



Original Research

Influence of Deficit Irrigation Regimes on the Growth Dynamics of the Indigenous Jamun

Ahsan Raza, Muhammad Ammar Amjad, Muhammad Azam* , Muhammad Jafar Jaskani , Rashad Qadri, Muhammad Haider Ali, Waleed Hasan, Muhammad Hassan Javed and Mohsin Raza

Pomology Laboratory, Institute of Horticultural Sciences, University of Agriculture, Faisalabad, 38040, Pakistan

ABSTRACT

Implementing water-saving strategies in agriculture is increasingly essential due to the world's water shortage. A research trial based on a pot experiment was conducted in a greenhouse to investigate the effects of four varying irrigation levels (100% field capacity (F.C.), 75% F.C., 50% F.C. and 25% F.C.) on the morphological, physiological, biochemical and antioxidative enzymes activity traits of jamun plants (*Syzygium cumini* cv. Desi). Plants treated with moderate level (50% F.Cs. increased plant height (58%), stem diameter (59%), intermodal distance (61%), number of leaves (68%), leaf length (83%), width (68%) and leaf area (65%) compared to control. In terms of phytochemical traits, plants subjected to 25% F.C. exhibited a higher phenolic content compared to the control. In comparison, chlorophyll content was highest at 50% full concentration (F.C.). Physiological traits indicated that control plants had the lowest stomatal conductance, transpiration rate, and water-use efficiency. Antioxidant enzymes, such as superoxide dismutase, peroxidase, and catalase, were at their maximum in plants treated with 25% F.C. Further insights are required regarding their comparative behaviour under field conditions.

Keywords: Sustainability, Irrigation, climate change, water-use efficiency, antioxidant enzymes.

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INTRODUCTION

The agricultural sector is the leading consumer of freshwater and plays a substantial role in food security. The availability of irrigation water is becoming increasingly limited worldwide, posing the most significant threat to agriculture (Malakar et al., 2019). The agricultural sector is one of the largest consumers of water, utilising approximately 80% of total global water resources (Frija et al., 2009). According to the IPCC, average temperatures are expected to rise by 1.8 to 4°C by 2100, which could lead to drought conditions in various agroecological regions worldwide (Ozturk et al., 2021). Poor irrigation practices and uneven rainfall in rain-fed areas can result in insufficient water availability (Wang et al., 2005). It is estimated that approximately 30% of the world's land area is classified as arid to semi-arid, with annual precipitation ranging from 50 to 150 mm (Eswaran et al., 1999). South Asia ranks fifth among the region's most severely affected by climate change (Aryal et al.,

2020). Pakistan is primarily an agricultural country, yet most regions experience an arid to semi-arid climate (Ahmed et al., 2019), resulting in insufficient rainfall for crop cultivation. The annual precipitation in Pakistan ranges from 150 to 250 mm, and the country faces a persistent water shortage issue (Zafar et al., 2021; Anjum et al., 2012). As a result, adopting water-saving strategies in agriculture is becoming crucial (García-Tejero and Durán-Zuazo, 2022). Technological methods, such as advanced irrigation systems and optimised irrigation scheduling, are the need of the time (Su and Singh, 2024).

Syzygium cumini, commonly known as jamun or black plum, belongs to the Myrtaceae family. This hardy, fruit-bearing tree (Parnell et al., 2006) can thrive in both subtropical and tropical environments (Gajera et al., 2018). It typically grows to a medium to tall height and produces nutritionally rich fruit that is usually consumed in the raw form. The fruit colour ranges from deep purple to black and has a unique flavour that possesses sweet to sour aspects with an astringent quality (Rizvi et al., 2022). It is rich in potassium, calcium, magnesium, vitamins A and C, anthocyanins, tannins, and antioxidant compounds (Uddin et al., 2024). It is capable of withstanding low salinity levels and can survive periods of drought, making it a species worth cultivating in various climatic areas (Wong, 2018). There is a lack of knowledge about the current water resources available for jamun cultivation in the region, which hinders the meeting of crop water requirements and the improvement of

* Corresponding author

Email: muhammad.azam@uaf.edu.pk (M. Azam)



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water productivity. Optimising irrigation levels will help to cope with challenges in this era of water scarcity. This study investigated the effects of four different irrigation levels on the morphological, physiological, biochemical traits and antioxidant enzyme activity of jamun plants.

