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Effect of UV exclusion and AMF inoculation on photosynthetic parameters of *Glycine max*

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Abstract

The study aims to understand the effect of UV exclusion and arbuscular mycorrhizal fungi (AMF) inoculation on the photosynthetic parameters of soybean. The study was conducted in nursery bags and plants were grown under iron mesh covered with UV cut-off filters. The plants grown under the exclusion of UV with AMF inoculation (I) showed higher photosynthetic pigments, carbonic anhydrase activity, reduced internal CO_2 concentration, enhanced transpiration rate, and stomatal conductance as well as improved photosynthetic rate over uninoculated plants. Moreover, –UVB+I and –UVAB+I plants exhibited an increased performance index, the activity of the water-splitting complex on the donor side of PSII, and the concentration of active PSII reaction centers per excited cross-section. Overall, UV-excluded and AMF-inoculated plants showed the highest quantum yield of PSII and rate of photosynthesis. Our study will pave the way for future investigation to identify the possible role of UV exclusion and AMF in improving the photosynthetic performance for better yield of soybean.

Keywords: arbuscular mycorrhizal fungi; photosynthesis; photosystem II; UV exclusion.

Introduction

UV radiation is the nonionizing region of the electromagnetic spectrum emitting from the sun. There are three classes of UV radiation: UV-C (200–280 nm), UV-B (280–315 nm), and UV-A (315–400 nm) (Kataria *et al.* 2014). Although UV-B radiation has important regulatory, photomorphogenic, physiological, and developmental

Highlights

- UV exclusion/AMF inoculation has a synergistic effect on the growth and pigments of soybean
- AMF with UV exclusion improve PSII efficiency and photosynthates synergistically
- Plants showed better photosynthetic performance to trigger yield with AMF and UV exclusion

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Abbreviations: AMF – arbuscular mycorrhizal fungi; Car – carotenoids; Chl – chlorophyll; DAE – day after emergence; *E* – transpiration rate; FC – filter control; FM – fresh mass; F_v/F_m – maximum quantum yield of PSII; F_v/F_0 – activity of PSII; OC – open control; $PI_{(ABS)}$ – performance index on absorption basis; RC/CSm – concentration of active PSII reaction centers per excited cross-section; UV – ultraviolet; –UVAB+I – plants grown under UV-A and B excluding filters with AMF inoculation; –UVB+I – plants grown under UV-B excluding filters with AMF inoculation.

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roles (Barnes *et al.* 2023), excessive UV-B radiation is harmful and can lead to photooxidative, cellular, and molecular damage (Bray and West 2005, Ruhland *et al.* 2005). Research from the last two decades suggests that nearly 50% of crops are affected by elevated levels of ambient UV-B (Kakani *et al.* 2003).

Soybean is an annual, self-pollinated, diploid (2n = 2x = 40), eudicot belonging to the family Fabaceae. Recently it has been reported that soybean crop growth and productivity were drastically reduced by the ambient and enhanced UV-B radiations (Kataria *et al.* 2021, Baroniya *et al.* 2023). Despite a rapid upsurge in production and coverage, soybean still suffers adversely on the productivity front. A possible increase in the exploitation of natural resources in the coming decades indicates increasing demand for sustaining the productivity of soybean (Rodrigues *et al.* 2023). This prognostication pushes us to look for alternative methods to increase the soybean yield and the challenge is to produce more soybeans strategically and sustainably. One potential alternative is the integrated use of UV exclusion and AMF (arbuscular mycorrhizal fungi) inoculation for the enhanced photosynthetic performance of soybean which has not yet been investigated.

UV exclusion or attenuation is a method of cutting off the UV radiations from sunlight by using UV filters (Kataria *et al.* 2013). Kataria and Guruprasad (2012) experimented on four cultivars of wheat (*Triticum aestivum* L.) and noted maximum height and biomass accumulation increase at maturity under UV-B exclusion. According to Baroniya *et al.* (2013, 2023), UV-B exclusion improved stem height, leaf area, biomass, and yield parameters of different cultivars of soybean. It was also proposed that the ambient UV-B radiation resulted in the reduced growth, development, and yield of soybean plants due to the production of active oxygen species (Baroniya *et al.* 2013).

