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BRIEF COMMUNICATION

# Alleviation of ultraviolet-B radiation-induced growth inhibition of green gram by triadimefon

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## Abstract

Supplementary UV-B (12.2 kJ $m^{-2}$ $d^{-1}$ UV-$B_{BE}$) provided to *Vigna radiata* for 2 h $d^{-1}$ suppressed the length of root, shoot and whole plants, number of leaves, total leaf area, leaf area index, specific leaf mass, fresh and dry mass of leaves and shoot, relative growth rate and net productivity. In unstressed green gram plants (10 kJ $m^{-2}$ $d^{-1}$ UV-$B_{BE}$), triadimefon (TRIAD) (20 mg $dm^{-3}$) enhanced growth in all parameters over control. The growth promoting effect of TRIAD enabled the UV-B impacted plants to overcome the growth inhibitions to varying degrees indicating its protective potential against UV-B stress.

*Additional key words*: growth regulator, leaf area index, relative growth rate, triazole, UV-B stress, *Vigna radiata* .

Increase in solar ultraviolet radiation, especially in the ultraviolet-B region (UV-B, 280 - 320 nm) due to a gradual depletion of stratospheric ozone layer has been found detrimental to plant growth and development of several crops (Lingakumar and Kulandaivelu 1993, Caldwell *et al.* 1998). Although plants have developed various kinds of defense mechanisms against UV-B damage (Kramer *et al.* 1991), very few manipulative attempts have been made to protect sensitive crop plants against UV-B injury through chemical intervention. Triadimefon (TRIAD), a member of the triazole family, protects the plants against ozone, sulphur dioxide, drought, salinity, chilling injury, *etc.* (Fletcher and Hofstra 1985, Muthukumarasamy and Panneerselvam 1997, Panneerselvam *et al.* 1997, 1998). Recently, Abbas and Zaidi (1997) have demonstrated that damage caused to the cell membranes by elevated UV-B stress, could be partially alleviated by the application of TRIAD. In this background, experiments were conducted to test its protective potential against UV-B stress in terms of growth and yield of green gram.

Green gram [*Vigna radiata* (L.) Wilczek cv. KM-2] plants were grown in pot culture in the naturally lit greenhouse (day temperature maximum 38 ± 2 °C, night temperature minimum 18 ± 2 °C, relative humidity 60 ± 5 %, maximum irradiance (PAR): 1400 µmol $m^{-2}$ $s^{-1}$, photoperiod 12 to 14 h). Supplementary UV-B radiation was provided by two UV-B lamps (*Philips TL20W/12 Sunlamps*, The Netherlands) which were suspended horizontally and wrapped with cellulose diacetate filters (0.076 mm) to filter UV-C radiation (< 280 nm). UV-B exposure was given for 2 h daily from 10:00 to 11:00 and 15:00 to 16:00 starting from the 5$^{th}$ day after sowing. Plants received a biologically effective UV-B dose (UV-$B_{BE}$) of 12.2 kJ $m^{-2}$ $d^{-1}$ equivalent to a simulated 20 % ozone depletion at Pondicherry (12° 2' N, India). The control plants, grown under natural solar radiation, received UV-$B_{BE}$ 10 kJ $m^{-2}$ $d^{-1}$ (Caldwell 1971). TRIAD was supplied through seed soaking in 20 mg $dm^{-3}$ concentration which was found suitable for alleviation of UV-B stress during preliminary trials. A booster dose of TRIAD as soil-drench on 30 d after sowing enhanced the effects admirably (Rajendiran and Ramanujam 2000).

Ten plants from each treatment viz. control, UV-B, TRIAD, UV-B + TRIAD were carefully uprooted on 15, 30, 45 and 60 d after sowing and their length (root and shoot length and plant height), and biomass were determined. Total leaf area (TLA) was determined using

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*Abbreviations*: LAI - leaf area index; NP - net productivity; PAR - photosynthetically active radiation; RGR - relative growth rate; SLM - specific leaf mass; TLA - total leaf area; TRIAD - triadimefon; UV-B - ultraviolet radiation-B.

