competing interests.

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تاثیر تنش خشکی و پایه بر رشد، اسمولیت‌های سازگار و فلاونوئیدهای گوجه فرنگی رقم دافنیس

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چکیده

تولید سبزی‌های گلخانه‌ای در مناطقی که دچار خشک‌سالی بوده و با کمبود آب مواجه می‌باشند، با چالش‌هایی مواجه است. پیوند سبزی‌ها در شرایط تنش، فرصت‌هایی را برای بهبود عملکرد به وجود می‌آورد. در این پژوهش، رشد و پاسخ‌های بیوشیمیایی گوجه فرنگی گلخانه‌ای دافنیس پیوند شده روی پایه‌های مختلف تحت سطوح مختلف آبیاری بررسی شد. در یک آزمایش گلخانه‌ای، هفت پایه متعلق به جنس سولانوم مورد استفاده قرار گرفت و گیاهان با سه دور آبیاری (با فاصله ۳ روز به عنوان شاهد و ۶ و ۹ روز به عنوان تنش خشکی ملایم و شدید) در مدت چهار ماه آبیاری گردیدند. نتایج بیان‌گر اثرات قابل توجه دور آبیاری و پایه بر رشد و ویژگی‌های بیوشیمیایی بود. افزایش دور آبیاری باعث کاهش وزن تازه شاخساره، طول ریشه و عملکرد گردید. برخی از پایه‌ها (*S. cheesmaniae*, *Solanum lycopersicum* var. cerasiforme) از نقطه نظر وزن تر شاخساره، طول ریشه و عملکرد نسبت به سایر پایه‌ها بهتر بودند. همچنین پایه‌ها بر تجمع ترکیبات فنولی کل، مجموع کربوهیدرات‌های محلول و مجموع فلاونوئیدها تاثیر داشتند. *S. lycopersicum* var. cerasiforme و *S. cheesmaniae* میزان کمتری از این ترکیبات را نشان دادند. برهمکنش دور آبیاری و پایه برای وزن تازه ریشه، نسبت شاخساره به ریشه و محتوای پرولین برگ معنی‌دار بود. پایه‌های *S. lycopersicum* var. cerasiforme و *S. cheesmaniae* وزن ریشه را در شرایط خشکی شدید حفظ کردند، درحالی‌که *S. nigrum* در همین شرایط منابع خود را به رشد شاخساره اختصاص داد. محتوای پرولین برگ در شرایط تنش خشکی شدید و برخی ترکیب‌های پیوندی افزایش یافت. به‌عنوان نتیجه‌گیری، نوع پایه به طور قابل توجهی بر رشد و پاسخ‌های بیوشیمیایی گوجه فرنگی رقم دافنیس تحت شرایط کم‌آبیاری تأثیر گذاشت. *S. cheesmaniae* و S. *lycopersicum* var. cerasiforme رشد بهتری را نشان دادند، درحالی‌که برخی از پایه‌ها سطح بالاتری از ترکیبات بیوشیمیایی را داشتند. این یافته‌ها اهمیت انتخاب پایه را در افزایش تحمل به خشکی در کشت گوجه فرنگی مورد تاکید قرار داده و اهمیت برخی ترکیبات بیوشیمیایی را در پایش وضعیت آبی گوجه‌فرنگی گلخانه‌ای نشان می‌دهد.

واژه‌های کلیدی: ترکیبات فنلی، تنش خشکی، تنظیم اسمزی، فلاونوئیدها، کربوهیدرات‌های محلول