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Research Article

INFLUENCE OF ELEVATED ULTRAVIOLET-B RADIATION ON THE MORPHOLOGY AND GROWTH OF THREE VARIETIES OF BLACK GRAM

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ABSTRACT
The growth parameters studied in three varieties of black gram *viz.* VAMBAN-3, NIRMAL-7 and T-9 after *in situ* supplementary ultraviolet-B (UV-B) radiation (2 hours daily @ 12.2 kJ m^{-2} d^{-1}; ambient = 10 kJ m^{-2} d^{-1}) showed variations in the plant height, number of leaves, total leaf area, fresh weight, dry weight and relative growth rate during different stages of growth (15, 30, 45 and 60 DAS - days after sowing). UV-B irradiation reduced leaves (20 to 50 %), total leaf area (maximum 92.86 %), leaf area index (LAI) (maximum 68.78 %), specific leaf weight (SLW) (13.39 to 60.10 %), fresh weight (14.02 to 87.16 %) and dry weight of leaves (27.46 to 87.62 %) in all stages of growth compared to their controls. UV-B exposure also reduced root length (4.21 to 42.34 %), shoot length (1.04 to 10.63 %) and S / R ratio (3.84 to 34.57 %). Biomass accumulation in root was inhibited by UV-B treatment by 14.22 to 94.52 %, in shoot by 2.36 to 87.13 % and in whole plant level (maximum 91.10 %). Same trend continued with dry weight of plant and relative growth rate (RGR) (11.11 to 93.22 %) in all UV-B irradiated crops, at all stages of growth. Overall, severity of UV-B stress was experienced by T-9 variety of black gram, while the plant growth was at its best in VAMBAN-3 followed by NIRMAL-7.

Keywords: *Ultraviolet-B, Black Gram, Three Varieties, Morphology, Growth*

INTRODUCTION
Climate change is already affecting agriculture, with effects unevenly distributed across the world. Despite technological advances, such as improved varieties, genetically modified organisms, and irrigation systems, weather is still a key factor in crop productivity. Crops are totally controlled by optimum levels of environmental factors and any deviation would create adverse effects (Rajendiran, 2001). Penetration of ultraviolet-B into the Earth's atmosphere damages the leaves (Kokilavani and Rajendiran, 2013; Kokilavani and Rajendiran, 2014a; Kokilavani and Rajendiran, 2014b; Kokilavani and Rajendiran, 2014c; Kokilavani and Rajendiran, 2014d; Kokilavani and Rajendiran, 2014f; Kokilavani and Rajendiran, 2014g; Kokilavani and Rajendiran, 2014h; Kokilavani and Rajendiran, 2014j; Kokilavani and Rajendiran, 2014k; Kokilavani and Rajendiran, 2014l; Kokilavani and Rajendiran, 2014m; Kokilavani and Rajendiran, 2014n; Kokilavani and Rajendiran, 2015a; Kokilavani and Rajendiran, 2015b), retards growth (Rajendiran and Ramanujam, 2003; Rajendiran and Ramanujam, 2004; Kokilavani and Rajendiran, 2014o), reduces yield of crops (Kokilavani and Rajendiran, 2014e) and hurdles with nodulation and nitrogen metabolism (Rajendiran and Ramanujam, 2003, Sudaroli and Rajendiran, 2013a; Sudaroli and Rajendiran, 2013b; Kokilavani and Rajendiran, 2014i; Sudaroli and Rajendiran, 2014a; Sudaroli and Rajendiran, 2014b; Sudaroli and Rajendiran, 2014c; Arulmozhi and Rajendiran, 2014a; Arulmozhi and Rajendiran, 2014b; Arulmozhi and Rajendiran, 2014c; Vijayalakshmi and Rajendiran, 2014a; Vijayalakshmi and Rajendiran, 2014b; Vijayalakshmi and Rajendiran, 2014c) of sensitive legumes.
Caldwell *et al.*, (1998) opined that literature on UV-B and plant interaction is voluminous but most of the studies deal with the gross effects on growth and yield under controlled environmental conditions with hardly 5% of the over 600 publications relate to field studies. Jordan (1997) blamed controlled environmental conditions as the major defect leading to overstating the damaging influence of UV-B. Adamse and Britz (1992) supported this view as plants under natural day light conditions with high PAR (photosynthetically active radiation) are affected very little. This paper outlines a projected climate

change in the form of enhanced UV-B radiation and its impact on the growth and morphology of three varieties of black gram *viz.* VAMBAN-3, NIRMAL-7 and T-9 grown under field conditions.