Plants can produce diverse secondary metabolites to prevent UV-B penetrating leaf mesophyll, which makes them more resistant to UV than microbes or mammalian cells (Mazza *et al.* 2000). UV radiations stimulate the accumulation of secondary metabolites such as flavonoids, anthocyanins, and methoxy cinnamic acid (Sytar *et al.* 2018, Apoorva *et al.* 2021). The deleterious effect of UV-B on the efficiency of photosynthesis can be attributed to specific reductions in the expression of critical photosynthetic genes (Mackerness *et al.* 1997). The decrease in Rubisco activity (Vu *et al.* 1984, Kataria *et al.* 2013), changes in ion permeability of thylakoid membranes (Doughty and Hope 1973), and lower contents of chlorophyll and carotenoids have been observed in response to UV stress (Kataria *et al.* 2021). There have been well-documented effects of UV radiation on crop plants such as barley (Schmitz-Hoerner and Weissenböck 2003), cotton (Gao *et al.* 2003), oats (Zuk-Golaszewska *et al.* 2003), maize (Barsig and Malz 2000), soybean (Li *et al.* 2002, Kataria *et al.* 2021), and wheat (Kataria *et al.* 2013). It has been shown that the content of chlorophyll (Chl) *a* and *b* dropped in *Phaseolus vulgaris* cultivated under UV-B stress (Michaela *et al.* 2000). UV-radiation stimulated the accumulation of flavonoids, proline, tocopherol, and ascorbate contents in plants (Carletti *et al.* 2003). Many indoor studies have shown that UV-B can harm the three necessary photosynthetic steps: the photophosphorylation reaction, the CO_2 fixation, and stomatal control of CO_2 supply, where PSII appears to be predominantly sensitive (Teramura and Sullivan 1994, Kataria *et al.* 2014). Studies utilizing filters to compare near ambient and reduced UV-B radiation indicate that current UV-B inhibits growth, photosynthesis, and yield of a number of plant species (Albert *et al.* 2005, Ruhland *et al.* 2005, Kataria *et al.* 2013, 2020; Baroniya *et al.* 2023). UV-B largely affects leaf area along with photosynthesis, which leads to a remarkable decrease in biomass accumulation (Kataria *et al.* 2013, 2014, 2021; Baroniya *et al.* 2023). Also, Bredahl *et al.* (2004) indicated decreased photochemical efficiency under ambient UV-B, while net assimilation remained unaffected. The morphological changes, especially reduced leaf area and plant height, were more evident along with lower photosynthetic rate due to UV-B exposure (Rai and Agrawal 2017, Kataria *et al.* 2021). UV exclusion affects positively the soybean plant growth, metabolism, and yield (Kataria *et al.* 2014, 2020, 2021; Baroniya *et al.* 2023).

Mycorrhiza has a symbiotic association with the plants and grows mutualistically with the root and forms a network of hyphae. More than 255 species of AM fungi have been found which offer multiple agricultural benefits (Douds *et al.* 2012, Khan *et al.* 2021). It has been promoted as a 'biofertilizer and bioprotector' endomycorrhiza in sustaining agriculture. AMF not just enhances Chl contents, but also increases the photosynthetic rate in cereal crops (Pepe *et al.* 2018). The contents of nitrogen and phosphorus increased in wheat fields due to AM fungi (Dai *et al.* 2014), which further helps in Chl synthesis. AM fungi increase photosynthetic activity in plants (Amerian *et al.* 2001, Abdel-Fattah *et al.* 2012, Mathur *et al.* 2018). According to Xu *et al.* (2018), maize plants that emerged from AMF-inoculated seeds showed improvement in different gas-exchange parameters, Chl content, light energy-utilization efficiency, and Rubisco activity. To the best of our knowledge, there is not a single report available on the combination of UV-B and AMF effects on plants. Therefore, the aim of the present study is to deploy both the beneficial treatments (*i.e.*, AM fungi inoculation and UV-exclusion method) to study the synergistic effect on growth, photosynthetic pigments, PSII efficiency, dark reaction, carbonic anhydrase activity, and yield of soybean.

