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BIOCHEMICAL CHANGES IN MICROCLONALLY PROPAGATED POPLARS UNDER ELEVATED UV-B RADIATION

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Background. Fast-growing poplar plantations are a promising source of woody biomass and biologically active compounds – chlorophyll, phenolics, flavonoids, and salicylic acid. However, their physiological tolerance to acute ultraviolet B radiation (UV-B) remains poorly understood.

Materials and Methods. Highly productive hybrid poplar *P. pyramidalis* × *P. laurifolia* cv. 'Novoberlinska-3' was exposed to UV-B radiation at an irradiance of 3.35 W/m^2 for 85 min, resulting in a total dose of 17 kJ/m^2. Chlorophyll content was determined using an MPM-100 multipigment fluorimeter on the first day, at intermediate periods from two to 33 days, and then 77 days after UV-B irradiation to assess short-term and long-term changes in the pigment apparatus. Flavonoid, total phenolic, and salicylic acid content were analyzed spectrophotometrically on the first and 33rd days after irradiation. In addition, stem height was assessed as an integral indicator of growth and development.

Results. UV-B irradiation caused a rapid increase in chlorophyll content immediately after irradiation, as well as a subsequent increase at later stages over a period of 33 to 77 days, indicating the possibility of long-term adaptive changes in the photosynthetic apparatus. A sharp increase in flavonoid and salicylic acid contents was observed within the first day after irradiation, consistent with the early activation of UV-sensitive signaling pathways. Total phenolic content in the experimental plants remained stable, while in the non-irradiated group, their levels decreased by almost half, possibly indicating adaptive stabilization of the antioxidant system in irradiated plants. Stem height remained unchanged, indicating no growth retardation.

Conclusions. The poplar clone 'Novoberlinska-3' showed high physiological stability under acute UV-B irradiation (17 kJ/m^2), combining rapid metabolic responses with long-term adaptive changes in pigment and phenolic profiles. The maintenance of growth and photosynthetic activity highlights its resilience to short-term UV-B stress and confirms the adaptive potential of poplars under fluctuating UV-B levels.

Keywords: UV-B radiation, Poplar (*Populus*), secondary metabolites, salicylic acid, phenolics, flavonoids

INTRODUCTION

The state of the stratospheric ozone layer largely determines the amount of ultraviolet radiation reaching the Earth's surface and shaping terrestrial ecosystems. In the second half of the 20th century, substantial ozone depletion increased UV-B irradiance in mid- and high-latitude regions (McKenzie *et al.,* 2011). The implementation of the Montreal Protocol halted further decline, and satellite observations now indicate a gradual, though spatially heterogeneous, recovery of the ozone layer (Bernhard *et al.,* 2023). Nevertheless, regional differences in cloud cover, aerosols, and pollution cause local UV level deviations from global trends, making it essential to investigate plant responses to UV radiation under diverse environmental conditions.

UV-B radiation is a key abiotic factor influencing plant physiology by acting as both a stressor and a regulatory signal integrated with UV-A, visible light, and temperature (Bornman *et al.,* 2019; Yadav *et al.,* 2020). Plants perceive UV-B through the UV RESISTANCE LOCUS 8 (UVR8) photoreceptor, which activates a transcriptional cascade involving CONSTITUTIVELY PHOTOMORPHOGENIC 1 (COP1), ELONGATED HYPOCOTYL 5 (HY5), HY5 HOMOLOG (HYH), REPRESSOR OF UV-B PHOTOMORPHOGENESIS 1 and 2 (RUP1/2), and MYELOBLASTOSIS (MYB) transcription factors (Podolec *et al.,* 2021). This pathway regulates photomorphogenesis, seedling development, stomatal patterning, and stress acclimation, while interacting with auxin, gibberellin, brassinosteroid, and salicylic acid signaling (Xie *et al.,* 2019). Excessive UV-B damages DNA, proteins, and membrane lipids, induces reactive oxygen species (ROS), disrupts the cell cycle, impairs reproductive development (Bornman *et al.,* 2019), and alters nitrogen metabolism by affecting pigment composition, enzyme activity, and nitrogen allocation (Kataria *et al.,* 2014; Klem *et al.,* 2022). One of the central protective mechanisms against UV-B involves the synthesis and accumulation of phenolic compounds. These metabolites, produced mainly via the phenylpropanoid pathway, include phenolic acids, lignin precursors, flavonoids, and other polyphenols (Naikoo *et al.,* 2019). Flavonoids – particularly flavonols and anthocyanins – are among the most effective UV screens, absorbing radiation in the 250–270 nm and 335–360 nm ranges (Patil *et al.,* 2024). They accumulate in epidermal tissues, where they limit UV penetration, protect DNA and membranes, and neutralize ROS (Csepregi & Hideg, 2018). Numerous studies confirm that UV exposure enhances flavonoid biosynthesis across species, namely in wheat (Kataria *et al.,* 2012), soybeans (Zhang *et al.,* 2014), lettuce (Zhang *et al.,* 2023), grapes (Martínez-Lüscher *et al.,* 2014), *Silene littorea* (Del Valle *et al.,* 2020), and peach and cherry fruits (Santin *et al.,* 2019; Şahin *et al.,* 2021). UV-induced activation of phenylpropanoid enzymes, including phenylalanine ammonia-lyase and chalcone synthase, has also been documented in legumes (Wang *et al.,* 2023; Li *et al.,* 2024).