MATERIALS AND METHODS

Plant material and treatments

This research was conducted in the Fruit Plant Nursery Area (greenhouse) at the Institute of Horticultural Sciences, University of Agriculture, Faisalabad, Pakistan, from October 20, 2022, to January 20, 2023. One-year-old (2 m height), uniform, and healthy jamun plants were chosen, transplanted into pots (1 foot in height, 25 x 35 cm and weight 270±5 g containing 7 kg of soil, which was a mixture of farmyard manure (FYM), sand and silt, and in a 1:1:1. Throughout the experiment, the temperature range in the greenhouse was maintained at 25±5°C, with a relative humidity of 55±5%. Four irrigation levels were established: Control (T₁) 100% F.C, (T₂) 75% FC, (T₃) 50% FC, and (T₄) 25% FC, following the protocols of [Rasheed et al. \(2016\)](#). To optimise nutrient balance, nitrogen (N), phosphorus (P) and potassium (K) fertiliser (15:5:5) was applied at a rate of 5 g kg⁻¹ of soil ([Zafar et al., 2021](#)).

Determination of morphological traits

Plant height (cm) and stem diameter (mm) were assessed with measuring tape and vernier calliper, respectively, during the experiment at every 30-day interval. Measurements of leaf growth parameters were taken from every tagged branch on each plant, and the average value was calculated. Leaf width and leaf length from each tagged branch were measured at the midpoint of the leaf using a meter ruler. Leaf area was obtained as described by [Amjad et al. \(2024\)](#).

Estimation of physiological traits

Stomatal conductance (SC) and transpiration rates (TR) were evaluated using a portable infrared gas analyser (CIRAS-3, Amesbury, USA). Mature leaves from every tagged branch were selected at every 30-day interval. Water use efficiency in mature leaves (WUEi, $\mu\text{mol mol}^{-1}$) was calculated following the methodology outlined by [Rasheed et al. \(2015\)](#).

Measurement of biochemical traits

Total chlorophyll content was measured from healthy leaves of each tagged branch at every 30-day interval using 80% acetone, following [Arnon \(1949\)](#) protocol. The total phenolic content (TPC) was evaluated following the method outlined by [Ainsworth and Gillespie \(2007\)](#).

Determination of antioxidant enzymes

Superoxide dismutase (SOD) was assessed through the photochemical reduction of nitroblue tetrazolium (NBT). The measurement of peroxidase (POD) and catalase (CAT) enzyme activity was conducted according to the method described by [Singh et al. \(2025\)](#).

Statistical analysis

The experiment was planned under a completely randomised design. The data were evaluated using the LSD test under a two-way factorial arrangement ($p \leq 0.05$) for mean comparison, as determined by Statistics 8.1 software.

RESULTS

Morphological traits

Plant height significantly differed among all jamun plants

Table 1: Plant height, stem diameter, and internodal length under different irrigation frequencies in jamun.