Materials and methods

Plant material, inoculation, experimental setup: Seeds of soybean (*Glycine max* (L.) Merr. var. JS-335) were obtained from the Indian Institute of Soybean Research, Indore. They were sown in the nursery (gusseted black polythene) bags (34 × 34 cm), filled with a mixture of coarse sand, black soil, and farmyard manure (1:4:1), and kept under microcosm trial (pot trial) conditions. The experiments were conducted from October 2018 to January 2019 following a completely randomized block design with five replicates for each treatment with three plants in each pot. For our study, AMF-starter soil with AM fungal inoculum (consisting of dominant populations of *Rhizophagus irregularis*, *Funneliformis mosseae*, and *Funneliformis geosporum*) was procured from Microbiology Section, ICAR-Indian Institute of Soybean Research, Indore, India. The starter inoculum was multiplied in pots by using sorghum as the host plant (Agnihotri *et al.* 2021). The mixed inoculum @ 50 g per plot containing 1,000 propagules (spores, hyphae, and infected roots) was applied by the layering method just below the seeds (Sharma *et al.* 2016, Agnihotri *et al.* 2021). The nursery bags were irrigated with water regularly.

Soybean plants were allowed to grow in specially designed UV-exclusion chambers (1.21 m L × 0.91 m W × 1.21 m H) wrapped with polyester cut-off filters (*Garware Polyester Limited*, Mumbai, India) to exclude UV-B (280–315 nm) or UV-A and B (280–400 nm), although transmit all visible wavelengths (400–700 nm). For controls, plants were grown either in cages covered with a polythene filter that transmits all the ambient solar radiation (filter control, FC) or in an open field without any filters, exposed to ambient solar radiation (open control, OC). The *Shimadzu* spectrophotometer (*UV-1800*) was used to measure the transmission characteristics of the UV-B and UV-AB cut-off filters as described previously in Kataria *et al.* (2013) and Baroniya *et al.* (2023). The plants were grown under the UV cut-off filters from seed germination to crop maturity. The solar intensities under all treatments (OC, FC, –UVB, and –UVAB) were used to estimate by a radiometer (*Solar Light PMA 2100*, Glenside, PA, USA). Throughout the experiments, the midday solar irradiance (in OC) was 1,451 μmol(photon) m^{-2} s^{-1}; the decrease in light intensity due to UV-B cut-off filters was 14% [1,240 μmol(photon) m^{-2} s^{-1}]; the decrease in light intensity due to UV-AB cut-off filter was 19% [1,180 μmol(photon) m^{-2} s^{-1}]; and the reduction in light intensity caused by the polythene filter (FC) transmissible to UV was 4% [1,390 μmol(photon) m^{-2} s^{-1}].

Growth parameters and yield: The plant dry mass was measured at the R5 stage (Kezar *et al.* 2023) or 50 d after the emergence of the seedlings (DAE) or pod-initiation stage. The harvested plants were dried at 80°C for 3 d and weighed on the analytical balance.

Leaf area: The leaf area of the 3rd trifoliate leaves was determined at the R5 stage (50 DAE) using leaf area meter (*CI-202* scanning planimeter).

Photosynthetic pigments: Chl *a*, Chl *b*, and carotenoids (Car) were extracted from the third trifoliate leaves and determined by the dimethyl sulfoxide (DMSO) method (Hiscox and Israelstam 1979). Wellburn's equation (Wellburn 1994) was used to calculate the contents of Chl *a*, Chl *b*, and Car. Chl and Car were expressed as mg g^{-1}(leaf fresh mass, FM).

Chlorophyll fluorescence: Chl *a* fluorescence transient exhibited by the dark-adapted (30 min) third trifoliate leaves of soybean was measured by a *Handy PEA* fluorimeter (*Plant Efficiency Analyzer*, *Hansatech Instruments*, King's Lynn, Norfolk). The following JIP-test parameters were measured in the current study: (*1*) the performance index, $PI_{(ABS)} = (RC/ABS) \times \Phi P_0/(1 - \Phi P_0) \times \psi_0/(1- \psi_0)$, where ΦP_0 is for maximal quantum yield for primary photochemistry; ψ_0 is the fraction of electrons transported beyond Q_A^- per exciton trapped by the open reaction centers (RCs) of PSII; (*2*) the F_v/F_m that is connected to the maximum quantum yield of PSII efficiency of the primary photochemical reaction, (*3*) water-splitting complex is represented by F_v/F_0 (Kalaji *et al.* 2016, 2017), and (*4*) RC/CSm, concentration of active PSII reaction centers per excited cross section.