Salicylic acid (SA), a low molecular weight phenolic phytohormone, plays a crucial role in regulating plant development and stress responses. While its function in pathogen defense is well established (Loake & Grant, 2007), increasing evidence highlights its involvement in UV-B responses (Hara *et al.,* 2012; Wani *et al.,* 2017). UV-B-induced ROS stimulate SA biosynthesis via the isochorismate and phenylalanine pathways (Chen *et al.,* 2009; Salinas *et al.,* 2024). Elevated SA levels enhance antioxidant defenses by activating superoxide dismutase, catalase, and glutathione peroxidase, as well as promoting the accumulation of low molecular weight antioxidants (Wani *et al.,* 2017). However, SA effects are dose-dependent: optimal concentrations improve UV tolerance, whereas excessive levels may intensify oxidative stress. Experimental studies show that UV-B increases SA content in barley and enhances cross-tolerance to drought (Bandurska & Cieslak, 2013). In peas, exogenous SA mitigated UV-B-induced growth inhibition (Martel & Qaderi, 2016), while in tomatoes UV exposure strengthened SA-dependent resistance to *Pseudomonas syringae* (Escobar-Bravo *et al.,* 2019).

UV radiation also modulates plant growth, biomass accumulation, and nitrogen metabolism. UV-B typically reduces leaf area, biomass, and yield due to damage to the photosynthetic apparatus and pigment degradation, whereas UV-A may exert stimulatory or inhibitory effects depending on species and conditions (Verdaguer *et al.,* 2017; Sharma *et al.,* 2017). In barley, exposure to UV-B under high photosynthetically active radiation (PAR) reduced leaf length and increased the root-to-shoot ratio (Singh *et al.,* 2015; Klem *et al.,* 2022). In legumes, exclusion of UV components enhanced root growth, nodulation, and nitrogenase activity, indicating that natural UV can limit symbiotic nitrogen fixation (Baroniya *et al.,* 2014; Sharma & Guruprasad, 2012). In rice, elevated UV-B reduced biomass and disrupted nitrogen distribution, whereas higher temperature partially compensated for these effects (Li *et al.,* 2026).

Members of the Salicaceae family, particularly *Salix* and *Populus*, are highly valued for their rapid growth, high biomass productivity, and rich secondary metabolite profiles, making them important for bioenergy, phytoremediation, and pharmacological applications (Roviello 2025; Tawfeek *et al.,* 2021). Interspecific willow hybrids demonstrate high biomass yield, bark production, and salicin content, combining value as bioenergy feedstocks and sources of bioactive compounds (Warmiński *et al.,* 2021; Guarino *et al.,* 2018; Jang *et al.,* 2023). Poplars and willows thus represent ecologically resilient woody species whose biochemical plasticity under UV-B stress remains insufficiently characterized, despite their high ecological and economic importance.

Therefore, investigating biochemical changes in poplar under UV-B stress is essential for understanding the mechanisms of stress tolerance and adaptation in woody plants of high ecological and economic importance.

