BRIEF COMMUNICATION

Improvement of biomass partitioning, flowering and yield by triadimefon in UV-B stressed *Vigna radiata* (L.) Wilczek

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Abstract

Elevated UV-B radiation (12.2 kJ m^{-2} d^{-1}) as against the ambient level of 10 kJ m^{-2} d^{-1} affected flowering, productivity and biomass partitioning of green gram [*Vigna radiata* (L.) Wilczek cv. KM-2]. UV-B stress delayed flowering initiation and achievement of 50 % flowering, reduced flower retention by 25 %, potential yield by 18 % and all yield attributes such as pod number (25 %), pod mass (41 %), seed number (32 %) and seed mass (45 %). Harvest index and shelling percentage were also reduced by 31 and 7 %, respectively. Application of triadimefon (20 mg dm^{-3}) to unstressed plants accelerated flowering and enhanced flower retention (21 %), potential yield (15 %) and yield attributes (7 to 44 %). The partitioning of biomass between plant parts also showed improvement over the control plants. In UV-B-stressed plants, triadimefon treatment compensated the inhibitions to varying extents.

Additional key words: alleviation of UV-B stress, elevated UV-B, plant growth regulator, triazole compounds.

Though UV-B radiation constitutes only 1.5 % of the solar energy, it is detrimental to the terrestrial eco-systems (Caldwell *et al.* 1998). Higher plants vary considerably in their response to enhanced UV-B radiation. Generally, plants tolerate smaller increases of UV-B dosage by activating or acquiring protective mechanisms like UV-B filters, quenchers of free radicals and reactive oxygen species, and repair systems (Caldwell *et al*. 2003, Bjorn *et al*. 2002). It appears that the majority of economically important species could become insensitive to future increases in UV-B but sensitive plants are likely to show considerable reductions in plant height and decreases in shoot mass and yield (Musil *et al*. 2002).

The triazole compounds have been shown to have both fungitoxic and plant growth regulator (PGR) like properties (Fletcher 1985). One of them, triadimefon, reduce the adverse impacts of several abiotic stresses by shifting the balance of plant hormones (Fletcher and Hofstra 1985, Fletcher *et al.* 2000) and by protecting the membrane system (Feng *et al.* 2003). Recently, Abbas and Zaidi (1997) observed that the application of triadimefon attenuated UV-B induced damages in *Cicer arietinum* plants by ensuring the structural integrity of plasma membrane. Rajendiran and Ramanujam (2003) have further demonstrated that the growth inhibitions of UV-B stressed green gram cultivar KM-2 could be partly ameliorated by treatment with triadimefon. In this background, the present study was undertaken to see whether the beneficial effects of triadimefon could be observed also in flowering and yield.

Green gram [*Vigna radiata* (L.) Wilczek cv. KM-2] was grown in pot culture. Triadimefon (20 mg dm^{-3}) was supplied through seed-soaking for 18 h, at 200 cm^{-3} per 100 g lot supplemented by a booster dose as soil drench at 30 DAS at 200 cm^{-3} per pot as standardized by Rajendiran and Ramanujam (2000). The experimental design and culture conditions were the same as described earlier (Rajendiran and Ramanujam 2003). The day on which the first plant formed floral buds marked onset of flowering. The number of floral buds/flowers/fruits in each plant and also the number of plants per treatment bearing flowers was recorded on every alternate day. The day on which 50 % of the plants flowered (F_{50}) and the

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Abbreviations: DAS - days after sowing; PAR - photosynthetically active radiation; PGR - plant growth regulator; UV-B - ultraviolet-B radiation; UV-B_{BE} - biologically efficient UV-B radiation.
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potential yield were calculated from the pooled data following Mark and Tevini (1997). Mature fruits were harvested from each plant and the length and mass of the pod, number of seeds per pod and mass of 100-seed lot were recorded.