Carbonic anhydrase activity: The activity of carbonic anhydrase (EC 4.2.1.1) in the third trifoliate leaves of soybean was determined by the method described by Li *et al.* (2004). Enzyme activity was distinct as 1 unit = $10(T_0 - T)/T$, in which T and T_0 symbolize the time(s) required for a pH reduction from 8.25 to 6.45, with and without enzyme, correspondingly.

Gas-exchange parameters: Photosynthetic parameters, such as photosynthetic rate, P_N [μmol(CO_2) m^{-2} s^{-1}], conductance by stomata, g_s [mol(H_2O) $m^{-2}s^{-1}$], rate of transpiration, *E* [mmol(H_2O) m^{-2} s^{-1}], and concentration of internal CO_2, C_i [μmol(CO_2) mol^{-1}], of the leaves (fully expanded third trifoliate at 50 DAE) were measured using a portable infrared gas analyzer (*IRGA-LI-6400*, *LI-COR Inc.*, Lincoln, USA). The leaf was fixed into a 6-cm^2 leaf chamber of IRGA and photosynthetic measurements were made under ambient solar radiations on clear sunny days in each treatment, the photosynthetic active radiation (PAR) was 1,000–1,200 μmol(photon) m^{-2} s^{-1} and CO_2 concentration 390–400 ppm.

Yield parameters were taken at maturity (120 DAE) and included the number of seeds per plant.

Statistical analysis: Data of the present study were expressed as means ± SEM and were evaluated by the analysis of variance (*ANOVA*) followed by post hoc *Newman–Keulis* multiple comparison test to show significance using *Prism 4* software for *Windows*, *Graph Pad Software*, *Inc.* (La Jolla, CA, USA) ($^{\#\#\#}$, $^{\#\#}$, and $^{\#}$ indicate significant differences at $P<0.001$, 0.01, and 0.05, respectively, after comparison of uninoculated treatments with OC uninoculated ones and ***, **, and * indicate significant differences at $P<0.001$, 0.01, and 0.05, respectively, after comparison of inoculated treatments with OC uninoculated ones).

Results

Growth parameters: The 3rd trifoliate leaf of soybean was measured for leaf area; it was found that –UVAB uninoculated treatment improved leaf area by 27% and –UVB uninoculated treatment improved leaf area by 15% as compared to OC uninoculated. Among AMF-inoculated treatments, –UVAB+I showed a maximum increase of 37%, followed by UVB+I treatment with an increase of 25% as compared to OC+I. Overall comparison through all the treatments, –UVAB+I was improved by 55% as compared to OC uninoculated (Fig. 1*A*).

There was an increase in plant dry mass by 73% in UVAB-excluded plants with AMF inoculation as compared to OC uninoculated. It was observed that UV exclusion and AMF inoculation led to a significant increase in plant dry mass. Both the factors, UV exclusion and AMF inoculation, played a vital role in the enhancement of plant dry mass accumulation (Fig 1*B*).

Photosynthetic pigments: UV exclusion and AMF inoculum proved helpful for enhancing pigment content in soybean plants. When compared with OC uninoculated control, –UVAB+I showed a 68% increase in the content of Chl *a* (Fig. 2*A*), while Chl *b* (Fig. 2*B*) increased remarkably (58.3%) in plants with –UVAB+I when compared with OC uninoculated. Also, total carotenoids (Fig. 2*C*) increased by 43% in –UVAB+I as compared to OC uninoculated.

Chl fluorescence: $PI_{(ABS)}$ (Fig. 3*A*) is a sensitive indicator to study the energy flow through the reaction center of PSII. Plants with –UVAB+I treatment showed maximum enhancement in PI as compared to OC, indicating lesser stress to plants. F_v/F_m (maximum quantum yield of PSII) (Fig. 3*B*) was improved by 32% in –UVAB+I as compared to OC uninoculated. Improvements were also noticed when F_v/F_0 (Fig. 3*C*) was studied. The efficiency of the water-splitting complex on the donor side of PSII (F_v/F_0) increased by 49% in –UVAB+I as compared to OC uninoculated. RC/CSm (Fig. 3*D*) showed also dramatic changes in –UVAB+I plants. This implies that UV exclusion and AMF inoculation have a synergistic effect on the photosynthetic processes of the plant.

Carbonic anhydrase: CA plays an imperative role in accelerating carbon metabolism by catalyzing reversible interconversions (Fig. 4). CA activity increased after AMF inoculation and UV exclusion. When compared with OC inoculated, –UVAB+I exhibited a 58% increase in enzymatic activity, followed by a 43% increase in –UVB+I. The difference between OC uninoculated and OC+I was 7% (Fig. 4).