Irrigation frequency	Days interval	Plant height (cm)	Stem diameter (mm)	Internodal length (cm)
Control (100% F.C.)	0	34±1.41 m	3.12±0.1 i	3.10±0.13 i
	30	46.5±1.57 kl	3.46±0.16 h	3.33±0.18 hi
	60	51.50±1.65 jk	3.59±0.21 efg	3.73±0.21 gh
	90	57±1.77 ij	3.77±0.27 gh	4.10±0.26 efg
	120	61.75±1.81 hi	4.00±0.32 g	4.50±0.33 de
75% F.C.	0	34±1.33 m	3.12±0.09 i	3.10±0.11 i
	30	64±1.44 ghi	4.62±0.11 f	4.30±0.16 fg
	60	74.5±1.51 fgh	4.98±0.15 fgh	4.83±0.19 ef
	90	80.5±1.67 ef	5.26±0.18 e	5.40±0.21 d
	120	83±1.71 de	5.62±0.21 d	6.40±0.27 c
50% F.C.	0	34±1.21 m	3.12±0.60 i	3.10±0.1 i
	30	85.5±1.29 cd	5.63±0.90 d	5.48±0.14 c
	60	91.75±1.32 bc	6.04±0.11 bc	6.30±0.15 b
	90	97.25±1.39 b	6.31±0.14 b	6.75±0.18 bcd
	120	105.7±1.41 a	6.75±0.17 a	7.28±0.23 a
25% F.C.	0	34±1.29 m	3.12±0.80 i	3.10±0.14 i
	30	69.75±1.33 fg	4.98±0.13 efg	4.50±0.16 de
	60	80±1.39 ef	5.24±0.17 efg	4.93±0.18 d
	90	85.7±1.43 de	5.61±0.19 d	5.40±0.23 cde
	120	91±1.56 cd	5.88±0.24 cd	5.70±0.29 c

Means followed by small letters differ significantly using the LSD test ($p \leq 0.05$).

Table 2: Leaf length, leaf width, leaf area and number of leaves under different irrigation frequencies in jamun.

Water Level	Days Interval	Leaf length (cm)	Leaf width (cm)	Leaf area (cm ²)	Number of leaves
Control (100% F.C.)	0	7.65 ± 0.19 g	3.43 ± 0.07 m	26.42 ± 1.41 i	21 ± 1.54 l
	30	8.11 ± 0.10 def	4.02 ± 0.11 kl	31.66 ± 1.49 hi	27.75 ± 1.61 k
	60	8.55 ± 0.90 efg	4.22 ± 0.03 jk	38.10 ± 1.55 ghi	35.75 ± 1.77 j
	90	9.06 ± 0.90 e	4.42 ± 0.11 ij	43.22 ± 1.61 fg	39.5 ± 1.87 hij
	120	9.34 ± 0.09 cd	4.46 ± 0.05 efg	46.23 ± 1.69 efg	45.75 ± 1.91 efg
75% F.C.	0	7.65 ± 0.17 g	3.43 ± 0.05 m	26.42 ± 1.37 i	21 ± 1.43 l
	30	9.04 ± 0.09 fgh	4.37 ± 0.07 j	39.51 ± 1.41 gh	37.25 ± 1.55 ij
	60	9.29 ± 0.136 fg	4.70 ± 0.14 hi	43.60 ± 1.44 f	46.75 ± 1.61 ghi
	90	9.61 ± 0.15 abc	5.04 ± 0.11 fg	52.36 ± 1.49 de	49.25 ± 1.71 ef
	120	9.90 ± 0.16 d	5.29 ± 0.14 ef	56.98 ± 1.54 bcd	54.75 ± 1.88 bc
50% F.C.	0	7.65 ± 0.38 g	3.43 ± 0.063 m	26.42 ± 1.21 i	21 ± 1.33 l
	30	9.99 ± 0.32 bcd	5.36 ± 0.18 de	53.53 ± 1.27 bcd	48.75 ± 1.41 de
	60	10.23 ± 0.36 abc	5.75 ± 0.22 bc	58.89 ± 1.31 b	53.5 ± 1.55 cd
	90	10.77 ± 0.60 ab	6.02 ± 0.23 b	64.92 ± 1.39 ab	59.5 ± 1.6 b
	120	11.13 ± 0.56 a	6.48 ± 0.11 a	70.46 ± 1.41 a	66.5 ± 1.65 a
25% F.C.	0	7.65 ± 0.21 g	3.43 ± 0.03 m	26.42 ± 1.34 i	21 ± 1.39 l
	30	8.73 ± 0.15 f	4.95 ± 0.10 gh	43.18 ± 1.38 def	35.25 ± 1.54 jkl
	60	9.11 ± 0.16 ef	5.20 ± 0.17 efg	47.35 ± 1.41 cd	42.5 ± 1.66 fgh
	90	9.40 ± 0.26 de	5.43 ± 0.07 de	55.43 ± 1.47 bcd	47.5 ± 1.71 f
	120	10.22 ± 0.13 cd	5.60 ± 0.11 cd	62.10 ± 1.88 abc	53.25 ± 1.88 cd

