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Intercropping UV-C lamp -treated *Narcissus tazetta* L. bulbs with mulberry field and its impacts on production of bulbs, flowers, mulberry trees, and the economical characters of silkworm, *Bombyx mor*i L.

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Abstract

Field experiments in mulberry fields estimated the effect of pre-planting UV-C lamp irradiation on *Narcissus tazetta* bulbs intercropped with mulberry trees. The study examined plant growth, flowering, bulb productivity, postharvest performance, and compatibility with mulberry and silkworm productivity over two growing seasons. Ten treatments were applied; UV-C lamp exposures of 1, 2, or 3 hrs. Applied as one, two, or three consecutive daily doses. UV-C lamp irradiation significantly improved most vegetative, floral, bulb, and postharvest characteristics, pre-planting UV-C irradiation for 2 hrs per day over three consecutive days produced the greatest improvements in plant performance and markedly enhanced the accumulation of amino acids and phenolic compounds. Molecular characterization revealed clear UV-C-induced genetic variability in *N. tazetta*. The highest genetic similarity was observed between the control and low-intensity treatment. All irradiation intercropped plants on mulberry trees did not show any adverse effect on mulberry characters i.e. number of shoots/tree, number of leaves/shoot, weight of leaf and leaf yield/tree. Also, moisture content, N, P, K, and manganese contents in tested mulberry leaves, most of the silkworm characters showed non-significant differences between intercrops treatments and sole mulberry plant for biological and economic characters as weight of full cocoon, cocoon shell, pupa, and adult weight, also cocoon sell ratio and silk productivity for females and males. These findings indicate that pre-planting UV-C lamp irradiation effectively enhances the growth and biochemical composition of *N. tazetta*, without negatively impacting mulberry or silkworm productivity. This method promotes land-use efficiency and boosts economic returns in integrated mulberry sericulture systems.

Keywords: Mulberry–sericulture system, intercropping, silkworm *Bombyx mori* L., *Narcissus tazetta*, ultraviolet-C radiation, ISSR and SCoT markers

Introduction

Crop diversification through intercropping is widely recognized as an effective strategy for enhancing land use efficiency, improving resource utilization, and increasing overall agricultural productivity. Intercropped systems have been shown to achieve yields comparable to or higher than monocultures, while simultaneously improving ecosystem services, nutrient-use efficiency, and system resilience (Li *et al*. (2023) [1]. In perennial agroecosystems, such as mulberry plantations, intercropping offers a particularly promising approach because of the temporal and spatial resource availability. Mulberry (*Morus alba* L.) is a perennial deciduous tree primarily cultivated as the sole food source for the domesticated silkworm *Bombyx mori* L., which forms the foundation of the sericulture industry (Ghazy *et al*. 2018& Fouad and Gad, 2022) [2, 3]. Sericulture is a labor-intensive cottage industry with significant potential for poverty reduction and rural livelihood improvement (Khan *et al*. 2022) [4]. However, mulberry plantations are often underutilized during the leafless period, creating opportunities for intercropping systems that enhance land-use efficiency, improve resource utilization, and increase farm profitability without compromising silkworm production (Rafiqui *et al*. 2023; Islam *et al*. 2023) [5, 6]. Previous studies have demonstrated that mulberry-based intercropping systems with crops such as onion, garlic, turnip, and legumes significantly improve productivity and economic returns compared to mono-cropping systems (Fotadar and Dhar, 2012) [7]. From an applied perspective, mulberry-based intercropping systems can simultaneously support sericulture productivity and generate additional agricultural outputs, leading to improved land use efficiency and enhanced economic sustainability. Importantly, these systems do not adversely affect silkworm performance, ensuring the stability of *Bombyx mori* L.-based production systems.

The genus *Narcissus*, particularly *Narcissus tazetta* L., is a bulbous ornamental plant widely cultivated in Egypt for cut flower production and essential oil extraction, with additional value in landscape design. Beyond their horticultural importance, *Narcissus* species contain a wide range of bioactive Amaryllidaceae alkaloids, including galanthamine, lycorine, haemanthamine, and narciclasine, which exhibit acetylcholinesterase inhibitory, anticancer, antiviral, antimicrobial, antioxidant, and wound-healing activities (Karakoyun *et al*. 2019; Gholami *et al*. 2024;

Rodríguez-Escobar *et al*. 2025) [8, 9, 10]. In addition, phenolic-rich extracts of *N. tazetta* demonstrate strong antioxidant activity, highlighting their pharmaceutical and biotechnological relevance. In ornamental and medicinal bulbous crops, controlled abiotic elicitation is widely used to enhance growth and secondary metabolite production. Ultraviolet-C (UV-C, <280 nm) radiation is a well-known abiotic elicitor capable of modulating plant physiological and biochemical pathways via stress-mediated signaling mechanisms. UV-C radiation is a high-energy portion of the electromagnetic spectrum that can induce microbial inactivation and disrupt chemical bonds, the most common source of UV-C in commercial applications is the low-pressure mercury germicidal lamp, which emits at approximately 254 nm (Li *et al*. 2021) [11]. Controlled UV-C exposure has been reported to enhance the accumulation of phenolics, flavonoids, and secondary metabolites by activating the biosynthetic pathways (Rai *et al*. 2011; Loconsole and Santamaria, 2021) [12,13]. In addition, UV-C irradiation can influence plant morphology, including reduced plant height, increased branching, and altered flowering behavior, providing a non-chemical approach to regulate plant growth (Bridgen, 2016 & Moreno *et al*. 2017) [14, 15]. The response of plants to UV radiation is strongly dependent on wavelength, intensity, and exposure duration, and is mediated by photoreceptors, which play a central role in UV stress acclimation (Loconsole and Santamaria, 2021) [13]. However, the effects of UV-C are highly dose-dependent. At the cellular level, UV-C induces photochemical reactions in nucleic acids, particularly the formation of cyclobutane pyrimidine dimers between adjacent pyrimidine bases. These lesions distort the DNA structure, interfere with replication and transcription, and may lead to irreversible genetic damage if the repair mechanisms are overwhelmed (Kowalski *et al*. 2009; Li *et al*. 2021) [16,11]. Therefore, optimizing exposure regimes is essential to balance the beneficial elicitation effects with potential genetic risks. Despite extensive studies on intercropping systems and UV-C lamp applications in horticultural crops, no previous research has investigated the integration of UV-C-treated *Narcissus* bulbs into mulberry-based sericulture systems. This represents a critical knowledge gap, particularly in terms of system-level interactions between ornamental crops, mulberry productivity, and silkworm performance. Therefore, the objectives of this study were to (i) evaluate the effects of UV-C dose magnitude and exposure pattern (continuous versus fractionated irradiation) on growth, flowering characteristics, pigmentation, bulb production, and postharvest quality of *Narcissus tazetta* L., and (ii) assess the agronomic, physiological, and economic implications of integrating UV-C-treated bulbs within mulberry intercropping systems in terms of land-use efficiency, productivity, and sericulture-related outcomes without adversely affecting the performance *of Bombyx mori* L.

Materials and Methods

a. Mulberry Cultivation, intercropping system, and soil characteristics

The mulberry field of the Sericulture Research Department (SRD), Plant Protection Research Institute, Agricultural Research Center (ARC), Giza, Egypt, was used in this study. The field was planted with *Morus alba* var. Canva-2, with a spacing of 200 cm between rows and 30 cm between plants within the same row. The mulberry plantation was established under a fist form system.

b. Physical and chemical analyses for the used soil.

The baseline physicochemical properties of the experimental soil (0–30 cm depth) are presented in Table 1. Soil pH, electrical conductivity (EC), soluble cations and anions, available nitrogen, phosphorus, potassium, total nitrogen, and calcium carbonate content were determined according to Page (1982) [17].

Table 1: Physical and chemical analyses for the used soil.

Soil texture	Particle size distribution (%)			Available (mg kg^{-1})					Cations (meq L^{-1})				Anions (meq L^{-1})		
	Fine sand	Silt	Clay	N	P	K	E.C (dS m^{-1})	pH	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	HCO_3^-	Cl^-	SO_4--
Calcareous Clay loam	27.21	33.12	39.67	46.30	8.63	375	1.53	7.21	2.90	2.14	6.36	3.64	3.00	6.46	5.58

c. Plant material

Narcissus tazetta L. bulbs were obtained from Floramix Farm (El-Mansouria, Giza, Egypt). Only uniform, healthy, and disease-free bulbs of similar size were selected for all treatments.

d. UV-C Lamp characteristics and exposure conditions

Before planting, selected *N. tazetta* bulbs were subjected to different UV-C irradiation treatments. The bulbs were arranged on trays at a fixed distance of 50 cm from a germicidal low-pressure mercury UV-C lamp (G_{13} T_8; General Electric, Japan). The lamp emitted short-wave UV-C radiation with a peak wavelength of 253.7 nm and a certified UV-C output power of 12.0 W. The lamp length was 0.895 m, and it was certified for germicidal applications (marked “GERMICIDAL”), operating at 220–240 V with an average service life of approximately 10,800 h, according to the manufacturer's specifications.

Irradiance Estimation:

According to Keitz (1971) [18] and Bolton and Santelli (2017) [19], the irradiance generated by a linear UV source can be described using the following geometric model:

$$I = \frac{P(2\alpha + \sin 2\alpha)}{2\pi^2 r L}$$

Where P is the UV-C output power of the lamp (W), r is the perpendicular distance from the lamp center to the target surface (m), L is the active lamp length (m), and α is the half-angle subtended by the lamp at the measurement point, defined as:

$$\tan \alpha = \frac{L}{2r}$$

According to the Keitz [18] model, the irradiance at the target surface was calculated by first determining the geometric half-angle α from the lamp length and the source-to-sample

distance. This angle was substituted into the Keitz equation to estimate the effective UV-C irradiance under free-space conditions.