Gas-exchange parameters: UV exclusion and AMF inoculum treatments proved helpful in enhancing the photosynthesis of soybean plants. After comparison

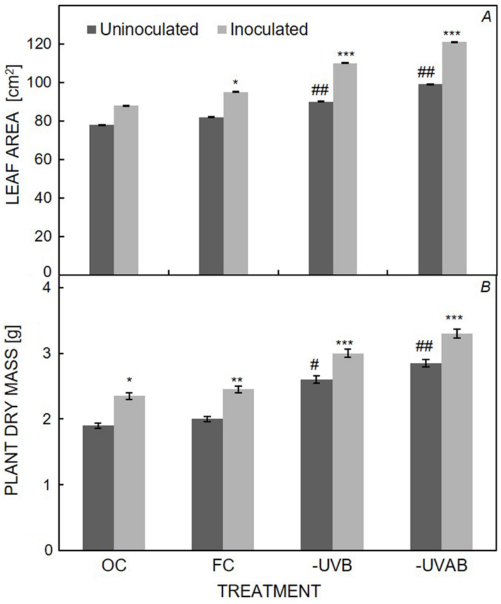

Fig. 1. Effect of UV exclusion and AMF inoculation on growth parameters. Leaf area (*A*) and plant dry mass (*B*) at the R5 stage. *The vertical bar* indicates ± SE for the mean. $^{\#\#}$ and $^{\#\#\#}$ indicate significant difference at $P<0.01$ and 0.05, respectively, after comparison of uninoculated treatments with OC uninoculated and ***, **, and * indicate significant difference at $P<0.001$, 0.01, and 0.05, respectively, after comparison of inoculated treatments with OC uninoculated ones.

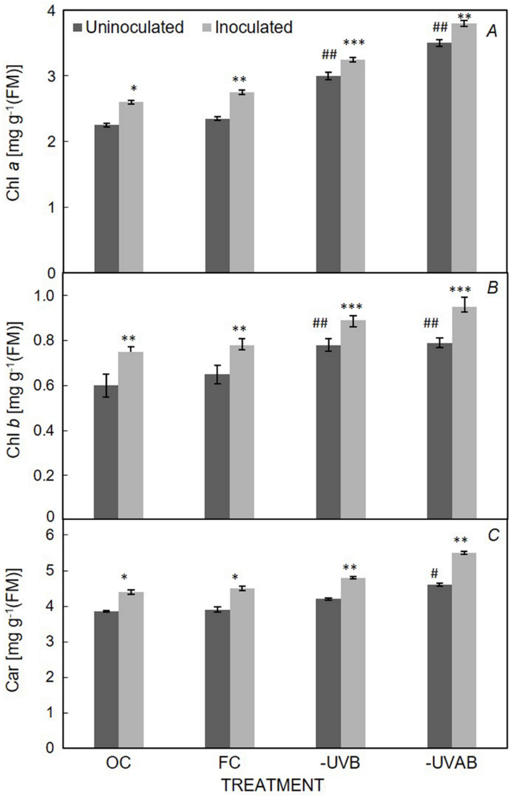

Fig. 2. Effect of UV exclusion and AMF inoculation on photosynthetic pigments. Chlorophyll (Chl) *a* (*A*), Chl *b* (*B*), and carotenoids (Car) (*C*) at the R5 stage. *The vertical bar* indicates ± SE for the mean. $^{\#\#\#}$, $^{\#\#}$, and $^{\#}$ indicate significant differences at $P<0.001$, 0.01, and 0.05, respectively, after comparison of uninoculated treatments with OC uninoculated and ***, **, and * indicate significant differences at $P<0.001$, 0.01, and 0.05, respectively, after comparison of inoculated treatments with OC uninoculated ones.