MATERIALS AND METHODS

Black gram (*Vigna mungo* (L.) Hepper), the nitrogen fixing grain legume was chosen for the study. Viable seeds of the three varieties of black gram *viz.* VAMBAN-3, NIRMAL-7 and T-9 were procured from Saravana Farms, Villupuram, Tamil Nadu and from local farmers in Pondicherry. The seeds were selected for uniform colour, size and weight and used in the experiments. The crops were grown in pot culture in the naturally lit greenhouse (day temperature maximum 38 ± 2 ºC, night temperature minimum 18 ± 2 ºC, relative humidity 60 ± 5 %, maximum irradiance (PAR) 1400 µmol m^{-2} s^{-1}, photoperiod 12 to 14 h).

Supplementary UV-B radiation was provided in UV garden by three 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 5th 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 (12º2'N, India).

The control plants, grown under natural solar radiation, received UV-B_{BE} 10 kJ m^{-2} d^{-1}. Ten plants from each treatment were carefully uprooted on 15, 30, 45 and 60 DAS and their axial growth (roots and shoot length and plant height) and fresh biomass were measured. They were then dried in an oven at 80º C for 48 h and weighed again for dry mass measurements. Alongside, morphological and developmental abnormalities if any, caused by UV-B radiation were also recorded. Assessment of growth of three varieties of black gram on 15, 30, 45 and 60 DAS were recorded and calculated using standard methods. Ten plants were selected at random from each of the treatments. The leaf area (the leaflets from all the nodes) was determined at various stages using Area meter (Analytical Development Corporation, UK, model AM100). The total leaf area per plant was obtained by summing up the area of the leaves from all the nodes of the plant. Leaf area index (LAI) (Williams 1946), specific leaf weight (SLW) (Pearce *et at.* 1968), relative growth rate (RGR) (Williams 1946) and shoot / root ratio (Racey *et at.* 1983) were calculated using the following formulae.

$$\text{LAI} = \frac{\text{Leaf area of the plants (cm}^2\text{)}}{\text{Ground area occupied (cm}^2\text{)}}$$

$$\text{SLW} = \frac{\text{Leaf dry weight (g)}}{\text{Leaf area (m}^2\text{)}}$$

$$\text{RGR} = \frac{\text{Log}_e W_2 - \text{Log}_e W_1}{t_2 - t_1}$$

where, W_1 and W_2 are dry masses of whole plants at t_1 and t_2 (time in days) respectively.

$$\text{S/R ratio} = \frac{\text{Shoot weight (g)}}{\text{Root weight (g)}}$$

At least ten replicates were maintained for all treatments and control. The experiments were repeated to confirm the trends. The result of single linkage clustering (Maskay, 1998) was displayed graphically in the form of a diagram called dendrogram (Everstt, 1985). The term dendrogram is used in numerical taxonomy for any graphical drawing giving a tree-like description of a taxonomic system. The similarity indices between the three varieties of black gram under study were calculated using the formula given by Bhat and Kudesia (2011).

$$\text{Similarity index} = \frac{\text{Total number of similar characters}}{\text{Total number of characters studied}} \times 100$$

Based on the similarity indices between the three varieties of black gram, dendrograms were draw to derive the interrelationship between them and presented in tables and plates.