Using the experimental parameters (P = 12 W, L = 0.895 m, r = 0.50 m), the half-angle was calculated as:

$\alpha = 0.732$ rad

According to the Keitz [18] irradiance model, the effective UV-C irradiance was calculated as:

$$I = \frac{P(2\alpha + \sin 2\alpha)}{2\pi^2 r L}$$

By substituting the corresponding values, we obtain the following:

$$I = \frac{12 \times (2(0.732) + \sin(2 \times 0.732))}{2\pi^2 \times 0.50 \times 0.895} = 3.34\, W/m^2$$

The calculated irradiance under ideal free-space conditions is equivalent to: I =0.334mW/cm^2

UV-C lamp dose (flounce)

UV-C lamp irradiance was expressed in mW/cm² and exposure time in seconds, according to Bolton and Linden (2003) [20]. The UV-C dose (fluence, J/cm²) was calculated based on the fundamental energy elationship, where (1 W = 1 J/s and 1 mW = 10^{-3} W). Accordingly, the flounce was determined by multiplying the irradiance by the exposure time as follows:

$$\text{Dose (J/cm}^2) = \frac{[\text{Irradiance (mW/cm}^2) \times \text{Exposure Time (Seconds)}]}{1000}$$

Where D is the UV-C dose (J/cm²), I is the irradiance (mW/cm² converted to W/cm²), and t is the exposure time in seconds. Based on the Keitz-derived irradiance model, the estimated irradiance at a distance of 50 cm was 0.334 mW/cm². Using this value, UV-C flounce was calculated for each exposure period.

UV-C lamp treatments

UV-C lamp treatments were applied either as a single continuous exposure or as fractionated exposures repeated every 24 hours for up to three consecutive days. Although some treatments received identical cumulative UV-C doses, they differed in the mode of delivery (continuous versus fractionated exposure). This design allowed evaluation of whether repeated UV-C exposure separated by recovery periods induces different physiological responses compared with a single continuous exposure of the same total dose. One dose represented a single irradiation event on day one, while two and three doses represented repeated daily exposures on the second and third days, respectively.

e. Experimental design and treatments

The field experiment was conducted during two successive growing seasons (2023–2024 and 2024–2025) using a Randomized Complete Block Design (RCBD) consisting of ten treatments with three replicates. Healthy and uniform *Narcissus tazetta* L. bulbs, with an average diameter of 4.0–5.0 cm and a fresh weight ranging from 10.20 to 12.24 g, were selected. Each treatment consisted of 18 bulbs (six bulbs per replicate). Ten treatments were applied, with T_1 serving as the untreated control. Treatments T_2–T_4, T_5–T_6, and T_7–T_8- T_9- and T_{10} represented exposure UV-C durations of 1, 2, and 3 h, respectively, applied either as a single continuous exposure or as fractionated daily doses repeated every 24 h for up to three consecutive days. Although some treatments received identical cumulative irradiation times, they differed in the mode of dose delivery (continuous versus fractionated exposure), allowing comparison of their physiological responses. Bulbs were irradiated at a fixed distance of 50 cm from the UV-C source under dark conditions to minimize ambient light interference and ensure uniform exposure, with a maximum cumulative dose of 7.20 J cm^{-2} (Table 2). After UV-C treatment, bulbs were planted on 15 October of each season within an established mulberry (*Morus Alba* L.) plantation under an intra-row intercropping system. Experimental plots measured 1.5 × 2.0 m and consisted of two north–south-oriented ridges spaced 50 cm apart. Bulbs were planted in clay soil at a depth of 5 cm and a spacing of 20 cm. Standard agronomic practices, including irrigation, fertilization, and weed control, were uniformly applied throughout the growing period. Plants were harvested at the beginning of flower coloration.

Table 2: UV-C irradiation treatments applied to *Narcissus tazetta* L. bulbs and the corresponding calculated irradiance and cumulative UV-C doses at a distance of 50 cm from the UV-C lamp.

Treatment Number	Treatment	Number of doses	Daily exposure Time (h)	Irradiance (mW/cm²)	UV-C dose (J/cm²)
1	Control	0	0	0	0
2	UV 1hour 1 dose	1	1	0.334	1.20
3	UV 1hour 2 doses	2	1	0.334	2.40
4	UV 1hour 3 doses	3	1	0.334	3.60
5	UV 2hour 1 dose	1	2	0.334	2.40
6	UV 2hour 2 doses	2	2	0.334	4.80
7	UV 2h 3 doses	3	2	0.334	7.20
8	UV 3hour 1 dose	1	3	0.334	3.60
9	UV 3hour 2 doses	2	3	0.334	7.20
10	UV 3hour 3 doses	3	3	0.334	10.80

Note: UV-C irradiance was measured at a fixed distance of 0.5 m from the lamp and remained constant at 0.334 mW cm^{-2} under experimental conditions. The UV-C dose (fluence, J cm^{-2}) was calculated as the irradiance multiplied by the exposure time (in seconds), divided by 1000 to convert mJ cm^{-2} to J cm^{-2}. Each "dose" represents a single irradiation event applied on one day, while the cumulative dose was calculated as follows: cumulative dose = single-dose value × number of applications. This calculation is consistent with standard UV fluency determination methods (Bolton & Linden, 2003; Kowalski, 2009) [20, 16].

f. Silkworm rearing procedures

Silkworm eggs of the local double hybrid H_2 (Giza R × Giza D), produced from the single hybrids Giza R (V_{389} × X_{258}) and Giza D (R_{153} × K_{232}), were obtained from the Sericulture Research Department breeding program (Ghazy 2012 and 2014) [21, 22]. Newly hatched larvae were brushed onto plastic trays (60 × 90 × 10 cm), and three independent replicates (300 larvae each) were maintained for every treatment. During rearing, the mean temperature and relative humidity were maintained at 21.5 ± 1.6°C and 59.3 ± 7.4%, respectively. Standard rearing procedures and disinfection practices were followed according to Hosny *et al*. (2002) [23]. Polyethene sheets and wet foam strips were used during the first to third instars (Ghazy, 2008) [24]. Young larvae were fed four times daily with chopped fresh mulberry leaves harvested from the corresponding intercropped treatments, whereas whole leaves were supplied during the fourth and fifth instars. Collapsible mount ages were provided for cocoon spinning, and cocoons were harvested seven days after mounting.

Pupation percentage was calculated according to Lea (1996) [25] using the following equation:

$$\text{Pupation ratio (\%)} = \frac{\text{No.of healthy pupae}}{\text{Correct basic No.of examined}} \text{ x } 100$$

Silk productivity (cg day^{-1}) was estimated according to Iyengar *et al*. (1983) [26] as follows:

$$\text{Silk productivity (cg/day)} = \frac{\text{Cocoons shell weight(cg)}}{\text{Fifth instar duration(day)}}$$

Where cg: Centigram

To assess sericultural compatibility, silkworm biological traits including fifth instar duration (day), total larval duration (day), larval mortality (%), cocooning percentage (%), pupation percentage (%), and number of cocoons per liter (No.) were recorded. Economic traits including cocoon weight (g), cocoon shell weight (g), pupal weight (g), cocoon shell ratio (%), and silk productivity (cg/day) were also determined for both sex's females and males.

g. Morphological and growth measurements of *Narcissus tazetta*

Morphological, flowering, and bulb characteristics of *Narcissus tazetta* L. plants were recorded throughout the growing seasons. Vegetative growth parameters included sprouting date (days, plant height (cm), number of leaves per plant, leaf length (cm), stem diameter (mm), and leaf fresh and dry weights per plant (g). Flowering traits were evaluated by recording flowering date, spike length (cm), spike fresh weight (g), number of flowers per spike, number of florets per spike, pedicel length (mm), floret diameter (mm), flowering period (days), and vase life (days). After flower senescence, plants were irrigated regularly until leaf yellowing commenced, after which irrigation was withheld to promote natural senescence. At maturity, bulbs were lifted and evaluated for bulb circumference (cm), bulb fresh and dry weights (g), and number of bulblets per plant.

h. Chemical Analysis

At the flower bud initiation stage during each growing season, the following chemical analyses were performed.

1. **Photosynthetic pigments:** Total chlorophyll content (mg g^{-1} fresh weight, FW) was determined in fresh leaves of *Narcissus tazetta* L. according to the method described by Moran (1982) [27].

2. **Macronutrient contents (N, P, and K %):** Leaf samples were harvested, oven-dried at 60 °C for 72 h, and finely ground. Total nitrogen (N), phosphorus (P), and potassium (K) were determined after wet digestion according to Parkinson and Allen (1975) [28]. Nitrogen, phosphorus, and potassium contents were quantified following the methods of Cottenie *et al*. (1982) [29] and Piper (1950) [30], respectively.

3. **Total phenolic content and antioxidant activity:** One gram of dried bulb powder was extracted with 80% ethanol for 72 h at room temperature. After filtration, a 1-mL aliquot of the extract was used for subsequent analyses. Total phenolic content (mg g^{-1} DW) was determined spectro-photometrically using a Pye Unicam SP1900 spectrophotometer according to the Folin–Denis method described by Manzoor *et al*. (2019) [31]. Antioxidant activity (%) was evaluated as DPPH (2,2-diphenyl-1-picrylhydrazyl) free radical scavenging activity according to Burits and Bucar (2000) [32].