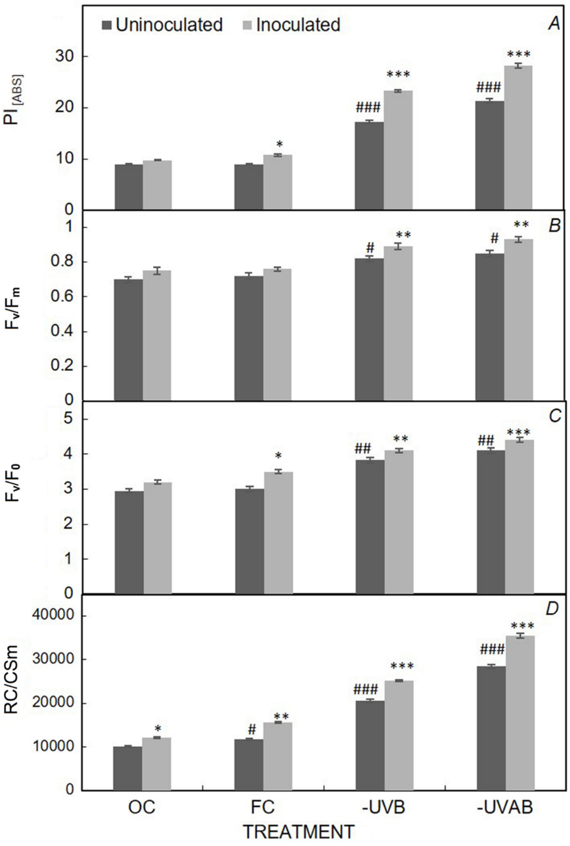

Fig. 3. Effect of UV exclusion and AMF inoculation on chlorophyll induction kinetics. Performance index on absorption basis, $PI_{(ABS)}$ (*A*), maximum quantum yield of PSII, F_v/F_m (*B*), activity of PSII, F_v/F_0 (*C*), and concentration of active PSII reaction centers per excited cross section, RC/CSm (*D*) at the R5 stage. *The vertical bar* indicates ± SE for the mean. $^{\#\#\#}$, $^{\#\#}$, and $^{\#}$ indicate significant differences at $P<0.001$, 0.01, and 0.05, respectively, after comparison of uninoculated treatments with OC uninoculated and *** and * indicate significant difference at $P<0.001$ and 0.05, respectively, after comparison of inoculated treatments with OC uninoculated ones.

with OC uninoculated, –UVAB+I was proved to give a maximum increase of 68% in P_N (Fig. 5*A*), followed by a 50% increase in –UVB+I. The stomatal conductance (Fig. 5*B*) revealed that –UVAB+I was the best treatment with a maximum rise of 100% when compared with OC uninoculated. When compared with OC uninoculated control, –UVAB+I showed a 71% increase in *E* (Fig. 5*C*), followed by a 51% increase in –UVB+I. Also, –UVAB+I had a maximum decrease of 16% in internal CO_2 concentration (Fig. 5*D*) as compared to OC uninoculated.

Yield: With UV exclusion and AMF treatment, seed count per plant was found to be enhanced. The –UVAB uninoculated plants had a 35%, and–UVB uninoculated had a 22% increase as compared to OC uninoculated. –UVAB + I showed a 44% increase, while –UVB+I had a 32% increase as compared to OC+I. The –UVAB+I treatment proved to be the best treatment with a maximum rise of 66% when compared with OC uninoculated. The difference between OC uninoculated and OC+I was found to be 15% (Fig. 6).

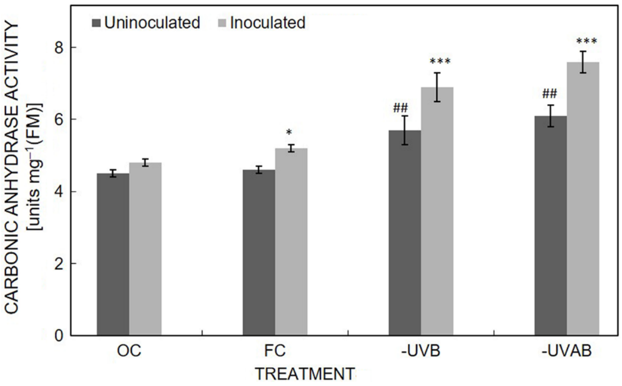

Fig. 4. Effect of UV exclusion and AMF inoculation on carbonic anhydrase activity at the R5 stage. *The vertical bar* indicates ± SE for the mean. $^{\#\#}$ indicates a significant difference at $P<0.01$ after comparison of uninoculated treatments with OC uninoculated and ***, **, and * indicate significant differences at $P<0.001$, 0.01, and 0.05, respectively, after comparison of inoculated treatments with OC uninoculated ones.