RESULTS AND DISCUSSION

The responses of three varieties of black gram *viz.* VAMBAN-3, NIRMAL-7 and T-9 in control and supplementary UV-B irradiation under *in situ* condition were assessed in terms of growth on 15, 30, 45 and 60 DAS. There were same number of leaves as that of controls under UV-B stress in all the three varieties of black gram in the initial stage (30 DAS) and there were fewer leaves only (20 to 50 %) on 30, 45 and 60 DAS compared with their control crops. Supplementary UV-B irradiation reduced the total leaf area throughout the growth period, the maximum being 92.86 % on 60 DAS in VAMBAN-3 (Table 1 to 4; Plate 1). The LAI was reduced by UV-B exposure to a larger extent, the maximum being 68.78 % over control on 60 DAS in VAMBAN-3. The SLW in UV-B irradiated decreased with age. An average decrease ranging from 13.39 to 60.10 % was observed on 15, 30, 45 and 60 DAS in all the three varieties of black gram. However, the pattern of SLW reduction was very severe in NIRMAL-7 on 60 DAS. UV-B stress decreased the fresh weight of leaves by 14.02 to 87.16 %, with the maximum reduction being in VAMBAN-3 on 45 DAS. However, T-9 which managed with 37 % reduction till 45 DAS suffered heavily (87.09 %) under UV-B stress on 60 DAS. The dry weight of foliage decreased by 27.46 to 87.62 % in all stages of UV-B exposed plants. UV-B stressed VAMBAN-3 and T-9 recorded heavy reduction compared to the respective controls (Table 1 to 4). On prolonged exposure to UV-B the leaves of all the three varieties of black gram exhibited various kinds of abnormalities. The leaves became generally pale which at times occurred in patches. The yellowing intensified and became discretely chlorotic. Browning developed in patches indicating necrosis of the underlying tissues during later stages. Necrotic lesions appeared in older leaves which have received UV-B over a long time. The leaves also exhibited curling of margins, followed by bronzing and later became silvery and brittle (Plate 2 to 4). Similar results were reported by Kokilavani and Rajendiran (2014o) in ten varieties of cowpea, Rajendiran *et al.,* (2015a) in *Amaranthus dubius* Mart. Ex. Thell., Rajendiran *et al.,* (2015b) in *Macrotyloma uniflorum* (Lam.) Verdc., Rajendiran *et al.,* (2015c) in *Momordica charantia* L., Rajendiran *et al.,* (2015d) in *Spinacia oleracea* L., Rajendiran *et al.,* (2015e) in *Trigonella foenum-graecum* (L.) Ser., Rajendiran *et al.,* (2015f) in *Benincasa hispida* (Thunb.) Cogn. and Rajendiran *et al.,* (2015h) in *Vigna mungo* (L.) Hepper var. ADT-3 after enhanced UV-B exposure. On the contrary Rajendiran *et al.,* (2015g). in *Portulaca oleracea* L. reported healthy and more number of leaves after UV-B irradiation. 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. According to Britz and Adamse (1994) inhibitions are part of general UV-B effects.

UV-B exposure reduced root length significantly by 4.21 to 42.34 % on all stages of growth till 60 DAS (Table 5 to 8; Plate 5). UV-B stressed T-9 showed maximum reduction of root growth which progressively decreased from 42.34 % on 45 DAS to 7.96 % on 60 DAS. However, root system of T-9 recovered after 45 DAS. Shoot length of UV-B stressed plants decreased by 1.04 to 10.63 % within 30 DAS and continued so till 60 DAS with 43.46 % reduction. T-9 recorded the major reduction in shoot growth compared to plants grown under control condition. The S / R ratio was decreased by UV-B stress by 3.84 to 34.57 % in VAMBAN-3, NIRMAL-7 and T-9 varieties of black gram, the maximum decrease being in NIRMAL-7. However, S / R ratio in all the three varieties showed recovery on 60 DAS as the values were less by only 7.45, 6.70 and 7.22 % in UV-B exposed VAMBAN-3, NIRMAL-7 and T-9 respectively. Fresh weight of roots increased with age in all treatments. But the biomass accumulation in root was inhibited by UV-B treatment by 14.22 to 94.52 % till 30 DAS, the maximum reduction being in T-9. On 45 and 60 DAS all the varieties of black gram did not show any recover as the reduction continued to reach 22.30 to 85.80 %. A general decrease of 2.36 to 87.13 % in shoot fresh weight of UV-B treated plants was observed with the maximum sensitivity shown by T-9. The same trend was maintained at all stages of growth and the inhibitions were consistent with little recovery with the advancing age of plants. The trends observed in root and shoot biomass pattern were reflected at the whole plant level too with inhibitions at UV-B, little improvement in later stages with maximum reduction of 91.10 % in T-9 on 30 DAS.