4. **Total amino acid assay (mg g^{-1} DW):** Total amino acid content in *Narcissus tazetta* L. bulbs was determined according to McGrath (1972) [33] with minor modifications. Briefly, one gram of dried bulb powder was extracted with 80% ethanol for 72 h at room temperature. The extract was filtered and centrifuged prior to analysis. One milliliter of the extract was mixed with 4 mL of distilled water and 1 mL of ninhydrin reagent. The reaction mixture was heated in a boiling water bath (95–100°C) for 20 min to allow color development. After cooling to room temperature (25–28°C), the volume was adjusted by adding 1 mL of a 50% ethanol–distilled water solution. Absorbance was measured at 570 nm using a spectrophotometer. Total amino acid concentration was calculated from a glycine standard curve and expressed as mg glycine equivalents (mg GE g^{-1} DW).

i. Molecular characterization

Genomic DNA of samples (1, 2, 7, 8, 9, and 10) was extracted using the CTAB procedure as mentioned by Doyle and Doyle (1987**)** [34] as follows: Fresh leaves (0.15 g) were cut into small pieces and grounded using mortar and pestle after 1.5 ml of CTAB buffer was added (8.4 g NaCl, 1.21g EDTA, 2g CTAB, 2g PVP, and 0.5% β-mercapto ethanol pH 8 in 100ml) and transferred to micro-centrifuge eppendorf 1.5ml and incubated in 65ºc for 30 min with turning over from up to down every 10 min. After centrifuging the samples at 10000 rpm/5min, 500µl of supernatant was transferred to fresh Eppendorf tubes. The supernatant was mixed well with 500 µl of chloroform: isoamyl-alcohol (24:1) using a vortex and the Eppendorf tubes were centrifuged at 10000 rpm/5 min. About 300 µl of aqueous phase was transferred to a new Eppendorf, and 500µl of cool isopropanol and 30 µl of sodium acetate (3M). Eppendorf tubes were centrifuged at 11500 rpm/10 min., and the supernatant was discarded. The pellet was

centrifuged at 7000 rpm/5min after being cleaned with 500µl of cold ethanol 70%. Lastly, 50µl of sterile dH_2O was used to resuspend the DNA pellet, which was then stored at 4ºC until needed.

j. PCR analysis

Polymerase chain reaction (PCR) was used to analyze the genome of treated plants comparing with the control. PCR was carried out using total of 16 primers according to Abouseada *et al*. (2023) [35]. Primers included 10 Start Codon Targeted (SCoT) and 6 Inter-Simple Sequence Repeat (ISSR) primers as shown in Table (3). The PCR reaction (25µl) comprises 12.5µl of TaqMan (OmniPCR, BIO-HELIX), 6.5µl of dH2O, 2 µl of DNA (~250–400ng), and 2 µl of each primer (10 p.mol). The MJ-Research thermo-cycler (PTC-200) was used to perform the PCR amplification protocol, which was 94ºC/5min, 35 cycles of 94ºC/45sec for denaturation, annealing as shown in table/45sec, 72ºC/90s, and 72ºC/7min. The samples were electrophoresed at 120V for 45 minutes using agarose (1.2%), and the gel was stained with ethidium bromide dye (1 mg/ml). The obtained data were analyzed according to Lewaa *et al*. (2024) [36] as follows: Only cleared ISSR-PCR/ SCoT fragments were scored, and amplified fragments were either present (1) or absent (0). The acquired data was analyzed using a matrix of similarity utilizing Jaccard's coefficient using the Past program (version 4.03).

Table 3: List of ISSR/SCoT primers sequence used in PCR

ISSR primers			SCoT primers		
Primers name	**Sequence 5'-3'**	**Annealing ºc**	**Primers name**	**Sequence 5'-3'**	**Annealing ºc**
ISSR-1	AGAGAGAGAGAGAGAGYC	52	SCoT-1	ACCATGGCTACCACCGAC	55
ISSR-2	AGAGAGAGAGAGAGAGYG	52	SCoT-2	ACAATGGCTACCACTGAC	51
ISSR-3	ACACACACACACACACYT	50	SCoT-3	ACCATGGCTACCACGGGC	58
ISSR-4	ACACACACACACACACYG	52	SCoT-4	ACCATGGCTACCACGGCA	55
ISSR-5	GTGTGTGTGTGTGTGTYG	52	SCoT-5	CCATGGCTACCACTAGCA	53
ISSR-6	CGCGATAGATAGATAGATA	48	SCoT-6	ACCATGGCTACCACCGTC	55
			SCoT-7	CAACAATGGCTACCACGA	51
			SCoT-8	CCATGGCTACCACCGCAG	58
			SCoT-9	ACCATGGCTACCACCGCA	55
			SCoT-10	ACCATGGCTACCAGCGCG	58

k. Statistical Analysis

Data from all treatments were averaged and subjected to analysis of variance (ANOVA) using MSTAT software (1985) [37]. Treatment means were compared using the least significant difference (LSD) test at 5% probability level according to Snedecor and Cochran (1980) [38] & SAS Program (1998) [39].

Results and Discussion

a. Effect of UV-C lamp treatments on vegetative growth parameters:

The vegetative growth of *Narcissus tazetta* L. was significantly influenced by UV-C irradiation treatments during the 2023-2024 and 2024-2025 growing seasons (Table 4), indicating a clear dose-dependent physiological response. Overall, a strong interaction between exposure duration and dose frequency was observed, where moderate UV-C stress significantly enhanced growth performance compared with the control. The earliest sprouting was observed under the 2 h × 3 doses treatment, occurring after 10.76 and 10.01 days in the first and second seasons, respectively, compared with 27.70 and 26.12 days in the control. Plant height was also markedly increased from 27.87 and 30.79 cm in the control to 45.62 and 47.22 cm under the same treatment. Extending exposure to 3 h reduced plant height, although values remained higher than those of the control. Similarly, stem diameter, leaf length, and leaf number increased under UV-C lamp treatments. The maximum stem diameter (0.68 and 0.67 cm), leaf length (33.49 and 33.25 cm), and number of leaves per plant (20.53 and 19.22) were recorded with the 2 h × 3 doses treatment, compared with 0.60 and 0.61 cm, 19.13 and 20.13 cm, and 9.20 and 10.41 leaves in the control, respectively. Leaf biomass was also enhanced by UV-C irradiation. Fresh leaf weight increased from 120.60 and 119.50 g in the control to 145.56 and 144.21 g under the 2 h × 3 doses treatment, while dry leaf weight increased from 13.63 and 13.54 g to 17.76 and 17.28 g, respectively. The 3 h × 1 dose treatment represented the second most effective treatment, producing values slightly lower than those obtained with the 2 h × 3 doses treatment. These findings suggest that moderate UV-C exposure acts as a beneficial eustress factor, promoting vegetative growth and biomass accumulation. The accelerated sprouting observed under the optimum treatment may reflect enhanced metabolic activation associated with UV-induced priming effects, which prepare plants for rapid transition to active growth (Hideg *et al*. 2013; Bornman *et al*. 2015) [40 , 41]. The improvement in vegetative growth was accompanied by enhanced biomass accumulation and may be associated with stimulation of metabolic pathways and increased availability of free amino acids required for protein synthesis and cell expansion. Moreover, the substantial increase in phenolic compounds observed in the biochemical analysis may have contributed to maintaining oxidative balance and protecting cellular structures from reactive oxygen species (ROS), thereby supporting sustained growth promotion. Activation of phenylpropanoid metabolism under UV-C lamp exposure has been recognized as a major mechanism involved in stress adaptation and growth regulation in plants (Ninkuu *et al*. 2025) [42]. The observed response pattern also demonstrated a non-linear dose-response relationship characteristic of hormesis, in which moderate stress stimulates physiological performance whereas excessive exposure limits growth enhancement. Similar findings were reported by Wargent and Jordan (2013) [43], who showed that low-dose UV radiation promotes plant growth and biomass accumulation through activation of antioxidant and hormonal pathways. Furthermore, the beneficial effects of UV-C irradiation may be partly attributed to its

antimicrobial activity, which improves bulb health and establishment capacity (Kim *et al*. 2022& Moreno *et al*. 2017) [44, 15]. In addition, UV-C exposure may induce ROS-mediated signaling cascades and photomorphogenic responses that regulate plant growth and defense mechanisms (Kaliapan *et al*. 2026) [45]. Overall, the superior performance of the 2 h × 3 doses treatment highlights the importance of optimizing both exposure duration and dose frequency to maximize the beneficial effects of UV-C irradiation while avoiding stress-induced growth limitations. These results agree with the findings of Zandi *et al*. (2022) [46] who reported that plant responses to ultraviolet radiation depend not only on irradiance but also on the interaction between radiation dose and exposure duration.

b. Effect of UV-C lamp treatments on flowering parameters:

Across the two growing seasons, UV-C lamp treatments significantly improved flowering performance of *Narcissus tazetta* L. compared with the control (Table 5), indicating a strong physiological carry-over effect from the pre-sowing UV-C lamp priming applied to the bulbs. This enhanced flowering response is consistent with the previously observed metabolic activation and increased accumulation of amino acids and phenolic compounds, which collectively contributed to improved vegetative vigor and reproductive transition. A clear reduction in time to flowering was observed under all UV-C lamp treatments. Control plants required approximately 65.20 and 64.00 days to flower, whereas the most effective treatment (2-hour exposure with 3 doses) significantly reduced flowering time to 44.11 and 43.16 days. The 3-hour, 1-dose treatment ranked second, recording 46.87 and 46.17 days. This acceleration in flowering can be attributed to UV-C lamp induced metabolic priming, where enhanced nitrogenous compound availability (particularly free amino acids) supports rapid synthesis of proteins and enzymes involved in floral initiation and transition from vegetative to reproductive growth. Similar UV-induced priming effects on developmental acceleration have been reported in previous studies (Hideg *et al.* 2013; Bornman *et al.* 2015) [40 , 41]. In parallel, all spike quality parameters showed marked improvements under UV-C lamp exposure. The 2-hour, 3-dose treatment produced the highest spike length (41.62 and 40.11 cm) and spike fresh weight (183.60 and 183.29 g), compared with control values of 23.23 and 22.00 cm, and 148.14 and 157.18 g, respectively. Similar trends were observed for pedicel length, number of florets per spike, and floret diameter, where superior performance under this treatment reflects enhanced assimilate availability and improved metabolic efficiency. These improvements are strongly linked to the previously reported increase in phenolic compounds, which not only regulate oxidative balance but also contribute to overall plant structural integrity and developmental stability through phenylpropanoid pathway activation (Ninkuu *et al.* 2025) [42]. In addition, pedicel length, number of florets per spike, and floret diameter exhibited a similar response pattern to UV-C treatments in both seasons. The highest values were consistently recorded under the 2 h × 3 doses treatment, with pedicel length reaching 45.45 and 44.15 mm compared with 30.12 and 29.45 mm in the control. The number of florets per spike increased from 6.10 and 6.13 in the control to 6.71 and 6.76 under the same treatment, while floret diameter improved from 30.13 and 30.03 mm to 45.23 and 45.00 mm, respectively. These results confirm that UV-C irradiation not only enhanced flowering earliness and spike yield but also significantly improved floral quality attributes in *Narcissus tazetta* L (Loconsole and Santamaria, 2021) [13]. Flowering duration and vase life were also positively affected by UV-C treatments. The flowering period increased from 17.56 and 17.22 days in the control to 28.15 and 27.23 days under the 2-hour, 3-dose treatment. Vase life also increased from 6.23 and 6.22 days in the control to 8.54 and 8.22 days under the same treatment. These improvements can be explained by enhanced antioxidant capacity, as previously observed in treated bulbs, where increased phenolic and flavonoid accumulation improves membrane stability and delays senescence processes. The role of UV-C in enhancing antioxidant systems and postharvest quality has been widely documented, particularly through the activation of secondary metabolite biosynthesis pathways (Fu *et al.* 2016) [47]. The improvement in flowering performance also reflects UV-C–induced regulation of oxidative signaling pathways. Moderate UV-C exposure generates controlled levels of reactive oxygen species (ROS). These molecular events contribute to improved floral differentiation, spike development, and reproductive efficiency, as previously described in UV-C signaling studies (Kaliapan *et al.* 2026) [45]. Overall, increasing UV-C exposure beyond the optimal regime did not result in further improvements in flowering traits, as some treatments with higher duration or less balanced dose combinations showed comparatively lower values across most parameters. This pattern confirms a hormetic dose–response relationship, where moderate UV-C stress enhances flowering quality and developmental efficiency, while excessive or imbalanced exposure may partially reduce physiological optimization. Such responses are consistent with previous reports showing that controlled UV exposure can enhance flowering and ornamental quality in several species, whereas excessive doses may induce inhibitory effects depending on species sensitivity (Bridgen, 2016; Darras *et al.* 2019) [14, 48]. In contrast, UV-C radiation has been reported to enhance flowering and increase flower number in ornamental plants such as wild pansy and freesia. This variability is consistent with the findings of the present study, in which UV-C treatments applied to *N. tazetta* bulbs induced a clear positive response, resulting in improved flower quality and enhanced bulb characteristics relative to untreated controls. Such responses likely reflect species-specific sensitivity to moderate UV-C doses, which may stimulate key physiological processes while simultaneously reducing surface-borne pathogens, thereby enhancing flowering efficiency, vegetative vigor, and overall plant architecture. In summary, the superior performance of the 2 h × 3 doses treatment highlights the importance of optimized UV-C priming in regulating both metabolic and developmental pathways, resulting in earlier flowering, improved spike quality, extended flowering duration, and prolonged vase life in *N. tazetta* L.

c. Bulb production of *Narcissus tazetta* L. as affected by UV-C lamp radiation treatments

Bulb production of *Narcissus tazetta* L. was significantly enhanced by UV-C radiation treatments during both the 2023 and 2024 growing seasons compared with the control (Table 6), indicating that the physiological benefits of UV-C

pre-treatment extended beyond vegetative and flowering traits to include storage organ development and propagation capacity. This enhancement is consistent with the previously observed UV-C–induced metabolic priming, where increased amino acid and phenolic accumulation improved overall growth efficiency and assimilate allocation. Across the two seasons, control plants consistently showed the lowest values for bulb circumference (12.20 and 12.67 cm), bulb fresh weight (44.38 and 46.89 g), bulb dry weight (12.12 and 12.25 g), and number of bulblets per plant (7.24 and 7.20). These lower values reflect limited metabolic activation and reduced assimilate partitioning toward storage organs in the absence of UV-C stimulation. Bulb circumference and bulb fresh weight increased progressively with UV-C exposure up to an optimal level. The highest values were recorded under the 2-hour, 3-dose treatment, reaching 17.52 and 17.89 cm for bulb circumference and 65.15 and 67.95 g for bulb fresh weight, compared with the control. This improvement can be attributed to enhanced metabolic efficiency and increased availability of nitrogenous compounds (free amino acids), which likely supported enhanced synthesis of structural proteins and storage reserves in developing bulbs. Similar UV-induced stimulation of biomass allocation and storage organ enhancement has been associated with primed metabolic states under controlled abiotic stress conditions (Hideg *et al.* 2013; Bornman *et al.* 2015) [40, 41].

This treatment also produced the highest bulb dry weight values (18.42 and 18.46 g), suggesting improved dry matter accumulation and more efficient carbon assimilation and partitioning. The enhanced dry matter content is strongly linked to the previously observed increase in phenolic compounds, which contribute not only to antioxidant defense but also to cellular stability and improved metabolic regulation under stress conditions (Ninkuu *et al.* 2025) [42]. Bulblet production followed a similar trend, with the highest values obtained under the 2-hour, 3-dose treatment (10.67 and 10.54 bulblets/plant), closely followed by the 3-hour, 1-dose treatment (10.24 and 9.65 bulblets/plant), whereas control plants recorded the lowest values. This increase in bulblet formation may be associated with UV-C–induced hormonal and signaling regulation, where moderate reactive oxygen species (ROS) act as secondary messengers to stimulate developmental differentiation and propagation-related pathways, as previously discussed in UV-C signaling mechanisms (Kaliapan *et al.* 2026) [45]. The observed improvement in bulb health following UV-C treatment can be partly attributed to its antimicrobial effects on the microorganisms associated with *Narcissus* bulbs. UV-C irradiation has been shown to effectively inactivate pathogenic bacteria, as reported by Kim *et al*. (2022) [44] and significantly reduce microbial loads while preserving tissue quality, as demonstrated by Moreno *et al.* (2017) [15]. The reduction in microbial proliferation observed in the present study likely contributed to improved bulb storability and reduced decay, which, in turn, may have enhanced plant vigor and subsequent growth performance after planting. This effect is particularly relevant in intercropping systems, where bulb health before planting plays a crucial role in the successful establishment and overall productivity. Notably, higher UV-C exposure levels, particularly the 3-hour treatments with 2 and 3 doses, resulted in a slight reduction in most parameters compared with the optimal treatment, although values remained significantly higher than the control across both seasons. This pattern reinforces the presence of a hormetic dose–response relationship, where moderate UV-C exposure enhances storage organ development, while excessive exposure may impose mild metabolic constraints that limit optimal assimilate allocation. The improvement in bulb quality and bulblet production is also consistent with UV-C–induced reductions in microbial load observed in earlier studies, which enhance bulb health and storability by minimizing pathogen-related losses (Kim *et al.* 2022; Moreno *et al.* 2017) [44, 15]. This antimicrobial effect likely contributed to improved bulb integrity and developmental capacity after planting. Furthermore, UV-C–mediated activation of phenylpropanoid metabolism may have contributed to improved structural development of bulbs through enhanced lignin and secondary metabolite biosynthesis, supporting tissue strength and storage efficiency. Such biochemical regulation is well documented in plants exposed to controlled abiotic stress, where secondary metabolism is redirected toward protective and structural compounds (Loconsole and Santamaria, 2021) [13]. Overall, the results clearly demonstrate that moderate UV-C exposure, particularly the 2-hour, 3-dose treatment, is the most effective regime for enhancing bulb growth, quality, and bulblet production in *Narcissus tazetta* L., while the 3-hour, 1-dose treatment represents the second most effective option. These findings confirm that UV-C acts as a controlled eustress factor, optimizing both metabolic activity and developmental allocation toward storage organ formation, thereby improving propagation potential and overall plant performance.

d. Effect of different UV-C lamp exposure durations and application frequencies on total chlorophyll content (mg g^{-1} FW) and macronutrient concentrations (N, P, and K%) in Narcissus Bulbs

Data presented in Fig. 1 indicated that UV-C irradiation significantly influenced chlorophyll content and macronutrient accumulation (N, P, and K) in *Narcissus tazetta* bulbs across both seasons. Total chlorophyll content increased under UV-C treatments compared with the control (1.75 and 1.70 mg g^{-1} FW), reaching maximum values under UV 2 hours × 3 doses (2.74 and 2.81 mg g^{-1} FW). A slight reduction was observed under prolonged exposure (3hours), suggesting an optimum irradiation threshold for photosynthetic pigment enhancement. This response may be associated with UV-C–induced stimulation of chloroplast development and modulation of photosynthetic metabolism under controlled oxidative signaling. Similarly, nitrogen content increased significantly, with the highest values recorded under UV 2 hours × 3 doses (2.55 and 2.59%), compared with the control (1.52 and 1.64%). This enhancement may reflect improved nitrogen assimilation efficiency and metabolic activation under moderate UV-C stress. Phosphorus accumulation followed the same trend, with maximum values under UV 2 hours × 3 doses (0.463 and 0.467%), while potassium content also peaked under the same treatment (1.95 and 1.96%). The observed increases in macronutrient uptake may be attributed to UV-C–induced stimulation of membrane transport activity and improved physiological efficiency under optimal stress levels. Overall, moderate UV-C exposure (2 hours × 3 doses) proved most effective in enhancing chlorophyll biosynthesis and macronutrient accumulation, whereas prolonged exposure (3

hours) reduced these benefits, indicating a dose-dependent response governed by stress–stimulation balance and ROS-mediated signaling pathways. The progressive increase in total chlorophyll and macronutrients (N, P, and K) under moderate UV-C exposure (2 hours × 3 doses) can be explained by eustress, in which low radiation doses stimulate physiological efficiency of the plant. This aligns with the results of Kaliapan *et al*. (2026) & Wargent and Jordan (2013) [45,43] who noted that controlled UV exposure modulates photosynthetic metabolism and enhances metabolic activation. The subsequent decline at three hour of exposure indicates a threshold where oxidative stress outweighs the stimulatory response, a dose-dependent behavior governed by ROS-mediated signaling pathways, as thoroughly discussed by Hideg *et al.* (2013) [40] and Zandi *et al*. (2022) [46].

e. Effect of UV-C lamp radiation on total phenols, antioxidant activity, and total amino acids in Narcissus bulbs