Discussion

AMF nourishes the plant with water and essential minerals. Facilitating the availability of various ions such as Mg^{2+}, phosphorus, and zinc by AMF helps in the synthesis of Chl and enhanced carotenoid content (Liu *et al.* 2023). In the present study, we found that UV exclusion destresses the plant and hence leads to an increase in Chl and carotenoid content in the leaves of soybean. Chl fluorescence measurements offer noninvasive means of understanding photosynthesis and its dynamics. Inoculation of AMF and exclusion of UV radiation, both individually and synergistically, destresses the soybean plants. Therefore, –UVB+I and –UVAB+I plants exhibited better photosynthetic capacity and photochemical efficiency. It may be due to nutrient supplementation by AMF and the removal of oxidative stress by solar UV exclusion. Protection of the oxygen-evolving complex through AMF and UV exclusion *via* increasing photochemistry of PSII leads to the higher efficiency of the oxygen-evolving complex on the donor side of PSII. In OC uninoculated plants, the damage occurred at the donor as well as the acceptor side of PSII. $PI_{(ABS)}$ offers reference to the general state of plants as well as the vitality index. It includes significant components: concentration of RC per chlorophyll, primary photochemistry parameter, and electron transport parameter. $PI_{(ABS)}$ was found to be better in plants with AMF inoculation and UV exclusion which indicates better antenna properties, trapping efficiency, and electron transport. The reason behind this can be related to an increased amount of Chl molecules and the formation of

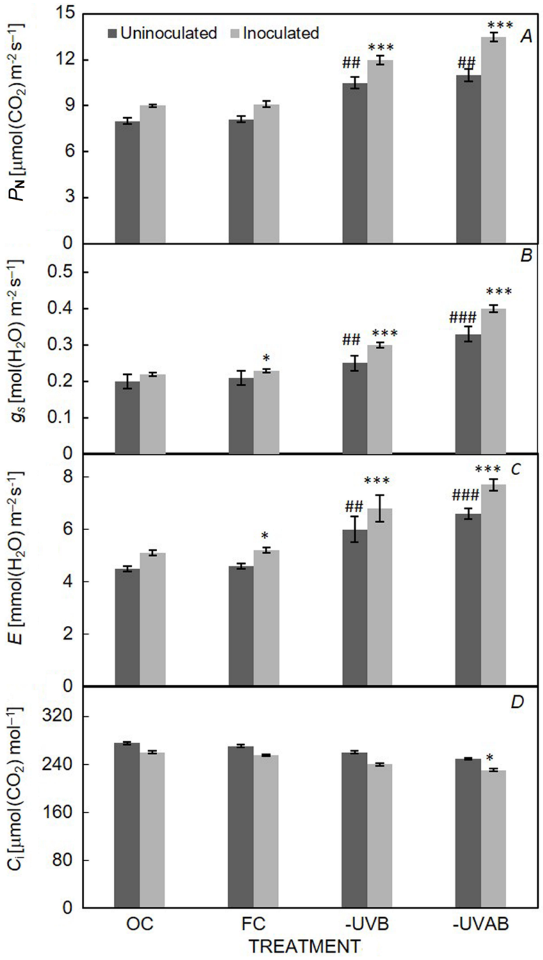

Fig. 5. Effect of UV exclusion and AMF inoculation on gas-exchange parameters. Photosynthetic rate (P_N) (*A*), stomatal conductance (g_s) (*B*), transpiration rate (*C*) (*E*), and internal CO$_2$ concentration (C_i) (*D*) at the R5 stage. *The vertical bar* indicates ± SE for the mean. $^{###}$ and $^{##}$ indicate significant difference at $P<0.001$ and 0.01, respectively, after comparison of uninoculated treatments with OC uninoculated and *** and * indicate significant difference at $P<0.001$ and 0.05, respectively, after comparison of inoculated treatments with OC uninoculated ones.