MATERIALS AND METHODS

Plant material and microclonal propagation. A highly productive hybrid poplar clone, 'Novoberlinska-3' (*Populus pyramidalis* × *P. laurifolia*), was used as the experimental material for microclonal *in vitro* culture propagation. Poplar explants were cultured on a medium containing Murashige and Skoog (MS) basal salt (2.18 g/L), sucrose (20 g/L), L-glutamine (0.2 g/L), myo-inositol (0.1 g/L), MES (0.26 g/L), 500 FV vitamins (0.1 g/L), agar (7.5 g/L), and indole-3-butyric acid (IBA, $0.1 \cdot 10^{-3}$ g/L).

Acclimatization and cultivation in soil. Well-developed poplar plantlets were carefully removed from the glass test tubes, cleaned of agar residues, rinsed with distilled water, and transplanted into Jiffy-7 peat pellets. The seedlings were placed in plastic bags for gradual acclimatization, and rooting occurred over two months. Plants with well-developed root systems, along with the peat pellets, were transplanted into 1-liter pots filled with a soil mixture containing chernozem, peat, and vermiculite at a ratio of 10:10:1.5 (by volume). After transplanting, the plants were grown under greenhouse conditions for 1 month at a constant temperature and humidity; watering was performed every 2–3 days to avoid both moisture deficiency and excess.

UV-B irradiation. The acclimatized plants were divided into two groups: a control group and an experimental group exposed to UV-B radiation at a dose of 17 kJ/m^2 using a TL 20W/12 RS ultraviolet-B lamp (Philips, Heerlen, The Netherlands) with an irradiance of 3.35 W/m^2 for 85 min. Each group consisted of seven plants. All plants from the experimental and control groups were kept indoors under identical temperature and humidity conditions. Plants were watered every 2–3 days, ensuring neither drying out nor overwatering.

Measurement of relative chlorophyll content. The relative chlorophyll content was determined using a portable multipigment fluorometer MPM-100 (Opti-Sciences, Hudson, USA). To minimize the effect of leaf age, measurements were performed on leaves between the 3rd and 6th nodes from the apical bud. The device uses 720 and 850 nm LEDs to measure leaf transmittance, and relative chlorophyll content was calculated as the T850/T720 transmittance ratio (Yatsiv *et al.*, 2025). Chlorophyll content was measured repeatedly throughout the experiment, whereas destructive sampling for biochemical analyses was performed on days 1 and 33 to characterize early and established physiological responses to UV-B exposure. Chlorophyll measurements were taken nine times: immediately before and after UV-B irradiation (day 0), six times during the following 33 days, and once on day 77, at the end of the growing season, to evaluate long-term and seasonal responses. Stem height was measured at the end of the experiment.

Collection and preparation of samples for light spectrophotometry. Leaf samples were collected on days 1 and 33 after irradiation, with three leaves sampled per plant. Composite samples representing all plants within each treatment were dried at room temperature to constant weight (7 days). Dried leaves (50 mg) were ground for 5 min in Eppendorf tubes using a digital disruptor Genie (Scientific Industries, USA). The material was extracted with 2.0 mL of 96 % ethanol by homogenization for 15 min and centrifugation at 15,000 *g* for 15 min. The supernatant was used for all subsequent analyses. Extraction with 96 % ethanol followed the salicylic acid protocol (Warrier, 2013), and the same extract was used for the determination of total phenolics and flavonoids. All spectrophotometric measurements were performed in at least three technical replicates using a Shimadzu UV-1280 spectrophotometer (Shimadzu, Japan) and 10-mm glass cuvettes.

Determination of total phenols by the Folin–Ciocalteu method. Total phenolic content (TPC) was determined by mixing 0.05 mL of leaf extract with 0.25 mL of 10-fold diluted Folin–Ciocalteu reagent, 0.50 mL of distilled water, and 0.75 mL of Na_2CO_3 solution. After incubation for 2 h in the dark at 24 °C, absorbance was measured at 760 nm. TPC was quantified using a gallic acid calibration curve and expressed as milligrams of gallic acid equivalents per gram of dry weight (mg GAE/g DW) (Sokolova *et al.,* 2024).