The results (Fig. 2) showed that UV-C irradiation significantly enhanced the total phenolic content, antioxidant activity, and total amino acid concentration in *N. tazetta* bulbs across both seasons compared to the control. These responses reflect UV-C–induced activation of secondary metabolism via photoreceptor-mediated signaling pathways that regulate stress adaptation and the biosynthesis of bioactive compounds (Rai *et al*. 2011; Kobayashi *et al*. 2013) [12, 49]. In close alignment with the observed phenolic accumulation, the total phenolic content increased markedly under UV-C treatment. The control recorded the lowest values (1.420 and 1.850 mg g^{-1} DW), whereas the highest accumulation was observed under UV 2 hours × 3 doses (6.900 and 6.960 mg g^{-1} DW in both seasons, respectively). However, prolonged exposure to 3 h reduced phenolic levels, indicating an optimum irradiation threshold. This confirms that UV-C acts as an abiotic elicitor, enhancing phenolic biosynthesis, including flavonoids and other defense-related compounds (Rai *et al*. 2011& Bridgen, 2016) [12, 14]. Antioxidant activity followed a similar pattern, with the lowest values recorded in the control (33.124 and 35.060%), whereas UV 2 hours × 3 doses produced the highest activity (66.834 and 66.976%). This increase reflects the stimulation of the antioxidant defense system under moderate UV-C exposure, which enhances the production of non-enzymatic antioxidants, such as phenolics and flavonoids. These compounds are essential for scavenging reactive oxygen species (ROS), thereby improving stress tolerance and plant performance. However, excessive UV-C exposure may induce oxidative damage and metabolic impairment (Sena *et al*. 2024) [50]. Antioxidant defense in plants involves both enzymatic systems (e.g., superoxide dismutase and glutathione peroxidase) and non-enzymatic molecules, which collectively mitigate oxidative stress (Sabreen and Masoodi, 2011) [51]. Total amino acids also increased significantly under UV-C treatments, with the highest values recorded under UV 2 hours × 3 doses (0.245 and 0.249 mg g^{-1} DW) compared with the control (0.020 and 0.018 mg g^{-1}DW). Although 3 hours of exposure maintained relatively elevated levels, it was less effective than the optimal treatment, confirming that moderate UV-C doses enhance primary metabolism, whereas excessive exposure reduces efficiency. Overall, the findings demonstrate that moderate UV-C irradiation (2 hours×3 doses) is the most effective treatment for enhancing phenolic biosynthesis, antioxidant capacity, and amino acid accumulation in *N. tazetta* bulbs. This effect is likely mediated by controlled ROS signaling, which regulates secondary metabolism and defense responses (Liu *et al*. 2012) [52]. The obtained results are consistent with previous reports showing that *N. tazetta* bulbs naturally contain high levels of phenolic and bioactive compounds, including flavonoids, alkaloids, saponins, tannins, steroids, terpenoids, and anthraquinones, which contribute to their pharmacological activities, such as antioxidant, antimicrobial, antiviral, anticancer, and immunomodulatory effects (Al-Snafi, 2020) [53] . Furthermore, phytochemical analyses confirmed the presence of phenolic acids, such as gallic, caffeic, chlorogenic, vanillic, and salicylic acids, supporting the high antioxidant potential observed in this study (Ali *et al*. 2023) [54].

f. Cluster analysis based on combined ISSR and SCoT marker data

As illustrated in Figs. 3 and 4, the combined analysis of ISSR (Inter Simple Sequence Repeat) and SCoT (Start Codon Targeted) molecular markers was performed to assess the genetic similarity among the control and UV-C–treated *Narcissus tazetta* plants subjected to different exposure regimes. This molecular characterization complements the previously observed physiological and biochemical responses, providing evidence of UV-C–induced genomic variability associated with differential stress intensity.

Table 6 shows that the control plant exhibited the highest similarity with plant sample 2 (UV 1 h, 1 dose) at 0.95, followed by sample 7 (UV- C lamp 2 h, 3 doses) at 0.45 and sample 8 (UV 3 h, 1 dose) at 0.42. The lowest similarity was observed with samples 9 and 10 (UV 3 h, 2 doses and UV 3 h, 3 doses), both showing a value of 0.30. These results indicate that increasing UV-C exposure intensity was associated with greater genetic divergence from the control, suggesting dose-dependent genomic alterations. For sample 2 (UV 1 h, 1 dose), similarity values with samples s 7, 8, 9, and 10 were 0.45, 0.42, 0.30, and 0.30, respectively, reflecting a gradual decrease in genetic similarity with increasing UV-C intensity. Sample 7 (UV 2 h, 3 doses) was most closely related to sample 8 (UV 3 h, 1 dose) with a similarity of 0.88, while showing moderate relatedness to samples 9 and 10 (0.55 and 0.54, respectively). Similarly, plant 8 shared intermediate similarity values with samples 9 and 10 (0.53 and 0.52), whereas sample s 9 and 10 (UV 3 h, 2 and 3 doses) exhibited the highest mutual similarity (0.90), indicating a consistent grouping of high-stress treatments. The dendrogram based on combined ISSR and SCoT data (Fig. 3) grouped the plants into two main clusters. The first cluster included the control and plant 2 (UV 1 h, 1 dose), representing low UV-C exposure and minimal genomic divergence. The second major cluster was further subdivided into two subclusters: the first contained

samples 7 and 8 (UV 2 h, 3 doses and UV 3 h, 1 dose), while the second included samples 9 and 10 (UV 3 h, 2 and 3 doses). This hierarchical grouping clearly reflects a gradient of genetic variation corresponding to increasing UV-C intensity. Overall, the cluster analysis based on ISSR and SCoT markers demonstrates that UV-C radiation induces a clear, dose-dependent pattern of genetic variation in *Narcissus tazetta*. This molecular differentiation supports the physiological and biochemical findings, confirming that UV-C acts as a powerful abiotic factor influencing both metabolic regulation and genomic architecture. The observed clustering pattern further emphasizes the importance of optimizing UV-C exposure to balance beneficial priming effects with potential genomic instability. These molecular findings are consistent with the known mechanisms of UV-C-induced DNA damage and repair, in which UV-C photons are absorbed by pyrimidine bases, leading to the formation of pyrimidine dimers and other DNA lesions that interfere with replication and transcription processes and may ultimately result in genomic variation if repair systems are insufficient (Gill *et al*. 2015; Li *et al*. 2021) [55, 11]. In the present study, prolonged UV-C exposure induced pronounced alterations in genomic DNA, whereas limited exposure exerted only minor effects, indicating that low UV-C doses had a negligible impact on genomic stability, while higher exposure levels promoted detectable molecular divergence. These observations agree with previous reports demonstrating that extended UV-C exposure increases mutation frequency and promotes genetic and epigenetic variation. Using the supF mutational reporter system, Nakamura *et al*. (2021) [56] reported a 26–45-fold increase in mutation frequency compared with untreated controls, with G:C→A:T transitions representing the predominant mutation type and pyrimidine dimers being frequently detected.

Table 4: Effect of UV-C lamp treatments on vegetative growth parameters of *Narcissus tazetta* L. intercropped with mulberry trees during the 2023-2024 and 2024-2025 seasons

Exposure Duration	Sprouting date (days)		Plant height		Stem diameter (cm)		Leaf length (cm)		Number of leaves		Fresh weight of leaves/plant (g)		Dry weight of leaves/plant (g)	
	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
Control	27.70	26.12	27.87	30.79	0.60	0.61	19.13	20.13	9.20	10.41	120.60	119.5	13.63	13.54
UV 1h 1 dose	25.30	24.70	34.51	37.57	0.61	0.62	24.47	24.37	11.65	11.23	127.14	126.20	14.81	14.10
UV 1h 2 doses	22.14	21.50	36.16	38.09	0.62	0.63	25.84	26.14	12.89	12.03	129.50	130.00	15.23	15.22
UV 1h 3 doses	20.00	19.22	38.89	39.12	0.63	0.64	27.27	27.87	13.56	13.01	133.23	132.51	15.46	15.10
UV 2h 1 dose	18.71	18.00	40.67	43.54	0.65	0.66	29.35	28.05	14.67	14.23	135.12	135.50	16.58	16.00
UV 2h 2 doses	15.30	14.23	41.73	45.60	0.65	0.66	29.23	30.15	15.44	15.11	138.45	138.25	16.69	16.41
UV 2h 3 doses	10.76	10.01	45.62	47.22	0.68	0.67	33.49	33.25	20.53	19.22	145.56	144.21	17.76	17.28
UV 3h 1 dose	11.45	11.12	39.15	37.88	0.67	0.66	32.65	32.55	18.54	18.00	144.57	143.23	17.47	17.01
UV 3h 2doses	13.20	12.50	37.05	34.35	0.66	0.67	32.20	32.40	17.53	17.31	142.5	141.23	17.30	16.25
UV 2h 3 doses	14.00	13.56	34.54	30.89	0.65	0.64	31.25	31.76	16.63	16.23	140.78	140.11	16.71	16.24
Mean	17.86	17.10	37.62	38.51	0.64	0.65	28.49	28.67	15.06	14.68	135.75	135.07	16.16	15.72
LSD 0.05	1.07	1.20	1.89	1.73	0.05	0.07	1.70	1.32	1.25	1.18	1.4	1.32	1.81	1.61

Dose refers to the number of consecutive UV-C irradiation applications. Bulbs treated with 1, 2, or 3 doses were exposed daily for one, two, or three consecutive days, respectively.

Table 5: Effect of UV-C lamp treatments on flowering parameters of Narcissus tazetta L. intercropped with mulberry trees during the 2023-2024 and 2024-2025 seasons.