Harvest index and shelling percentage were calculated using the formulae of Francis *et al*. (1978). Ten plants from each treatment were carefully uprooted at 60 DAS and the biomass of various plant parts was measured after drying in an oven (80 °C, 48 h).

Flowering initiation was delayed by 3.5 days in UV-B stressed plants (Table 1) while it was advanced by one day by triadimefon. The triadimefon + UV-B treated plants began flowering simultaneously with the controls. Flower shedding was more in plants under UV-B stress and was the least in triadimefon treatment. UV-B stressed plants took 1.6 d more than control plants to achieve 50 % flowering in contrast to triadimefon treated ones which flowered more briskly. Plants treated with UV-B + triadimefon also took less time than the control plants. The data are comparable partially with those from bush bean (*Phaseolus vulgaris*) cultivars where the flower initiation was postponed by a day but the 100 % flowering was reached simultaneously to the control (Mark and Tevini 1997). The delay may be due to the increased sensitivity of the test plants to UV-B damage, which resulted in their reduced growth. Suffering heavily from the UV-B stress, green gram plants could have taken more time to commence and complete the flowering phase.

Elevated UV-B decreased flower retention by 25.44 %, but it was not changed in triadimefon + UV-B treatment. Alone, triadimefon enabled the plants to retain the maximum number of flowers, 20.5 per plant, which matured into fruits. The potential yield – the sum of floral buds formed in a plant – was the lowest under UV-B and the highest in triadimefon-treated plants. No significant difference was found between control and UV-B + triadimefon treatment. The inhibition of flowering and poor flower retention caused yield reduction by 30 - 40 % under UV-B stress and this conformed to the inhibitory trends reported widely (Caldwell *et al*. 1998, Musil *et al.* 2002). Mark and Tevini (1997) found a correlation between the size and number of fruits and yield reductions in several bush bean cultivars, a trend reflected in our study also. UV-B stress affected all the yield components, the decreases being 25 % in the pod number, 41 % in pod mass, 32 % in seed number and 45 % in seed mass (Table 1). UV-B treatment reduced the number of seeds per pod and the seeds were also smaller than those of other plants.

Triadimefon treatment increased the number of pods (21 %), seed number (34 %) and seed mass (44 %). The beneficial effects of triadimefon, evident in yield attributes, are in conformity with the 50 % yield increase in soybean and pea after receiving 20 mg dm^{-3} of triadimefon as soil drench at the flower initiation stage (Fletcher and Nath 1984). In the present experiment, the triadimefon was supplied twice – one as seed soaking and another by soil drench at 30 DAS. While the seed soaking could alleviate the UV-B impacts during early vegetative phase, the booster dose at 30 DAS could improve the yield appreciably. In UV-B + triadimefon plants, the pod production was increased by 31 %, pod mass by 66 % and the seed mass by 77 % over the UV-B stressed plants.

Elevated UV-B significantly lowered the harvest index by 31 %, which was increased by triadimefon by

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

Characteristics	Control	UV-B	Triadimefon	UV-B + triadimefon
Flowering initiation [d]	29.50a	33.00b	28.20a	29.40a
50 % flowering (F_{50}) [d]	35.40ba	37.00c	33.80a	34.60a
Flower shedding [plant^{-1}]	4.20a	4.70c	3.90b	4.40a
Flower retention [plant^{-1}]	16.90b	12.60a	20.50c	17.20b
Potential yield [plant^{-1}]	21.10b	17.30a	24.40c	20.00b
Pod number [plant^{-1}]	16.90b	12.60a	20.50c	16.50b
Single pod mass [g]	0.52b	0.40a	0.64c	0.49b
Pod mass plant^{-1} [g]	8.26b	4.86a	11.13c	8.09b
Length of pod [cm]	7.39b	5.56a	8.57c	7.45b
Seed number [pod^{-1}]	11.90b	9.16a	14.20c	10.91b
Seed number [plant^{-1}]	168.50b	113.20a	226.70c	158.30b
Seed mass pod^{-1} [g]	0.44b	0.31a	0.62c	0.41b
Mass of 100 seed lot [g]	4.68b	3.16a	6.51c	4.54b
Seed mass plant^{-1} [g]	7.04b	3.84a	10.16c	6.81b
Shelling percentage [plant^{-1}]	85.26b	79.03a	91.59c	84.11b
Harvest index	64.03b	43.94a	69.71c	63.19b