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*Leaf Area Meter AM100* (*Analytical Development Corporation*, London, UK). Leaf area index (LAI) (Williams 1946) and specific leaf mass (SLM = leaf dry mass/leaf area) (Pearce *et al.* 1968) were also determined. Relative growth rate (RGR) (Williams 1946), shoot/root (S/R) ratio and net productivity (NP) (Jain *et al.* 1999) were calculated from the primary data. NP was obtained by subtracting the values of biomass from that of subsequent stage.

Growth of green gram was progressively inhibited by the UV-B radiation. Inhibitions of root and shoot length ranged from 19 to 30 % over 15 to 60 d. Consequently, the plant height was reduced by 21 to 30 %. In unstressed plants, TRIAD stimulated root, shoot and plant height by 25 to 32 %. When TRIAD was supplied to UV-B stressed plants (UV-B + TRIAD), the values were almost equal to the control (Table 1). The S/R ratio was decreased by UV-B stress initially on 15 d by 4.5 % while it was comparable to control at other stages of growth. The S/R ratios differed only insignificantly between the treatments (Table 1). UV-B treatment reduced the biomass by 24 to 29 % in root and 22 to 39 % in shoot and 22 to 38 % in whole plants (Table 3). TRIAD-treated plants accumulated more fresh and dry biomass in root by 20 to 33 %, and in shoots by 26 to 33 %. The control and UV-B + TRIAD plants did not differ significantly.

Table 1. Growth characteristics of green gram (*Vigna radiata* cv. KM-2) exposed to supplementary UV-B radiation, TRIAD (20 mg $dm^{-3}$) and their combinations. Mean values of an attribute followed by different letters are significantly different at $P = 0.05$ (Tukey's Multiple Range Test), $n = 10$.

| Growth | Time [d] | Control | UV-B | TRIAD | UV-B + TRIAD |
|---|---|---|---|---|---|
| Root length [cm] | 15 | 12.21b | 9.86a | 14.53c | 12.09b |
| | 30 | 17.54b | 12.98a | 23.33c | 18.62b |
| | 45 | 22.81b | 16.20a | 30.11c | 23.20b |
| | 60 | 25.79b | 18.05a | 34.30c | 26.26b |
| Shoot length [cm] | 15 | 18.77b | 14.45a | 23.65c | 18.88b |
| | 30 | 31.38b | 22.91a | 41.42c | 31.60b |
| | 45 | 38.23b | 26.38a | 49.31c | 38.46b |
| | 60 | 42.42b | 29.69a | 53.02c | 42.76b |
| Plant height [cm] | 15 | 30.98b | 24.34a | 38.18c | 29.97b |
| | 30 | 48.92b | 35.89a | 64.75c | 49.23b |
| | 45 | 61.04b | 42.57a | 79.43c | 62.36b |
| | 60 | 68.21b | 47.75a | 87.33c | 69.12b |
| Shoot/root ratio | 15 | 1.55 | 1.48 | 1.64 | 1.56 |
| | 30 | 1.79 | 1.79 | 1.78 | 1.80 |
| | 45 | 1.68 | 1.68 | 1.64 | 1.68 |
| | 60 | 1.65 | 1.66 | 1.55 | 1.59 |

Inhibition of growth indicated by reductions in root and shoot length and biomass content due to UV-B stress were apparent at all stages. Such inhibitions are characteristic of UV-B stressed legumes as in *Vigna unguiculata* (Kulandaivelu *et al.* 1989), *Glycine max, Vigna mungo* and *Vigna radiata* (Singh 1996) and *Phaseolus vulgaris* (Mark and Tevini 1997). The stunting of UV-B stressed plants is attributed to destruction of endogenous IAA whose photo-oxidative products may be inhibitory (Kulandaivelu *et al.* 1989, Tevini and Teramura 1989) as indicated by a decrease in IAA content concomitant with a corresponding increase in IAA oxidase activity in rice leaves (Huang *et al.* 1997). By comparison, TRIAD-treated green gram plants grew better than the control which is consistent with the increases observed in shoot growth of radish, pea and soybean (Fletcher and Nath 1984), wheat (Gao *et al.* 1988), peanut (Muthukumarasamy and Panneerselvam 1997), and increased biomass recorded in radish (Fletcher and Nath 1984) and bean (Asare-Boamah and Fletcher 1986).