Exposure Duration	Flowering date (days)		Spike length (cm)		Spike fresh weight (g)		Pedicel length (mm)		Number of florets/spikes		Floret diameter (mm)		Flowering period (days)		Vase life (days)	
	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
Control	65.20	64.00	23.23	22.00	148.14	157.18	30.12	29.45	6.10	6.13	30.13	30.03	17.56	17.22	6.23	6.22
UV 1h 1 dose	62.74	62.11	24.11	23.45	166.22	167.16	32.69	31.27	6.24	6.35	31.78	31.22	18.73	18.45	6.34	6.30
UV 1h 2 doses	60.15	59.23	26.16	25.43	168.48	169.19	34.60	33.15	6.34	6.38	33.67	33.00	19.22	19.23	6.45	6.42
UV 1h 3 doses	56.18	55.00	28.89	27.01	172.80	172.18	36.25	35.50	6.41	6.45	34.65	34.11	20.45	20.45	6.52	6.48
UV 2h 1 dose	54.00	53.25	30.67	30.11	174.50	175.12	36.80	36.63	6.47	6.49	36.76	36.45	21.34	21.00	6.45	6.43
UV 2h 2 doses	51.56	50.56	31.73	30.65	176.58	175.29	37.55	37.40	6.51	6.53	38.35	38.10	22.78	22.45	6.66	6.60
UV 2h 3 doses	44.11	43.16	41.62	40.11	183.6	183.29	45.45	44.15	6.71	6.76	45.23	45.00	28.15	27.23	8.54	8.22
UV 3h 1 dose	46.87	46.17	38.17	37.11	179.83	179.82	43.32	42.11	6.66	6.68	43.33	43.13	26.35	26.40	7.41	7.52
UV 3h 2doses	47.18	46.23	35.45	34.87	178.60	178.40	41.34	40.12	6.63	6.65	41.65	41.24	25.76	25.45	7.31	7.20
UV 2h 3 doses	48.56	48.12	33.56	32.00	177.64	177.25	38.46	37.10	6.54	6.61	39.87	39.34	23.76	23.11	6.72	6.56
Mean	59.02	58.06	34.50	33.30	189.90	190.84	36.88	40.36	7.11	7.15	41.30	40.88	24.65	24.31	7.55	7.47
LSD 0.05	2.28	2.15	1.70	1.61	2.42	2.67	1.45	1.38	1.35	1.07	1.32	1.28	1.10	1.05	1.55	1.89

Dose refers to the number of consecutive UV-C irradiation applications. Bulbs treated with 1, 2, or 3 doses were exposed daily for one, two, or three consecutive days, respectively.

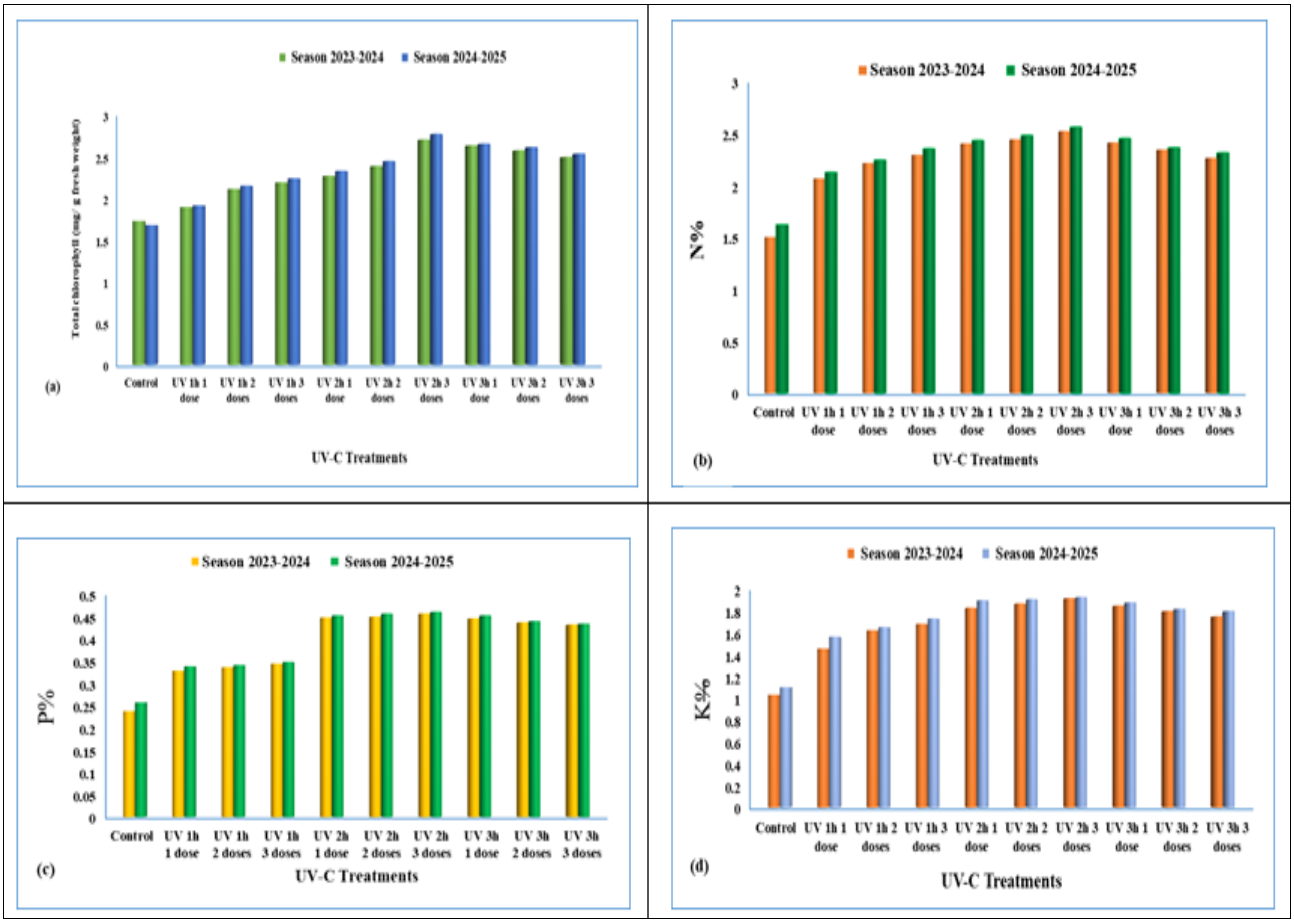

Fig 1: Effect of different UV-C exposure durations and application frequencies on (a) total chlorophyll content, (b) nitrogen percentage, (c) phosphorus percentage, and (d) potassium percentage in Narcissus bulbs during both growing seasons. Dose refers to the number of consecutive UV-C irradiation applications

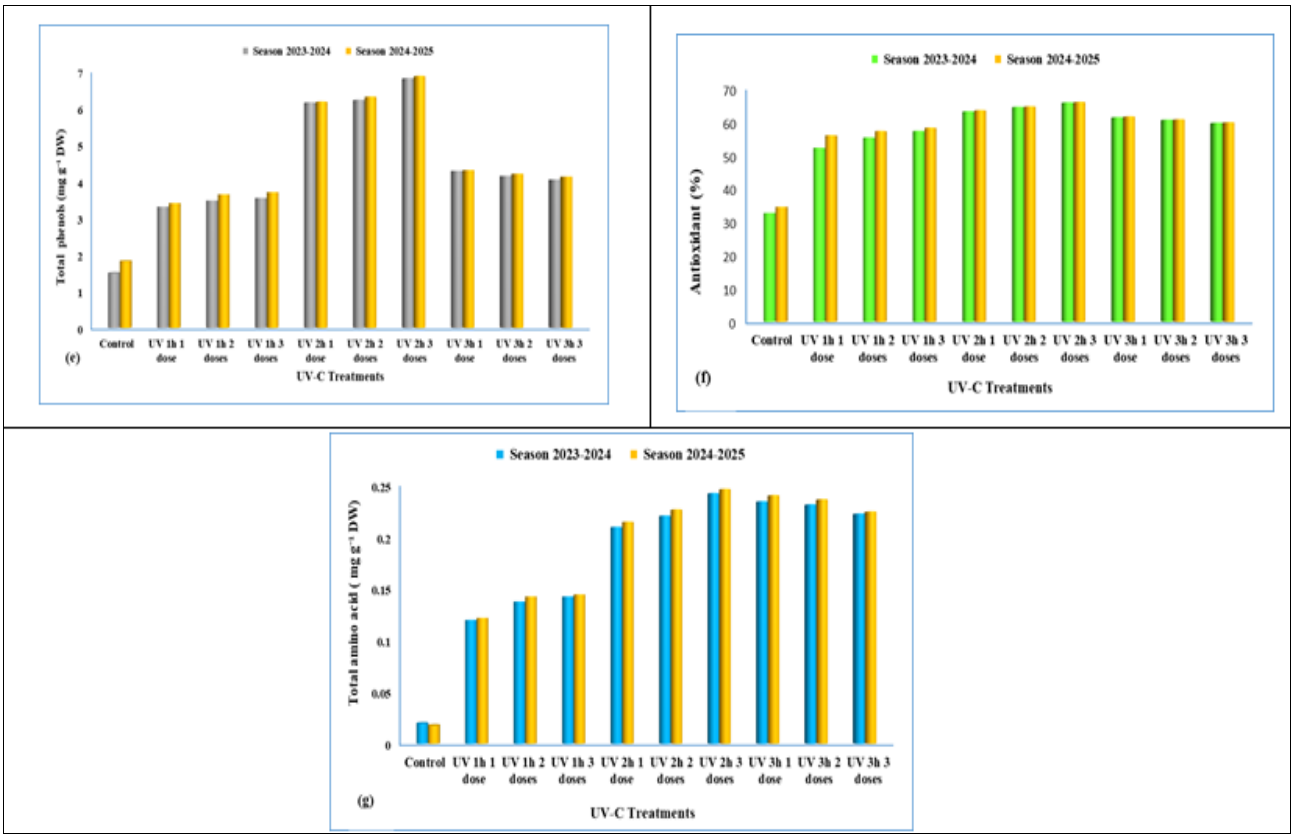

Fig 2: Effect of different UV-C exposure durations and application frequencies on (e) total phenolic content (mg g^{-1} DW), (f) antioxidant activity (%), and (g) total amino acid content (mg g^{-1} DW) in *Narcissus bulbs* during the both seasons. Dose refers to the number of consecutive UV-C irradiation applications**.**