Determination of flavonoids. Total flavonoid content (TFC) was determined by adding 0.25 mL of 2 % $AlCl_3$ solution (in 50 % ethanol) and 1.25 mL of 70 % ethanol to

0.05 mL of leaf extract. The reference solution contained 0.25 mL of extract, one drop of diluted acetic acid, and 1.25 mL of ethanol (Sokolova *et al.,* 2024). After incubation for 20 min at room temperature, absorbance was measured at 410 nm. TFC was quantified using a quercetin calibration curve and expressed as milligrams of quercetin equivalents per gram of dry weight (mg QE/g DW).

Determination of salicylic acid. Salicylic acid was determined according to R. R. Warrier *et al.* (2013) by complex formation with Fe^{3+} ions. Briefly, 0.10 mL of leaf extract was mixed with 1.50 mL of 0.1 % $FeCl_3$ solution in 96 % ethanol and incubated for 20 min at room temperature. Absorbance was measured at 540 nm against the corresponding blank. Salicylic acid concentration was calculated from a calibration curve and expressed as milligrams per gram of dry weight (mg/g DW).

Statistical analysis. Data processing and calculation of physiological and biochemical criteria were executed using the OriginPro 2019 software package (OriginLab) alongside MS Excel. The Shapiro–Wilk test was applied to confirm that the investigated samplings conformed to a normally distributed general population. Intergroup variances were evaluated by employing Student's t-test for independent samples, accounting for either equal or unequal variances. Quantitative values are stated as the mean ± standard error of the mean (SE). For all statistical tests, a p-value of less than 0.05 was chosen as the threshold for statistical significance, where n represents the number of individual measurements or analytical replicates as specified in the figure captions.

RESULTS AND DISCUSSION

On day 0, before UV treatment, the relative chlorophyll content was identical in both the control and experimental groups (0.32 ± 0.04; **Fig. 1**). In contrast, immediately after UV-B exposure (day 0), irradiated poplars exhibited a significant increase in relative chlorophyll content, which persisted over the subsequent few days. During the period of 23–30 days after irradiation, the differences between the experimental and control groups were not statistically significant. However, during the period of 33–77 days after irradiation, plants in the experimental group showed an increased relative chlorophyll content compared to plants in the control group.

The TPC in poplar leaves decreased significantly by day 33 of the experiment. On the first day after irradiation, the treated plants showed lower TPC in the leaves relative to the control; however, by day 33, the UV-irradiated trees had a higher content of phenolics relative to the control plants (**Fig. 2*A***). At the same time, the TPC in the control group decreased by almost half on day 33 of the experiment. Changes in the control plants between sampling dates most likely reflect normal developmental and seasonal adjustments associated with leaf maturation and plant development rather than treatment effects.

On the 1st day after irradiation, an almost threefold increase in TFC was observed in the experimental group of poplar compared to the control (**Fig. 2*B***). On day 33 after irradiation, the TFC increased significantly in both groups; furthermore, no statistically significant differences were found between the experimental and control groups on day 33. SA content in the control poplar plants remained unchanged. However, on the 1st day after irradiation, experimental plants exhibited a short-term increase in SA content compared to the control (**Fig. 2*C***). Throughout the experiment, no statistically significant differences in stem height were observed between the experimental and control groups.

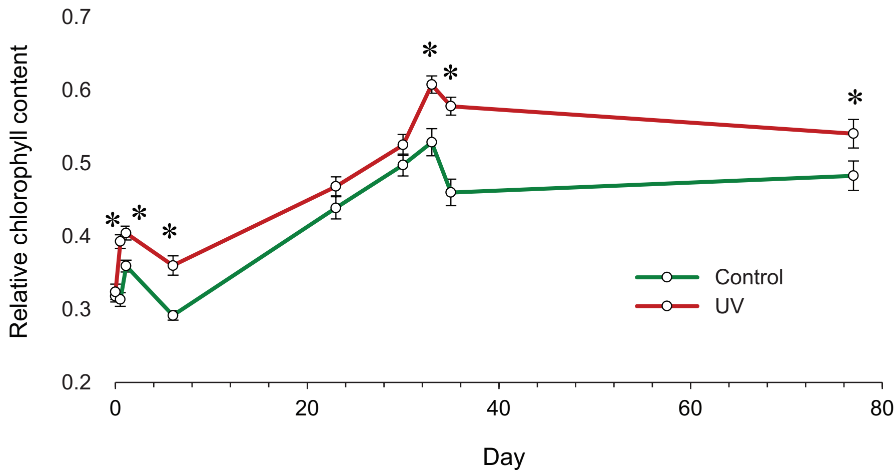

Fig. 1. Changes in relative chlorophyll content in the leaves of 'Novoberlinska-3' poplar after acute UV-B irradiation. * – differences between UV-B irradiated and control variants are significant according to Student's *t*-test for independent samples ($P < 0.05$); n = 28 measurements