Roots of TRIAD-treated green gram were profusely branched and were also pale in colour. This is corroborated by the root systems of TRIAD-treated cucumber (Fletcher and Arnold 1986) and bean hypocotyls (Davis *et al.* 1988, Fletcher *et al.* 1988) which were profusely branched and whitish too. Fletcher and Arnold (1986) also demonstrated that TRIAD is a more potent stimulator of adventitious roots than either polyamine or IAA. They further observed highest cytokinin-like activity in TRIAD-treated cucumber plants, which was traced to the enhanced cytokinin synthesis from an elaborate root system. It is plausible that the profusely branched root system of green gram with numerous sites of synthesis produced copious cytokinin which stimulated shoot growth.

A maximum of 39 % reduction of TLA occurred under UV-B stress and the LAI by 38.25 % over control on day 60. But these were increased by TRIAD by 26 to 29 % and 25 %, respectively (Table 2). TLA and LAI of UV-B + TRIAD plants were comparable to control. The SLM in UV-B irradiated plants increased by 2.55, 9.0, 12.62 and 14.64 % on day 15, 30, 45 and 60, respectively. The values for UV-B + TRIAD plants as well as TRIAD-treated plants did not differ from control (Table 2). Fresh and dry mass of leaf lowered by 32 and 30 % respectively under UV-B stress across the experimental period. In contrast, application of TRIAD to UV-B stressed plants maintained the leaf biomass more or less equal to the control. TRIAD increased the fresh mass of leaves by about 30 % and dry mass by 28.40 to 30.24 % over control (Table 2).

Reductions in leaf area and mass were observed in the field-grown sweetgum plants exposed to elevated UV-B radiation (Sullivan *et al.* 1994). According to Britz and Adamse (1994) changes in the leaf area and dry mass indicated that cell elongation as well as cell contents were affected. Whereas the inhibitions are part of general UV-B effects (Biggs *et al.* 1981, Britz and Adamse 1994), the increase in SLM may be due to increased cell thickness or high cell density (Tevini *et al.* 1983, Adamse

Table 2. Foliage characteristics (number of leaves, total leaf area, leaf area index, specific leaf mass, fresh and dry mass) of green gram (*Vigna radiata* cv. KM-2) exposed to supplementary UV-B radiation, TRIAD and their combinations. Means followed by different letters are significantly different at $P = 0.05$, $n = 10$.

| Growth | Time [d] | Control | UV-B | TRIAD | UV-B + TRIAD |
|---|---|---|---|---|---|
| Leaf number [plant$^{-1}$] | 15 | 1.90b | 1.40a | 2.00b | 1.90b |
| | 30 | 4.90b | 3.80a | 5.00b | 4.90b |
| | 45 | 5.90b | 4.70a | 6.00b | 5.90b |
| | 60 | 6.90b | 5.60a | 7.00b | 7.06b |
| TLA [cm$^2$] | 15 | 40.44b | 26.29a | 51.76c | 39.52b |
| | 30 | 280.20b | 176.53a | 361.45c | 281.24b |
| | 45 | 490.21b | 303.93a | 622.57c | 494.13b |
| | 60 | 589.88b | 359.83a | 743.25c | 591.65b |
| LAI | 15 | 0.32b | 0.21a | 0.40c | 0.32b |
| | 30 | 0.95b | 0.60a | 1.20c | 0.96b |
| | 45 | 1.61b | 0.99a | 2.03c | 1.66b |
| | 60 | 1.83b | 1.13a | 2.29c | 1.79b |
| SLM [g m$^{-2}$] | 15 | 20.03a | 20.54b | 20.09a | 20.60b |
| | 30 | 22.66a | 24.70b | 22.88a | 22.72a |
| | 45 | 20.36a | 22.93b | 20.74a | 20.25a |
| | 60 | 20.97a | 24.04d | 21.58c | 21.09b |
| Fresh mass [g plant$^{-1}$] | 15 | 0.40b | 0.27a | 0.51c | 0.39b |
| | 30 | 3.17b | 2.16a | 4.13c | 3.19b |
| | 45 | 5.00b | 3.45a | 6.46c | 5.02b |
| | 60 | 6.20b | 4.31a | 8.01d | 6.22c |
| Dry mass [g plant$^{-1}$] | 15 | 0.08b | 0.05a | 0.10c | 0.08b |
| | 30 | 0.64b | 0.44a | 0.83c | 0.64b |
| | 45 | 1.00b | 0.69a | 1.29c | 1.01b |
| | 60 | 1.24b | 0.87a | 1.60c | 1.25b |