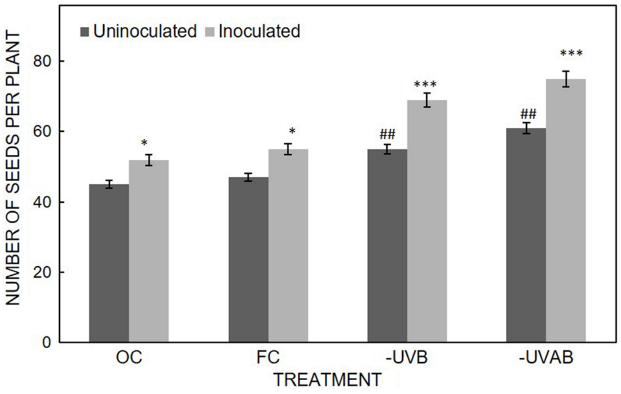

Fig. 6. Effect of UV exclusion and AMF inoculation on seed count per plant at maturity. *The vertical bar* indicates ± SE for the mean. $^{##}$ indicates a significant difference at $P<0.01$ after a comparison of uninoculated treatments with OC uninoculated and *** and * indicate a significant difference at $P<0.001$ and 0.05, respectively, after a comparison of inoculated treatments with OC uninoculated ones.

precursors of the molecules in the electron transport chain. These results positively affected light reaction and thereby producing more assimilatory powers for dark reaction. Also, directing photosynthates towards the AMF leads to triggered photosynthesis in plants with AMF inoculation, which is also facilitated by solar UV exclusion.

An increase in pigments also led to an enhancement of carbonic anhydrase activity. An increase in pigment content due to the synergistic effect of AMF and UV exclusion led to the formation of more assimilatory powers and thereby triggering the action of CA. Although CA activity increased under ambient UV conditions by AMF in a limited range, which indicates that AMF does not directly and significantly enhance enzymatic activity. Our results agree with the studies conducted by Mathur *et al.* (2018) for AMF and Kataria and Guruprasad (2015) for UV exclusion independently.

It has been reported that the enhanced UV-B irradiation arrests plant growth (Kakani *et al.* 2003, Kataria *et al.* 2014, 2021), suppresses Chl synthesis, inhibits electron transport (Noorudeen and Kulandaivelu 1982, Kakani *et al.* 2003, Kataria *et al.* 2014, 2021), and net photosynthesis (Teramura and Sullivan 1994, Kakani *et al.* 2003, Piccini *et al.* 2020, Kataria *et al.* 2021). Enhanced levels of UV-B also interfere at different steps of the photosynthetic electron transfer pathway, inactivate oxygen evolution and the reaction centers of PSII (Hideg *et al.* 2003), and decrease the efficiency of the Hill reaction, cyclic photophosphorylation, and the activity of Rubisco (Reuber *et al.* 1996), and it also alters the light-harvesting phycobilisomes in cyanobacteria. Further, UV-B induces the loss of the water oxidation capacity of PSII due to the loss of the D1 and also D2 proteins of the PSII reaction centers in isolated thylakoids (Kataria *et al.* 2014). Contrastingly, our study on the exclusion of UV suggests the increase in photosynthetic pigments along with the enhanced photosynthetic rate, transpiration rate, and stomatal conductance. Structural amendments in the plastids suggested that UV-B exclusion from sunlight directly affects PSII (Amudha *et al.* 2005). Similarly, increases in plant height, leaf size, dry leaf mass, and changes in branching pattern were reported in soybean grown under low UV-B, along with an increase in Chl, efficiency of PSII, and the rate of photosynthesis (Guruprasad *et al.* 2007, Baroniya *et al.* 2011, 2023). The solar UV-B exclusion studies suggested that additional fixation of carbon due to the exclusion of ambient UV-B was directed toward crop productivity as there was a decrease in the concentration of active oxygen species and UV-B-absorbing substances and an increase in soluble proteins (Kataria *et al.* 2013).

Conclusion: UV light is abiotic stress that negatively affects the photosynthetic parameters of the plant. When the UV-B is excluded from the ambient sunlight with the help of filters, it leads to enhanced photosynthetic processes. During experimentation, we observed that plants grown under the UV cut-off filters were destressed as the metabolites were directed towards pigment synthesis and maintenance of molecules involved in the photosynthetic process. Moreover, plants supplemented by the inoculation of AMF enriched metabolic pool with necessary nutrients as well as water. AMF mediation offers defense to the plant against pathogens, which saves the nutrients for the synthesis of photosynthetic pigments and the molecules involved in photosynthetic processes. Hence, the plants with –UVAB+I and –UVB+I showed excellent photosynthetic performance due to the synergistic effect of UV exclusion and AMF inoculation. Solar UV exclusion prevents the plants from stress, at the same time nutrient supplementation through AMF has resulted in better photosynthesis. This combination method is sustainable and can be useful for improving the yield of soybean.

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