The results obtained indicate that the reactions of the 'Novoberlinska-3' poplar to acute UV-B irradiation are distinctly time-dependent, combining short-term metabolic changes with long-term adaptive adjustments. Plant responses to UV irradiation exhibit a pronounced temporal pattern: changes in the relative content of chlorophyll and secondary metabolites developed gradually throughout the entire observation period. The contents of chlorophyll, TPC and TFC were time-dependent, whereas the effect of ultraviolet radiation manifested itself primarily as short-term shifts during the first day and long-term changes in later stages.

The current experiment revealed a clear and consistent stimulatory impact of the 17 kJ/m^2 dose on chlorophyll content, as irradiated plants consistently exceeded the non-irradiated control group at most measurement points. The increase in chlorophyll content immediately after irradiation and its subsequent rise on days 33–77 is consistent with data indicating that moderate doses of ultraviolet radiation have a stimulating or neutral effect on the pigment system of woody plants. For example, J. Ren *et al.* (2010) showed that elevated UV levels increased the chlorophyll and carotenoid content in *Populus cathayana* and *Populus kangdingensis*. In our experiments, a dose of 17 kJ/m^2 did not decrease chlorophyll content and stem height remained stable, indicating an absence of morphological abnormalities and the relative resistance of poplar to acute ultraviolet radiation.

Studies on other *Populus* species further support the view that UV-B triggers coordinated adjustments in phenolic metabolism and stress-response pathways. Wong (2022) demonstrated that moderate to high UV-B exposure induces the accumulation of flavonoids, anthocyanins, and lignin precursors in both natural and transgenic *Populus* lines, including those with impaired lignin biosynthesis. This highlights the metabolic flexibility of the phenylpropanoid pathway acclimation in UV-B-irradiated plants. Similarly, the UV-B pre-treatment activates cross-adaptation mechanisms in hybrid poplar, enhancing the expression of genes involved in metal uptake and detoxification and thereby modifying physiological responses to subsequent cadmium stress (He *et al.,* 2023). In addition, Gourlay (2022) provided evidence that condensed tannins act as potent plant antioxidants that protect poplar leaves from oxidative damage under drought and UV-B exposure, maintaining PS II function and reducing ROS accumulation. Together, these studies emphasize that *Populus* species rely on diverse phenolic-based mechanisms to mitigate UV-B-induced oxidative stress, consistent with the phenolic stabilization and preserved photosynthetic performance observed in our experiment.