Table 3. Biomass and growth rate of green gram (*Vigna radiata* cv. KM-2) exposed to supplementary UV-B radiation, TRIAD and their combinations. Means followed by different letters are significantly different at $P = 0.05$, $n = 10$.

| Growth | Time [d] | Control | UV-B | TRIAD | UV-B + TRIAD |
|---|---|---|---|---|---|
| Root fresh mass [g plant$^{-1}$] | 15 | 0.21b | 0.16a | 0.25c | 0.21b |
| | 30 | 0.71b | 0.53a | 0.93c | 0.71b |
| | 45 | 1.59b | 1.14a | 2.09c | 1.59b |
| | 60 | 2.69b | 1.92a | 3.61c | 2.70b |
| Shoot fresh mass [g plant$^{-1}$] | 15 | 1.18b | 0.92a | 1.50c | 1.19b |
| | 30 | 4.44b | 3.22a | 5.87c | 4.45b |
| | 45 | 11.31b | 7.04a | 15.02c | 11.34b |
| | 60 | 26.11b | 15.88a | 34.71c | 26.15b |
| Root dry mass [g plant$^{-1}$] | 15 | 0.04b | 0.03a | 0.05c | 0.04b |
| | 30 | 0.14b | 0.11a | 0.19c | 0.14b |
| | 45 | 0.31b | 0.23a | 0.42c | 0.32b |
| | 60 | 0.54b | 0.38a | 0.72c | 0.54b |
| Shoot dry mass [g plant$^{-1}$] | 15 | 0.24b | 0.18a | 0.30c | 0.24b |
| | 30 | 0.89b | 0.64a | 1.18c | 0.89b |
| | 45 | 3.34b | 2.09a | 4.45c | 3.35b |
| | 60 | 10.45b | 6.41a | 13.91c | 10.47b |
| RGR [d$^{-1}$] | 30 | 0.09b | 0.08a | 0.09b | 0.09b |
| | 45 | 0.08b | 0.07a | 0.09b | 0.08b |
| | 60 | 0.08a | 0.07a | 0.08a | 0.08a |
| NP [g plant$^{-1}$] | 15 | 0.28b | 0.22a | 0.35c | 0.27b |
| | 30 | 0.75b | 0.54a | 1.01c | 0.74b |
| | 45 | 2.63b | 1.57a | 3.49c | 2.79b |
| | 60 | 7.33b | 4.47a | 9.76c | 7.38b |

*et al.* 1994, Britz and Adamse 1994). TRIAD-induced simulations were evident in leaf area, as well as leaf mass and number of leaves. Though the leaf thickness was not affected by TRIAD, they were heavier. This might be due to a combined effect of increased leaf area and intense cell packing. This is consistent with the reports that under the influence of TRIAD, the leaves become thicker and heavier (Davis *et al.* 1988).

RGR was lowered only in UV-B irradiated plants. The RGR decreased more in the initial stages (4.60 and 10.71 % over control, on day 30 and 45, respectively), but was only 1.37 % less at 60 d. NP was reduced in UV-B irradiated plants by 23.40, 28.95, 40.14 and 39.03 % on day 15, 30, 45 and 60, respectively (Table 3). Similar inhibitions of RGR and NP by UV-B were observed by Jain *et al.* (1999) in mungbean. TRIAD increased RGR over control by 3.45 and 1.19 % compared to control on day 30 and 45, respectively. UV-B + TRIAD-treated plants had higher RGR than UV-B stressed plants and were closer to control. Significant increases in NP ranging from 25 to 33 % were observed in TRIAD treatment, while UV-B + TRIAD plants did not differ significantly from the controls. With a pronounced stimulation of vegetative growth by TRIAD shown in the foregoing, increases in RGR and NP are not surprising.

In conclusion, the UV-B impacted green gram seems to have benefited from the TRIAD-induced stimulations to ward off the inhibitory effects of UV-B. This has enabled the plants under the combined treatment of UV-B + TRIAD to grow like control plants. In the light of the above, the mechanism underlying the protective effect is worth investigating.

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