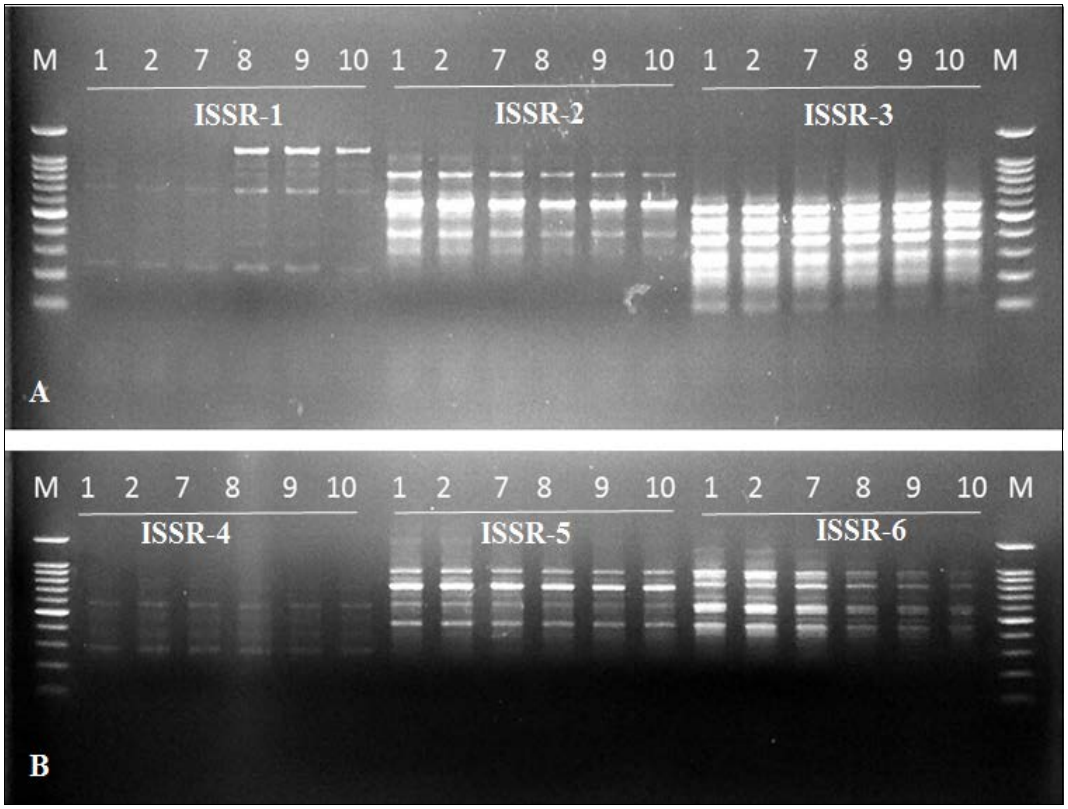

Fig 3: Gel profile for 6 treated samples with ISSR-PCR primers using ISSR-1, ISSR-2, and ISSR-3 in A) and using using ISSR-4, ISSR-5, and ISSR-6 in B). M= marker 100 bp

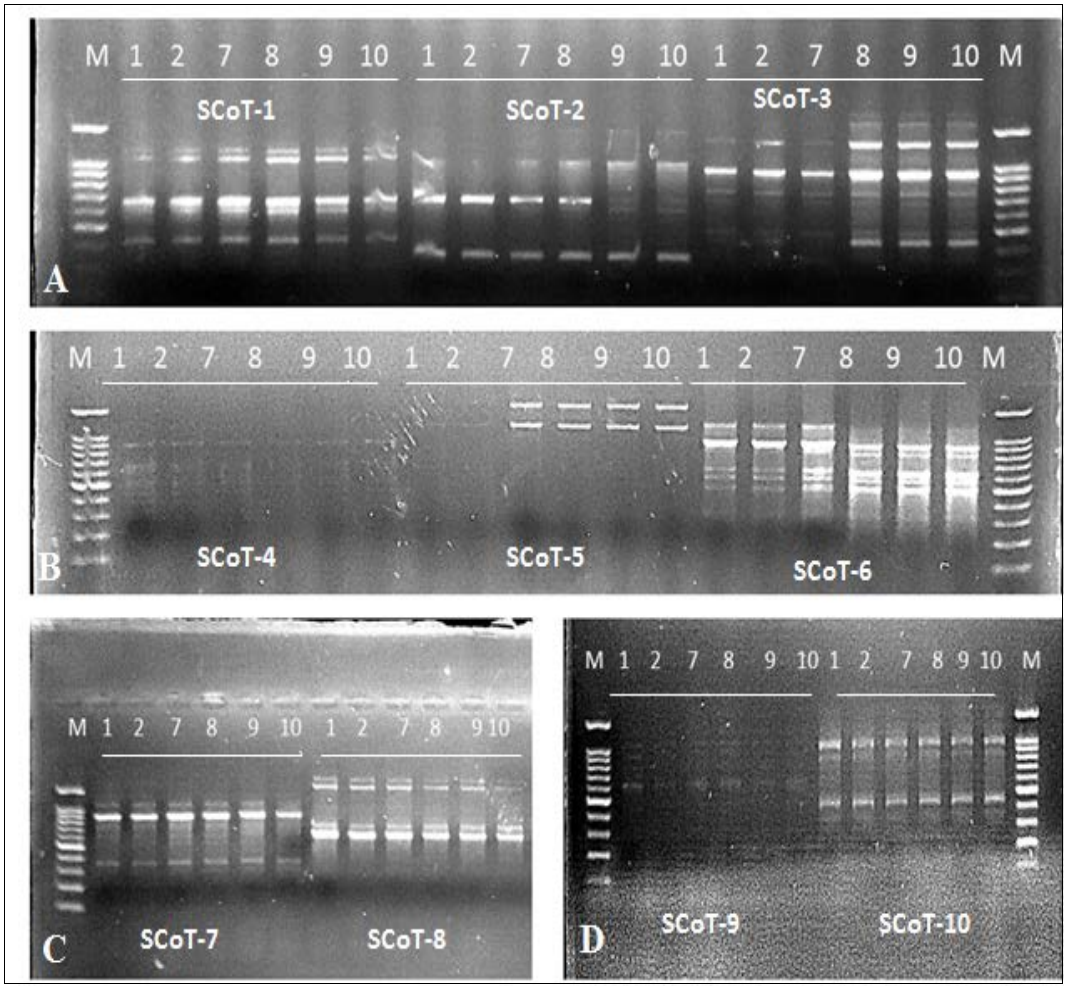

Fig 4: Gel profile for 6 treated samples with SCoT-PCR primers using SCoT -1, SCoT -2, and SCoT -3 in A) and using using SCoT -4, SCoT -5, and SCoT -6 in B), SCoT -7, and SCoT -8 in C), and SCoT -9, and SCoT -10 in D), M= marker 100 bp

Table 6: Effect of different UV-C lamp treatments on bulb characteristics and bulblet production of *Narcissus tazetta* L. during the 2023-2024 and 2024-2025 seasons.

Exposure Duration	Bulb circumference (cm)		Bulb fresh weight (g)		Bulb dry weight (g)		Number of new bulblets/plant	
	1st	2nd	1st	2nd	1st	2nd	1st	2nd
Control	12.20	12.67	44.38	46.89	12.12	12.25	7.24	7.20
UV 1h 1 dose	13.13	13.73	49.68	53.12	14.34	14.78	7.34	7.44
UV 1h 2 doses	14.30	14.70	53.15	55.54	15.12	15.21	7.54	7.59
UV 1h 3 doses	15.54	15.87	54.71	57.78	15.09	15.98	7.70	7.75
UV 2h 1 dose	16.00	16.26	57.34	59.87	16.14	16.19	8.45	8.40
UV 2h 2 doses	16.31	16.47	58.98	62.00	17.14	17.21	9.34	9.22
UV 2h 3 doses	17.52	17.89	65.15	67.95	18.42	18.46	10.67	10.54
UV 3h 1 dose	17.00	17.45	62.30	63.91	18.19	18.68	10.24	9.65
UV 3h 2 doses	16.35	16.42	59.62	60.23	17.01	17.98	9.74	9.42
UV 3h 3 doses	15.34	15.53	57.25	59.15	16.42	16.52	8.54	8.46
Mean	15.37	15.70	56.26	58.64	16.00	16.33	8.68	8.58
LSD 0.05	0.31	***0.43***	3.23	4.30	0.53	0.82	0.34	0.31

Dose refers to the number of consecutive UV-C irradiation applications. Bulbs treated with 1, 2, or 3 doses were exposed daily for one, two, or three consecutive days, respectively.

Similarly, Virgen *et al*. (2025) [57] showed that continuous UV-C exposure over 25 generations in Arabidopsis thaliana enhanced both genetic and epigenetic diversity, resulting in increased frequencies of single nucleotide polymorphisms and deletions, with cytosine substitutions (C→T, C→A, and C→G) being the most common. They also observed significant changes in DNA methylation patterns, particularly in the CHG and CHH sequence contexts. The clustering of high-dose treatments into a distinct group suggests that UV-C stress not only affects physiological and biochemical characteristics but also contributes to measurable genomic differentiation. Importantly, these molecular changes should be interpreted within the framework of UV-C-induced ROS signaling and stress adaptation. As previously discussed, controlled ROS accumulation activates transcriptional reprogramming and defense pathways (Kaliapan *et al*. 2026) [45], which may coexist with DNA-level modifications depending on stress intensity. Therefore, moderate UV-C treatments likely operate within a hormetic window, enhancing physiological performance while maintaining relatively higher genetic similarity to the control, whereas excessive exposure shifts the balance toward greater molecular divergence and genomic alteration.