Means followed by small letters differ significantly using the LSD test ($p \leq 0.05$).

subjected to different irrigation levels (Table 1). Plant height was maximum at 50% of the available water in the soil after 120 days (T_3), which was 58% more compared to the control (T_1). The stem diameter of jamun plants increased substantially over time. When subjected to 50% of the irrigation frequency (T_3), plants exhibited a maximum stem diameter (59%) compared with the control (T_1), followed by plants exposed to 25% (T_4) and 75% (T_2) of the available water in the soil. Internodal

distance demonstrated substantial variation in all jamun trees subjected to different irrigation levels and their interaction over days. Furthermore, internodal distance was significantly maintained at 50% of the available water in the soil (T_3), 61% more than in the control (T_1) (Table 1).

The number of leaves, leaf area, leaf length, and leaf width increased, indicating significant variation in all jamun plants

Table 3: Total chlorophyll content, total phenolic content, stomatal conductance, transpiration rate, and water-use efficiency under different irrigation frequencies in jamun.

Water level	Days interval	TCC (SPAD)	TPC (mg g ⁻¹ FW)	SC (mol/m/s)	TR (mmol/m/s)	WUE (μmol mol ⁻¹)
Control (100% F.C.)	0	28.92 ± 0.76 a	23.40 ± 1.210 j	2.13 ± 0.12 a	2.03 ± 0.041 a	3.87 ± 0.04 a
	30	21.27 ± 0.86 ef	26.91 ± 1.26 i	1.33 ± 0.13 ef	1.46 ± 0.04 f	2.48 ± 0.04 ef
	60	17.26 ± 0.92 hi	30.57 ± 1.32 gh	1.19 ± 0.13 ij	1.31 ± 0.05 g	2.27 ± 0.05 gh
	90	13.36 ± 0.99 kl	33.26 ± 1.37 fg	1.03 ± 1.14 l	1.22 ± 0.05 hi	2.19 ± 0.06 hi
	120	10.87 ± 1 m	36.44 ± 1.43 de	0.75 ± 0.15 m	1.10 ± 0.06 j	1.82 ± 0.07 j
75% F.C.	0	28.92 ± 0.65 a	23.40 ± 1.14 j	2.13 ± 0.11 a	2.03 ± 0.03 a	3.87 ± 0.04 a
	30	23.52 ± 0.86 c	28.43 ± 1.18 hi	1.59 ± 0.11 b	1.61 ± 0.03 cde	2.55 ± 0.04 de
	60	20.41 ± 0.72 ef	30.82 ± 1.21 fg	1.40 ± 0.13 de	1.42 ± 0.03 f	2.46 ± 0.04 ef
	90	15.97 ± 0.77 ij	34.58 ± 1.27 de	1.32 ± 0.12 fg	1.33 ± 0.04 g	2.28 ± 0.05 cd
	120	12.37 ± 0.83 lm	37.02 ± 1.31 bc	1.23 ± 0.12 hi	1.23 ± 0.05 h	2.07 ± 0.05 i
50% F.C.	0	28.92 ± 0.55 a	23.40 ± 1 j	2.13 ± 0.11 a	2.03 ± 0.02 a	3.87 ± 0.03 a
	30	26.42 ± 0.65 b	29.63 ± 1.12 fg	1.49 ± 0.12 c	1.72 ± 0.06 b	2.71 ± 0.04 c
	60	23.47 ± 0.69 cd	33.05 ± 1.14 cd	1.30 ± 0.12 fgh	1.66 ± 0.03 bc	2.48 ± 0.50 ef
	90	21.86 ± 0.71 de	36.44 ± 1.17 b	1.24 ± 0.12 ghi	1.63 ± 0.03 cd	2.34 ± 0.06 fg
	120	19.86 ± 0.73 fg	39.77 ± 1.19 a	1.13 ± 0.13 jk	1.59 ± 0.04 de	2.17 ± 0.06 hi
25% F.C.	0	28.92 ± 0.59 a	23.40 ± 1 j	2.13 ± 0.11 a	2.03 ± 0.02 a	3.87 ± 0.03 a
	30	24.35 ± 0.62 c	33.30 ± 1.21 hi	1.45 ± 0.11 cd	1.54 ± 0.02 e	2.94 ± 0.04 ab
	60	21.23 ± 0.66 ef	38.10 ± 1.24 gh	1.26 ± 0.12 hi	1.31 ± 0.02 g	2.80 ± 0.04 bc
	90	18.75 ± 0.69 gh	41.43 ± 1.29 ef	1.20 ± 0.12 ij	1.21 ± 0.03 hi	2.68 ± 0.05 gh
	120	14.79 ± 0.75 jk	44.93 ± 1.35 cde	1.10 ± 0.12 kl	1.15 ± 0.03 ij	2.43 ± 0.06 ef