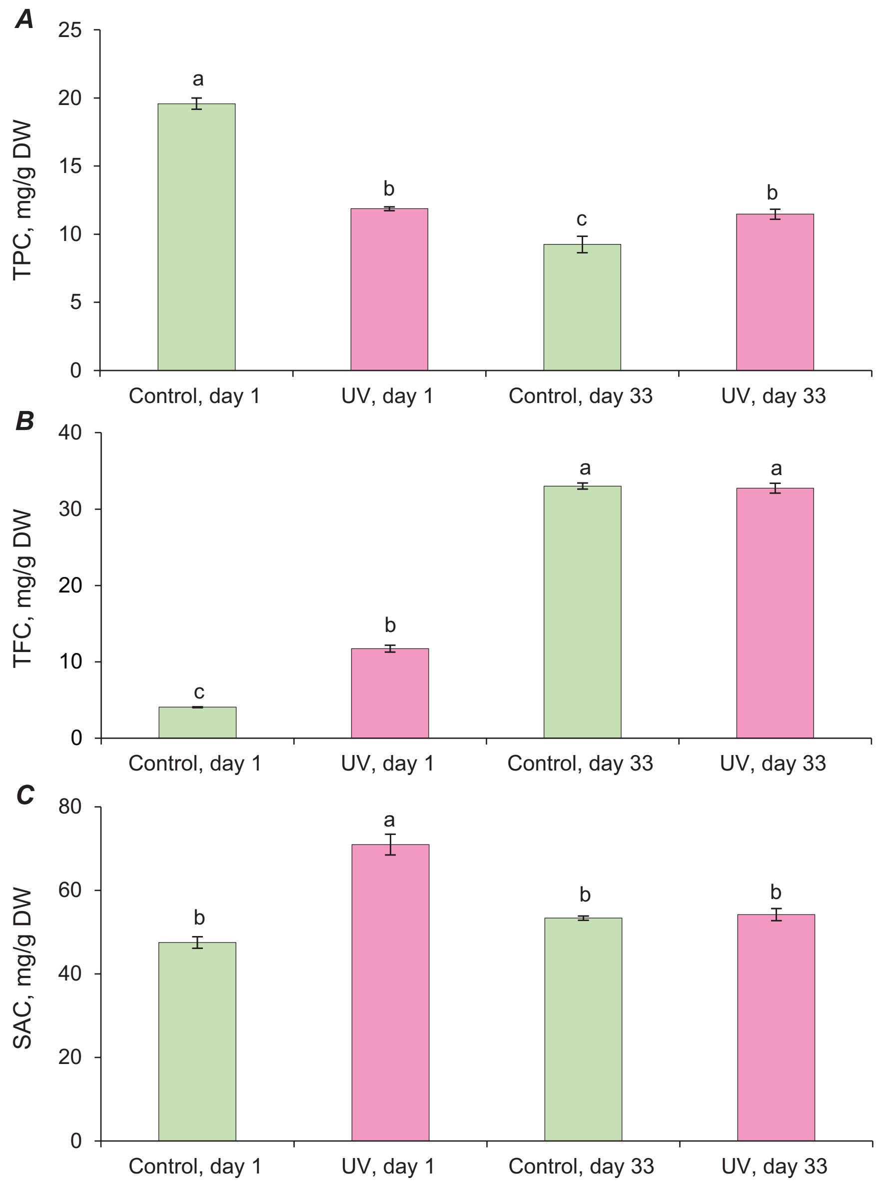

Fig. 2. Effect of UV-B irradiation on (***A***) total phenolic content (TPC), (***B***) total flavonoid content (TFC) and (***C***) salicylic acid content (SAC) (mg/g dry weight (DW) in the leaves of 'Novoberlinska-3' poplar on the 1st and 33rd days after treatment. Different letters denote statistically significant differences between groups based on Student's *t*-test for independent samples (P < 0.05); n = 3 analytical replicates per group

The short-term increase in TFC on the first day after irradiation is consistent with rapid activation of the phenylpropanoid pathway. In peach fruit, UV irradiation induced the expression of *chalcone synthase* (*CHS*), *flavanone 3-hydroxylase* (*F3H*), *dihydroflavonol 4-reductase* (*DFR*), and *MYELOBLASTOSIS* (*MYB*) transcription factors within 6–24 h (Santin *et al.,* 2020). In our case, the increase in TFC on the first day may be associated with the early activation of the UV RESISTANCE LOCUS 8 (UVR8)-dependent signaling pathway and reactions related to the formation of reactive oxygen species, which, according to the literature, stimulate the synthesis of phenolic compounds. At the same time, on day 33, TFC increased in plants of both groups, which likely reflected seasonal changes in metabolism.

Interestingly, in our study the TPC did not increase under UV exposure but remained stable, whereas in the control it decreased by nearly half. This can be explained by metabolic competition between flavonoids and other phenolic compounds from the shikimate pathway for the synthesis substrate from photoassimilates, which prevented a seasonal decrease in phenolic content and may be a sign of adaptive stabilization of the antioxidant system. *In vitro* cultivation causes an increase in polyphenolic compounds and the total amount of flavonoids in *Crambe aspera* plants (Pushkarova *et al.,* 2019). Similar responses have been described in *Salix myrsinifolia*, where UV-B exposure promoted the accumulation of flavonoids, condensed tannins, and salicylates in plants of both sexes, although females exhibited a significantly stronger response, suggesting sex-specific differentiation in UV tolerance (Randriamanana *et al.,* 2015).