Table 7: Similarity between treated samples using ISSR and SCoT combination

Sample	1	2	7	8	9	10
1	1					
2	0.95	1				
7	0.45	0.45	1			
8	0.42	0.42	0.88	1		
9	0.3	0.3	0.55	0.53	1	
10	0.3	0.3	0.54	0.52	0.9	1

g. Evaluation of silkworm (*Bombyx mori* L.) economic traits and sex-based interaction responses under intercropping treatments

Data in Table 8. Represented the impact of intercropping irradiated *Narcissus tazitta* on mulberry, *Morus alba* var. Canava-2 trees characters. The results approved that, the mulberry characters i.e. number of shoots/tree, number of leaves /shoot, weight of leaf and leaf yield/tree did not show any significant differences when mulberry was grown with different intercropping UV-C Irradiation *Narcissus* plants or control treatment. These results are coincidence with data recorded by Mahmoud and Hosny, (2002) [58], they noted that, there no adverse effect on intercropped mulberry trees of Squash or growing mulberry as a sole crop. Whereas, Islam *et al*. (2023) [6] noted that, intercropping of vegetables in mulberry garden has a significant impact on mulberry plant productivity. The recorded greater average leaf yield was recorded in sole mulberry with maximum number of branches/plant, total leaf number/plant, total branch height/plant, node/meter, length of shoot, leaf present/branch, 10 leaves areas/plant, total leaf weight/plant and total shoot weight/plant followed by the intercropping treatments. Shankar *et al*. (1994 & 1999) [60, 59]. approved that, mulberry leaf yield from five harvest at an interval of 60 days was superior when mulberry was intercropped with foxtail millet, little millet, soybean, barnyard millet and pros millet over control. Also, as the same line Yadav and Kumar (1998) [61] noted that Canva-2 mulberry variety intercropping with soybean and green gram recorded significantly higher profitability. Shankar *et al*. (2000) [62] intercropping flower crops i.e., aster, gladioli, tuberose and marigold in S-36 mulberry field did not affect the growth of mulberry, no significant differences detected on the number of shoots and leaves and shoot height as compared to pure mulberry crop. Also, Murugesh, (2010) [63] registered that, the growth parameters of mulberry intercrops with cluster bean and cowpea was superior than the mulberry without any intercropping i.e. shoot length, number of branches per plant.

The illustrated data in Table 9 obvious the effect of intercropping irradiated *Narcissus tazitta* on mulberry, *Morus alba* var. Canava-2 trees on macro and micro elements in mulberry leaves. The registered data approved that, all treatments did not show any significant differences between all mulberry leaves in moisture content, N, P, K, Manganese, and Copper except Iron and Zink recorded significant differences between the treatments and the control may be due to the competition between mulberry trees and Narcissus plants. These data are coincidence with Feng *et al*. (2025) [64] who noted that, intercropping soybeans with forage mulberry encouraged the growth and nodulation of the above-ground portion of the soybeans rather than causing shade stress. Also, Shashidhar *et al*.

(2022) [65] noted that the growth characters and leaf yield of mulberry trees grown as a solo crop and tree mulberry with intercropping did not significantly differ. The best cropping was tree mulberry + field bean since it yielded the highest return per rupee spent, followed by tree mulberry with groundnut and tree mulberry with ragi. In the same line (Murugesh, 2010) [63] proved that, biochemical analysis of mulberry leaf revealed superior impact of different intercrops on the nutritional contents of mulberry. Significantly higher nitrogen content was registered in mulberry leaf intercropped with cluster bean and cowpea over the mulberry grown without any plant. Ramamurthy and Prasad (2006) [66] they proved that, mulberry with intercrops such as mung bean, marigold, and chick-pea in shallow soils gave superior crops especially chick pea is the most economical intercropping system so rearers must be practice intercropped with short term crops. Sridhar Babu (1994) [67] noted that, nitrogen levels in the mulberry leaves intercropped with leguminous crops. Islam *et al*. (2023) [6] who mentioned that, the leaf quality of mulberry, moisture, total chlorophyll, crude protein, total sugar, reducing sugar and mineral content in mulberry leaf were significantly enhanced by pulses intercropped with mulberry for the mulberry with chickpea intercropped, the mulberry with pea, mulberry with mug bean and mulberry intercropping with grass pea.

The results in Table 10 showed that, impact of intercropping irradiated *Narcissus tazitta* on mulberry trees and its impacts on the economical characters of silkworm, *Bombyx mori* L. performance of intercropping UV-C Irradiation *Narcissus* plants on mulberry plants and effect on silkworm characters i.e. fifth larval duration, larval duration, larval mortality , cocooning percentage, number of cocoon/Liter, pupation ratio, cocoon weight, cocoon shell weight, Pupa weight, cocoon shell ratio, and silk productivity. The data showed that, there is

Table 8. Impact of intercropping irradiated *Narcissus tazitta* on mulberry, *Morus alba* var. Canava-2 trees characters.

Character / Treatment	Number of Shoots/tree (No)	Total shoot length/tree (cm)	Number of leaves /shoot (No)	Weight of leaf (g)	Leaf yield/tree (g)
T_1	37.000	14.467	37.102	1.700	2331.700
T_2	37.000	14.493	37.667	1.667	2302.800
T_3	37.000	14.680	37.916	1.667	2336.400
T_4	37.333	14.630	37.316	1.767	2456.600
T_5	37.000	14.527	37.409	1.733	2409.900
T_6	37.000	14.770	37.280	1.767	2435.400
T_7	38.000	14.347	37.667	1.733	2477.600
T_8	37.333	14.376	37.129	1.700	2364.400
T_9	37.000	14.355	37.688	1.767	2464.200
T_{10}	37.333	14.331	37.408	1.733	2415.300
F Between treatments	0.050	0.090	0.120	0.060	0.070
LSD 5%	-	-	-	-	-

Where: T_1 to T_{10} treatments of the mulberry trees canava-2 included the control treatment which intercropping UV- treated Narcissus bulbs planted in-between mulberry rows; (*) significant at 0.05, (**) highly significant at 0.01.

Table 9: Effect of intercropping irradiated *Narcissus tazitta* on mulberry, *Morus alba* var. Canava-2 trees on macro and micro elements in mulberry leaves.

Character / Treatment	Moisture %	N%	P%	K%	Iron mg.kg^{-1}	Zinc mg.k^{-1}	Manganese mg.kg^{-1}	Copper mg.kg^{-1}
T_1	63.580	3.380	0.220	1.050	100.010	19.080	49.210	16.570
T_2	64.200	3.330	0.230	1.150	112.000	21.310	52.620	17.820
T_3	63.220	3.490	0.240	1.190	114.210	23.500	55.710	19.010
T_4	64.220	3.780	0.250	1.230	121.530	25.000	55.800	20.000
T_5	64.000	3.840	0.250	1.250	137.600	25.920	56.030	21.900
T_6	64.200	3.290	0.270	1.290	149.000	27.020	56.210	23.000
T_7	64.000	3.960	0.290	1.330	163.110	28.110	56.930	24.020
T_8	65.000	4.100	0.310	1.360	166.250	29.000	57.410	25.390
T_9	65.200	3.930	0.240	1.200	160.630	26.740	56.440	22.650
T_{10}	65.000	3.810	0.220	1.160	150.070	25.090	55.610	19.320
F Between treatments	64.262	3.690	0.250	1.220	137.440	25.080	55.190	20.970
LSD 5%	0.64	0.230	0.63	0.090	56.760**	2.570*	0.600	0.480

Where: T_1 to T_{10} treatments of the mulberry trees canava-2 included the control treatment which intercropping with UV- treated *Narcissus* bulbs planted in-between mulberry rows; (*) significant at 0.05, (**) highly significant at 0.01.

No any significant differences between intercropping mulberry and control in larval mortality, cocooning percentage, cocoon/Liter, pupation ratio, cocoon weight and cocoon shell ratio. In contrary the 5th and total larval durations, cocoon and pupa weight, and silk productivity recorded highly significant differences between treatments. The previous data are agreeing with Islam *et al*. (2023) [6] who described that, intercropping treatments, were better in the characters of the weight of larvae, cocoon weight, shell weight, cocoon shell ratio, highest filament length, renditta and cocoon productivity/100 dfls in intercropping mulberry chickpea, pea, grasspea, mugbean, than the sole mulberry.

Table 11 showed the impact of intercropping irradiated *Narcissus tazitta* on mulberry trees of the interactions between treatments, and sex on the mulberry silkworm, *B. mori* L. characters. All registered data showed non-

significant differences between intercrops treatments and sole mulberry plant for weight of full cocoon, cocoon shell, pupa, and adult weight, also cocoon sell ratio and silk productivity for females and males. These data are go in line with the data proved by Mahmoud and Hosny, (2002) [58] they noted that, growing mulberry with vegetables does not any adverse effect on the silkworm larvae *Bombyx mori* L. Also, Rajegowda *et al*. (2020) [68] who mentioned that, the intercropping will enhance the profit of sericulture output along with the sericulture activities. Growing cowpea as intercrop in tree mulberry given more enhancing in the silkworm characters such as larval, cocoon, and pupa, weight. From the previous results the intercropping with mulberry fields enhanced the profit of sericulture activities with along with silkworm characters which leads to efficiency the land use and mulberry fields. Intercropping seasonal plants with other crops could have a lot of potential because it helps rearers realize the full potential of the crop and guarantees efficient use of land resources. Also, Shashidhar *et al*. (2022) [65] noted that, cropping system mulberry trees with ragi, groundnut, and bean resulted that, no significant difference in the growth parameters and leaf yield of mulberry. Intercrop tree mulberry with bean was the superior output. Singhvi and Katiyar (2009) [69] noted that, the intercropping mulberry trees with garlic, onion, carrot gave the best results than mulberry as sole crop.

Conclusion

Sericulture has become a good source for economic outcome of rearers. Intercropping with mulberry trees is the effective method to raise the outcome. The intercropping in mulberry fields with different plants and crops is an effective way to enhance the land use. Among all the tested treatments, pre-planting UV-C lamp irradiation for 2 h per day over three consecutive days (UV 2h 3-doses; 7.20 J cm^{-2}) proved to be the most effective, resulting in the greatest improvements in vegetative growth, floral quality, bulb productivity, and the accumulation of free amino acids and phenolic compounds, without adversely affecting the biological performance of the silkworm (*Bombyx mori* L.). Therefore, pre-planting UV-C lamp irradiation for 2 h per day over three consecutive days (UV 2h lamp 3-doses; 7.20 J cm^{-2}) is strongly recommended as an efficient, environmentally friendly, and sustainable bio stimulatory treatment for enhancing the performance of *Narcissus tazetta* bulbs and improving the productivity and economic returns of integrated mulberry–sericulture systems.

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