8 %. It was similar to the controls in UV-B + triadimefon treated plants (Table 1). Data on shelling percentage also followed the same trend. Whereas the harvest index shows the contribution of economically useful part over total production, the shelling percentage indicates the actual seed mass over the fruits. Both UV-B + triadimefon and control plants had maximum allocation to fruits, while the increase by triadimefon and decrease by UV-B stress were significant. According to Mark and Tevini (1997) the potential yield, which denotes the sum of buds, opened flowers and fruits of a plant, was decreased by UV-B exposure in bush beans which is corroborated by our study. Considering that these plants were grown under natural conditions, the reductions in yield recorded here may have serious economical implications.

By contrast, the significant increase in yield of triadimefon-treated plants could be due to the combined effect of having more flowers and enhanced pod retention. Consequently, the potential yield, harvest index and shelling percentage were the highest for triadimefon treated plants.

The distribution of dry matter in root, stem, leaves and fruits was analysed at harvest stage (60 DAS). It was the maximum in fruits registering 75.1, 71.5, 74.8 and 76.1 % in control, UV-B stressed, UV-B + triadimefon and triadimefon-treated plants, respectively (Table 2). The shoot (leaves + stem) accumulated 20.0, 22.8, 20.3 and 19.0 % biomass in control, UV-B, UV-B + triadimefon and triadimefon-treated plants, respectively. The highest percentage in shoot and lowest in fruits under UV-B stress suggested an interference in the transfer of reserves to flowers and fruits. Significant total mass reductions in plants under UV-B stress is in line with the observations of Jain *et al*. (1999) who found the biomass of UV-B stressed *Vigna radiata* reduced by 30 %. The biomass partitioning pattern, with more in leaf and stem than in roots has also been recorded in UV-B stressed *Vigna radiata* (Jain *et al*. 1999) and in soybean (Tevini and Teramura 1989).

Table 2. Partitioning of biomass [%] at harvest stage (60 DAS) between parts of green gram (*Vigna radiata* cv. KM-2) exposed to supplementary UV-B radiation, triadimefon (20 mg dm^{-3}) and their combinations. Means followed by different letters are significantly different at P = 0.05 (Tukey's Multiple Range Test), n = 10.

Plant organ	Control	UV-B	Triadimefon	UV-B + triad.
Nodule	0.4b	0.3a	0.4b	0.4b
Root	4.5a	5.4b	4.5a	4.5a
Stem	8.7b	10.1c	8.0a	8.6b
Leaf	11.3b	12.7c	11.0a	11.6b
Fruit	75.1b	71.5a	76.1c	74.8b

It conclusion, triadimefon partially alleviate negative UV-B impacts. UV-B induced inhibitions could have been compensated by the stimulatory influence of triadimefon, thereby rescuing the green gram from UV-B stress and improving its performance towards the control level. Triadimefon is a plant multi-protectant which prevented plants from chilling, drought and ozone injuries (Fletcher and Hofstra 1985, Fletcher and Kraus 1995) and salt stress (Gopi *et al*. 1998, Karikalan *et al*. 1999, Panneerselvam *et al.* 1998, Sujatha *et al*. 1999) and increased the growth and yield by modifying the hormonal balance while encountering the environmental stresses (Fletcher and Hofstra 1985, 1988). It is plausible that the protective effect of triadimefon in green gram against elevated UV-B radiation could also be regulated by a similar mechanism. However, how far the role of plant growth regulators and the underlying metabolic events like photosynthesis, transpiration and nitrogen fixation have contributed to the course of events in overcoming the UV-B impacts remains to be investigated.

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