The short-term increase in SA content observed during the first day after irradiation is consistent with data on the role of this phytohormone as an early signaling component of the stress response. In our case, however, the increase in SA was shortlived and superimposed on a presumably high constitutive background typical of poplars (Ullah *et al.,* 2023; Zhang *et al.,* 2024). This suggests a rapid but controlled activation of defense signaling rather than a shift toward chronic stress. The absence of persistent changes in SA content, together with the absence of growth inhibition or morphological abnormalities, is consistent with the idea that SA in Salicaceae family plants promotes flexible, lineage-specific acclimation to stress rather than long-term trade-offs between growth and defense.

Salicylic acid metabolism in poplars and other members of the Salicaceae family has several unique features that differ from herbaceous model plants. Poplars mainly rely on the phenylalanine ammonialyase pathway for the production of SA, while the isochorismate pathway plays only a minor role. This results in naturally higher basal levels of SA and a distinct regulatory system compared to *Arabidopsis* (Ullah *et al.,* 2023). SA and jasmonic acid often rise together in stress-resistant poplar genotypes, suggesting coordinated rather than antagonistic signaling (Zhang *et al.,* 2024). Genetic experiments further support this connection: disruption of the glycosyltransferase UGT71L1, which participates in salicinoid biosynthesis, leads to a strong increase in both SA and jasmonic acid contents, demonstrating a close metabolic link between these compounds (Gordon *et al.,* 2022). Such findings highlight that SA regulation in the Salicaceae family is lineage-specific and may contribute to the stable growth and stress tolerance observed in our study.

Our study revealed no reduction in stem height or other morphometric parameters, which is consistent with data on the resistance of tree species to ultraviolet radiation (Ren *et al.,* 2010; Roviello, 2025), the poplar exhibits significantly higher tolerance to ultraviolet radiation than herbaceous crops (Podolec *et al.,* 2021). This also confirms that a dose of 17 kJ/m^2 does not exceed the threshold at which structural damage to the photosynthetic apparatus begins.

Thus, the results indicate that the responses of the 'Novoberlinska-3' poplar to UV-B radiation combine short-term metabolic changes (increases in TFC and salicylic acid content) with long-term adaptive reorganizations (increased chlorophyll content and stabilization of the phenolic pool). The absence of negative effects on growth and the preservation of functional activity in the photosynthetic apparatus indicate this clone's high tolerance to acute UV exposure.

CONCLUSIONS

According to the data obtained, the time factor significantly influenced the dynamics of the physiological and biochemical parameters in the leaves of the 'Novoberlinska-3' poplar clone. The relative chlorophyll content exhibited a biphasic response: an increase was observed immediately after irradiation and during the first few days, whereas between 23 and 30 days, the difference between the variants leveled off. At later stages (33–77 days), the chlorophyll content rose again in the irradiated plants, suggesting the development of long-term adaptive changes in the photosynthetic apparatus. Regarding TPC, contrasting changes over the 33-day period were observed: in control plants, TPC decreased by nearly half by day 33, whereas in irradiated plants, it remained stable relative to the first day after irradiation. This may indicate the maintenance of phenolic composition under acute UV-B radiation, which potentially ensures the preservation of antioxidant activity in the leaves of the 'Novoberlinska-3' poplar clone during the later stages of the growing season. The TFC was characterized by a sharp, short-term increase on the first day after irradiation, consistent with known photoprotective reactions in plants. By day 33, TFC increased in plants of both groups, and no statistically significant differences were found between treated and control plants, which may be related to seasonal changes in flavonoid metabolism.

Salicylic acid content in the experimental plants also increased only during the early stage, which may reflect the early activation of UV-B-sensitive signaling mechanisms, in particular the UVR8-dependent pathway and reactions associated with the formation of reactive oxygen species, which may stimulate salicylic acid synthesis.

Throughout the experiment, no statistically significant differences in stem height were found between control and irradiated plants, indicating the absence of growth inhibition under a dose of 17 kJ/m^2.