Means followed by small letters differ significantly using the LSD test ($p \leq 0.05$). TCC= Total Chlorophyll contents, TPC= Total Phenolic content, SC= Stomatal conductance, TR= Transpiration rate, WUE= Water-use efficiency.

Table 4: Superoxide dismutase, peroxidase and catalase activity under different irrigation frequencies in jamun.

Water level	Days interval	Superoxide dismutase (μmg^{-1} FW)	Peroxidase (μmg^{-1} FW)	Catalase (μmg^{-1} FW)
Control (100% F.C.)	0	0.21 $\pm$ 0.02 l	0.29 $\pm$ 0.01 l	0.25 $\pm$ 0.02 m
	30	0.26 $\pm$ 0.02 k	0.33 $\pm$ 0.02 kl	0.29 $\pm$ 0.02 l
	60	0.30 $\pm$ 0.02 i	0.39 $\pm$ 0.02 hij	0.33 $\pm$ 0.02 jk
	90	0.34 $\pm$ 0.03 ghi	0.43 $\pm$ 0.03 fg	0.36 $\pm$ 0.03 ij
	120	0.38 $\pm$ 0.03 def	0.48 $\pm$ 0.03 de	0.41 $\pm$ 0.03 def
75% F.C.	0	0.21 $\pm$ 0.01 l	0.29 $\pm$ 0.01 l	0.25 $\pm$ 0.01 m
	30	0.29 $\pm$ 0.02 fg	0.34 $\pm$ 0.02 fgh	0.31 $\pm$ 0.02 kl
	60	0.32 $\pm$ 0.02 d	0.4 $\pm$ 0.02 cd	0.35 $\pm$ 0.02 hij
	90	0.36 $\pm$ 0.02 ab	0.45 $\pm$ 0.02 b	0.38 $\pm$ 0.02 fgh
	120	0.40 $\pm$ 0.02 a	0.49 $\pm$ 0.03 bc	0.43 $\pm$ 0.03 cd
50% F.C.	0	0.21 $\pm$ 0.01 l	0.29 $\pm$ 0.01 l	0.25 $\pm$ 0.01 m
	30	0.31 $\pm$ 0.01 ij	0.36 $\pm$ 0.01 jk	0.34 $\pm$ 0.01 ijk
	60	0.35 $\pm$ 0.01 fgh	0.43 $\pm$ 0.01 fgh	0.37 $\pm$ 0.01 ghi
	90	0.39 $\pm$ 0.01 de	0.48 $\pm$ 0.02 de	0.41 $\pm$ 0.01 de
	120	0.43 $\pm$ 0.02 bc	0.53 $\pm$ 0.02 a	0.45 $\pm$ 0.02 c
25% F.C.	0	0.21 $\pm$ 0.01 l	0.29 $\pm$ 0.01 l	0.25 $\pm$ 0.01 m
	30	0.35 $\pm$ 0.01 j	0.42 $\pm$ 0.01 ijk	0.39 $\pm$ 0.02 efg
	60	0.39 $\pm$ 0.01 hij	0.49 $\pm$ 0.02 ghi	0.44 $\pm$ 0.02 c
	90	0.45 $\pm$ 0.01 efg	0.54 $\pm$ 0.02 ef	0.49 $\pm$ 0.02 b
	120	0.48 $\pm$ 0.02 cd	0.59 $\pm$ 0.02 cd	0.54 $\pm$ 0.03 a