The responses of the poplar clone 'Novoberlinska-3' to UV-B radiation were characterized by a combination of short-term metabolic shifts (increased flavonoid and salicylic acid content) and long-term adaptive changes (stabilization of the phenolic pool and an increase in chlorophyll content). The absence of a negative effect on morphometric parameters and the preservation of the functional activity of the photosynthetic apparatus indicate the high tolerance of this clone to acute UV-B exposure at the applied dose.

COMPLIANCE WITH ETHICAL STANDARDS

Conflict of Interest: the authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Animal Rights: this article does not contain any studies with animal subjects performed by any of the authors.

Human Rights: this article does not contain any studies with human subjects performed by any of the authors.

AUTHOR CONTRIBUTIONS

Conceptualization, [N.R.; N.K.; V.Ya.]; methodology, [V.Zh.; I.Zh.; N.K.]; validation, [V.Zh.; I.Zh.; V.Ya.]; formal analysis, [N.K.; V.Ya.; V.Zh.].; investigation, [V.Ya.; V.Zh.; I.Zh.]; resources, [V.Zh.; I.Zh.; N.K.; N.R.]; data curation, [V.Ya.; N.K.]; writing – original draft preparation, [V.Ya.; I.Zh.; V.Zh.]; writing – review and editing, [V.Ya.; N.K.; I.Zh.; N.R.; V.Zh.]; visualization, [V.Ya.; N.K.]; supervision, [N.K.]; project administration, [N.K.; N.R.]; funding acquisition, [-].

All authors have read and agreed to the published version of the manuscript.

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БІОХІМІЧНІ ЗМІНИ У МІКРОКЛОНАЛЬНО РОЗМНОЖЕНИХ ТОПОЛЬ ЗА ДІЇ ПІДВИЩЕНОГО РІВНЯ УФ-В ВИПРОМІНЮВАННЯ

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Обґрунтування. Швидкорослі плантації тополь розглядають як перспективне джерело деревної біомаси та біологічно активних сполук – хлорофілів, фенолів, флавоноїдів і саліцилової кислоти. Водночас їхня фізіологічна стійкість до гострої дії ультрафіолетового випромінювання діапазону В (УФ-В) залишається недостатньо вивченою.

Матеріали та методи. Високопродуктивний гібрид тополі *Populus pyramidalis* × *Populus laurifolia* клону “Новоберлінська-3” опромінювали УФ-В з інтенсивністю 3,35 Вт/м² протягом 85 хв, що забезпечило сумарну дозу опромінення 17 кДж/м². Вміст хлорофілу визначали за допомогою мультипігментного флуориметра MPM-100 через 1 добу, у проміжні періоди від 2-х до 33-х діб, а також на 77-му добу після опромінення для оцінки короткочасних і довготривалих змін пігментного апарату. Вміст флавоноїдів, загальних фенолів і саліцилової кислоти аналізували спектрофотометрично на 1-шу і 33-тю добу після опромінення. Додатково оцінювали висоту пагонів як інтегральний показник росту й розвитку.

Результати. УФ-В опромінення спричинило швидке зростання вмісту хлорофілу одразу після його дії, а також подальше підвищення на пізніших етапах – у період від 33-х до 77-ми діб, що свідчить про ймовірність довготривалих адаптивних змін у фотосинтетичному апараті. Протягом першої доби після опромінення спостерігали різке збільшення вмісту флавоноїдів і саліцилової кислоти, що узгоджується з ранньою активацією УФ-чутливих сигнальних шляхів. У дослідних рослин рівень загальних фенолів залишався стабільним, тоді як у неопроміненій групі він знижувався майже удвічі, що може свідчити про адаптивну стабілізацію антиоксидантної системи в опромінених рослин. Висота пагонів не змінювалася, що вказує на відсутність пригнічення росту.

Висновки. Клон тополі “Новоберлінська-3” продемонстрував високу фізіологічну стійкість до гострого УФ-В опромінення (17 кДж/м²), поєднуючи швидкі метаболічні реакції з довготривалими адаптивними змінами пігментного та фенольного профілів. Збереження росту й фотосинтетичної активності підкреслює його резистентність до короткочасного УФ-В стресу та підтверджує адаптивний потенціал тополь за умов коливань рівня УФ-В.

Ключові слова: УФ-В випромінювання, тополя (*Populus*), вторинні метаболіти, саліцилова кислота, феноли, флавоноїди

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