Means followed by small letters differs significantly using LSD test ($p \leq 0.05$).

related to different irrigation levels and their interaction with the number of days. However, the highest was evidenced in plants treated with 50% field capacity, exhibiting maximum (11.13 cm) leaf length, (6.48 cm) leaf width, (70.46 cm²) leaf area, and 66.5 leaves per plant after 120 days. However, minimum was noted in control (9.34 cm) length, (4.46 cm) width, (46.23 cm²) leaf area, and 45.75 number of leaves (Table 2).

Phytochemical traits

The total phenolic content decreased significantly with an increase in irrigation frequency, regardless of the interval between days. Maximum phenolic contents were observed in T₄ (25% F.C.), 44.93 mg g⁻¹ FW, while minimum phenolic contents were observed in the control, 36.44 mg g⁻¹ FW, after 120 days. Considering the total chlorophyll content, it significantly increased with an increase in the number of days. Maximum chlorophyll content was observed in T₃ after 120 days (50% F.C.), at 19.86 (SPAD), with an increase in the number of days between observations.

Physiological traits

Stomatal conductance was maximum (2.13 mmol m⁻² s⁻¹) at 0 days among all treatments; however, it significantly decreased with days' intervals (Table 3). Moreover, a minimum stomatal conductance was observed in the control after 120 days in T₁ (100% F.C.), i.e., 0.75 mmol m⁻² s⁻¹. Taking into consideration (Table 3), the transpiration rate exhibited a decreasing trend with an increase in the number of days. The minimum transpiration rate was observed in the control (1.10 mmol m⁻² s⁻¹), followed by T₄ (1.15 mmol m⁻² s⁻¹), T₂ (1.23 mmol m⁻² s⁻¹), and T₃ (1.59 mmol m⁻² s⁻¹). With the increase in the number of days, the water-use efficiency of the jamun plants substantially decreased. Maximum water-use efficiency was observed in all

treatments at 0-day, exhibiting 3.87 $\mu\text{mol mol}^{-1}$.

Antioxidant enzyme activity

The activity of antioxidant enzymes varied significantly (Table 4). SOD, POD, and CAT progressively increased under treatments with low irrigation frequencies, i.e., 50% and 25% F.C. The maximum SOD (0.48 μg^{-1} FW), POD (0.59 μg^{-1} FW), and CAT (0.54 μg^{-1} FW) levels were observed in the 25% F.C. treatment compared to the other control.

DISCUSSION

The water scarcity worldwide highlights the importance of understanding the effects of reducing water usage on more efficient and competitive crop irrigation. This study examined the impact of four different irrigation levels on the morphological, physiological, phytochemical traits, and antioxidative enzyme activity of jamun plants. Stunted plant growth is the most critical initial effect of low water levels in plants (Trabelsi et al., 2019). In this study, plants with low (25% F.C.) and high levels (100% and 75%) of irrigation frequencies exhibited a decreasing trend in morphological traits; however, moderate irrigation levels (50%) showed enhanced morphological traits in terms of plant height, stem diameter, and intermodal length. Reduced plant growth is linked to inhibited cell elongation. This process is interlinked with reduced water uptake by the roots, resulting in a lower plant water potential and decreased water transpiration from the leaves through stomata (Blum, 2011). However, in the current study, moderate irrigation levels exhibited better morphological traits, suggesting a noticeable change in behaviour in response to water shortage (Pigliucci, 2005; Wang et al., 2017). For plant species, low water levels adjust leaf gas exchange parameters primarily by reducing stomatal conductance (Bacelar et al., 2007). Stomatal conductance exhibited a significant decrease

with a decrease in irrigation frequency, as shown in Table 3. Our results are similar to those of Zafar et al. (2021), who reported similar findings in *Syzygium cumini* and *Populus deltoides*. A rise in WUEi is a crucial physiological trait contributing to a species' tolerance to low water availability (Rasheed et al., 2015). Changes influence the variation in WUEi in stomatal conductance. In this research, WUEi was raised in response to water scarcity, as indicated in Table 3, leading to the conclusion that plants effectively managed SC by allocating more assimilated carbon towards root growth. Considering Table 2, the total chlorophyll content significantly increased with an increase in the number of days. Maximum chlorophyll contents were observed at 50% F.C. with the increase in a number of days' intervals. We suggested that the observed decrease in SC may be linked to the overall reduction in photosynthetic capacity. Our study is somewhat in agreement with the study of Bogeat-Triboulot et al. (2007). Phenolic compounds are secondary metabolites that significantly enhance plants' tolerance to water stress. They function as antioxidants, protecting against oxidative stress (Khan et al., 2015). Phenolic content plays a crucial role in protecting subcellular structures under stressful conditions (White et al., 2000). In this study, TPC increased with the decrease in irrigation frequency (Table 3). A similar finding was observed in *Conocarpus*, mulberry, and jamun (Zafar et al., 2021). The most important antioxidant enzymes are superoxide dismutase (SOD), peroxidase (POD) and catalase (CAT). These enzymes scavenge excess oxidants and prevent cellular damage in plants during stress conditions (Laxa et al., 2019). SOD, POD and CAT progressively increased with treatments involving low irrigation frequencies, specifically 50% and 25% field capacity (F.C.). This hypothesis is based on the role of SOD, which converts superoxide radicals (O_2^-) into hydrogen peroxide (H_2O_2). Subsequently, other antioxidants, such as CAT and POD, convert H_2O_2 into water (H_2O) (Laxa et al., 2019). Similar findings were reported in the studies on *Salix sinopurpurea* and *Salix suchowensis* (Jia et al., 2020).

CONCLUSION

This research investigated the morphological, physiological, phytochemical, and antioxidative enzyme responses of jamun plants to varying irrigation levels. Plants treated with moderate level (50% field capacity) exhibited increased plant height, stem diameter, intermodal distance, number of leaves, leaf length, width and leaf area. Regarding phytochemical traits, plants subjected to 25% field capacity (F.C.) exhibited higher phenolic content. In comparison, chlorophyll content was higher at 50% full concentration (F.C.). Physiological traits showed that plants treated with 100% F.C. had the lowest water-use efficiency, transpiration rate, and stomatal conductance. Antioxidative enzyme activity (SOD, POD, and CAT) was maximum in plants treated with 25% field. So, we conclude that jamun plants are successful in moderate water availability. Further insights are required regarding comparative behaviour under field conditions.

DECLARATION OF COMPETING INTERESTS

The authors declare that they have no conflict of interest.

AUTHOR CONTRIBUTION STATEMENT

Ahsan Raza: Methodology, Investigation. **Muhammad Ammar Amjad:** Writing – original draft. **Muhammad Azam:** Supervision, Writing – review and editing. **Muhammad Jafar Jaskani:** Supervision. **Rashad Qadri:** Supervision. **Muhammad Haider Ali, Mohsin Raza:** Writing – review and editing. **Waleed Hassan:** Data collection. **Muhammad Hassan Javed:** Statistical analysis.

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ETHICAL STATEMENT

Not applicable.

AVAILABILITY OF DATA AND MATERIAL

All data is published in this research article.

INFORMED CONSENT

Not applicable.

CONSENT FOR PUBLICATION

All authors submitted consent to publish this research article in the 'Journal of Horticulture Science and Technology'.

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