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Research Article

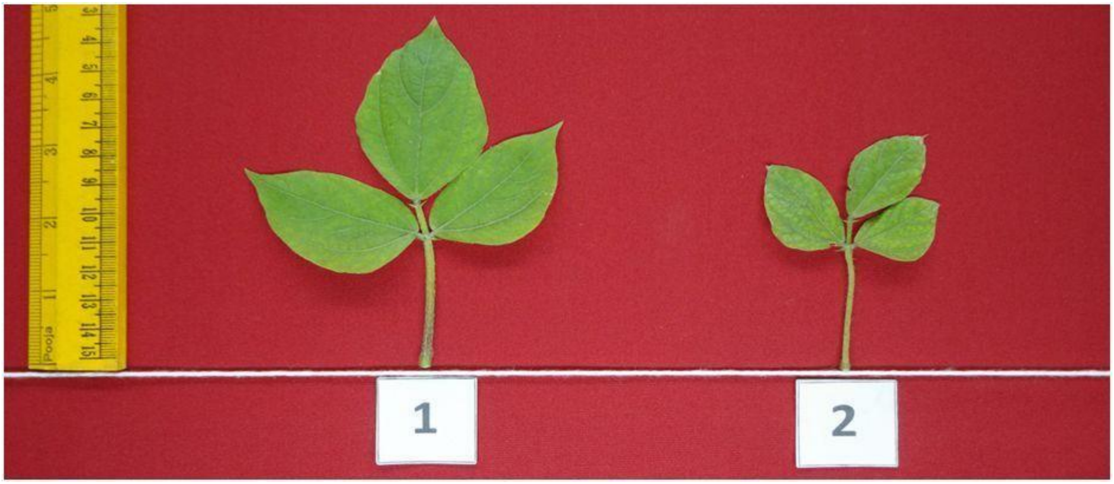

Figure 1: VAMBAN-3

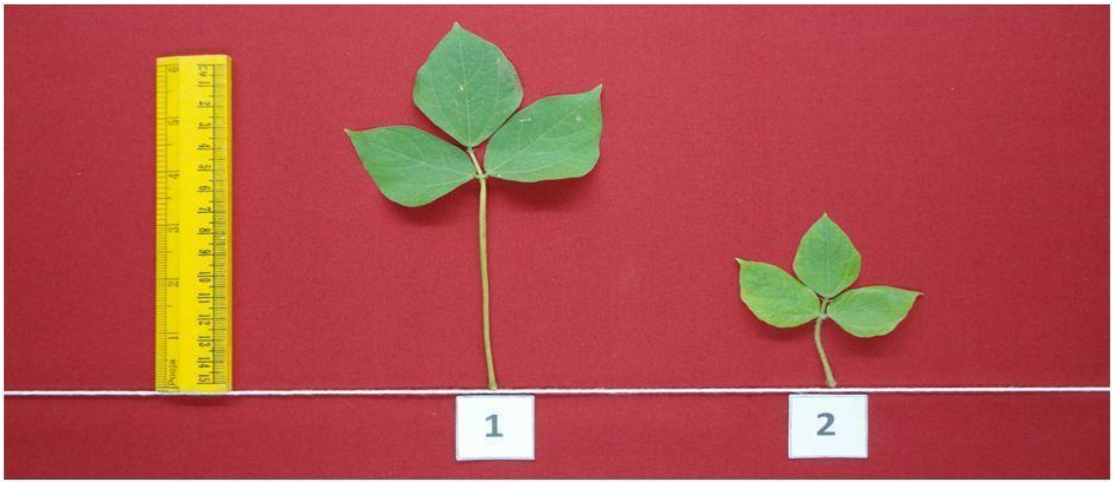

Figure 2: NIRMAL-7

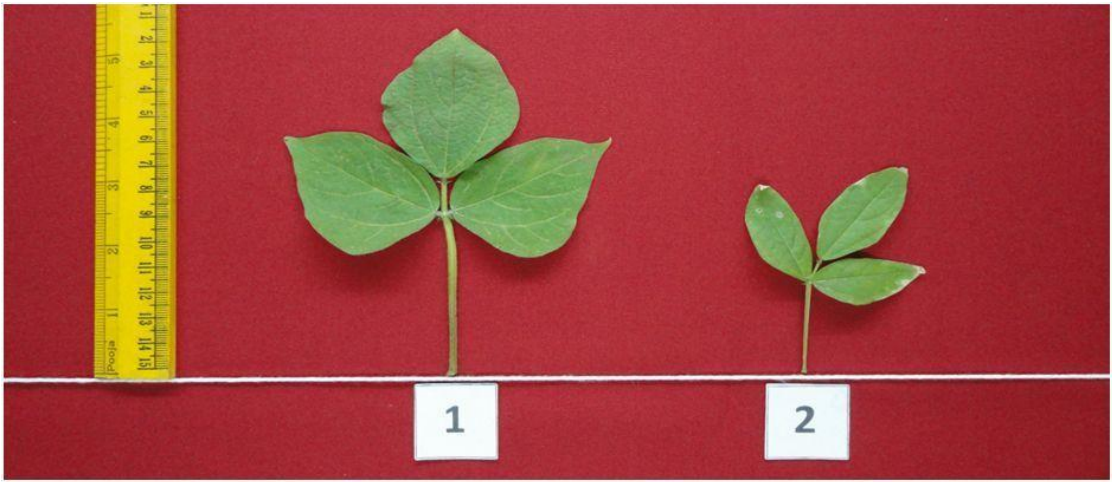

Figure 3: T-9

Plate 1: First fully expanded trifoliate leaves from the three varieties of *Vigna mungo* (L.) Hepper on 45 DAS. (1: Control, 2: UV-B)

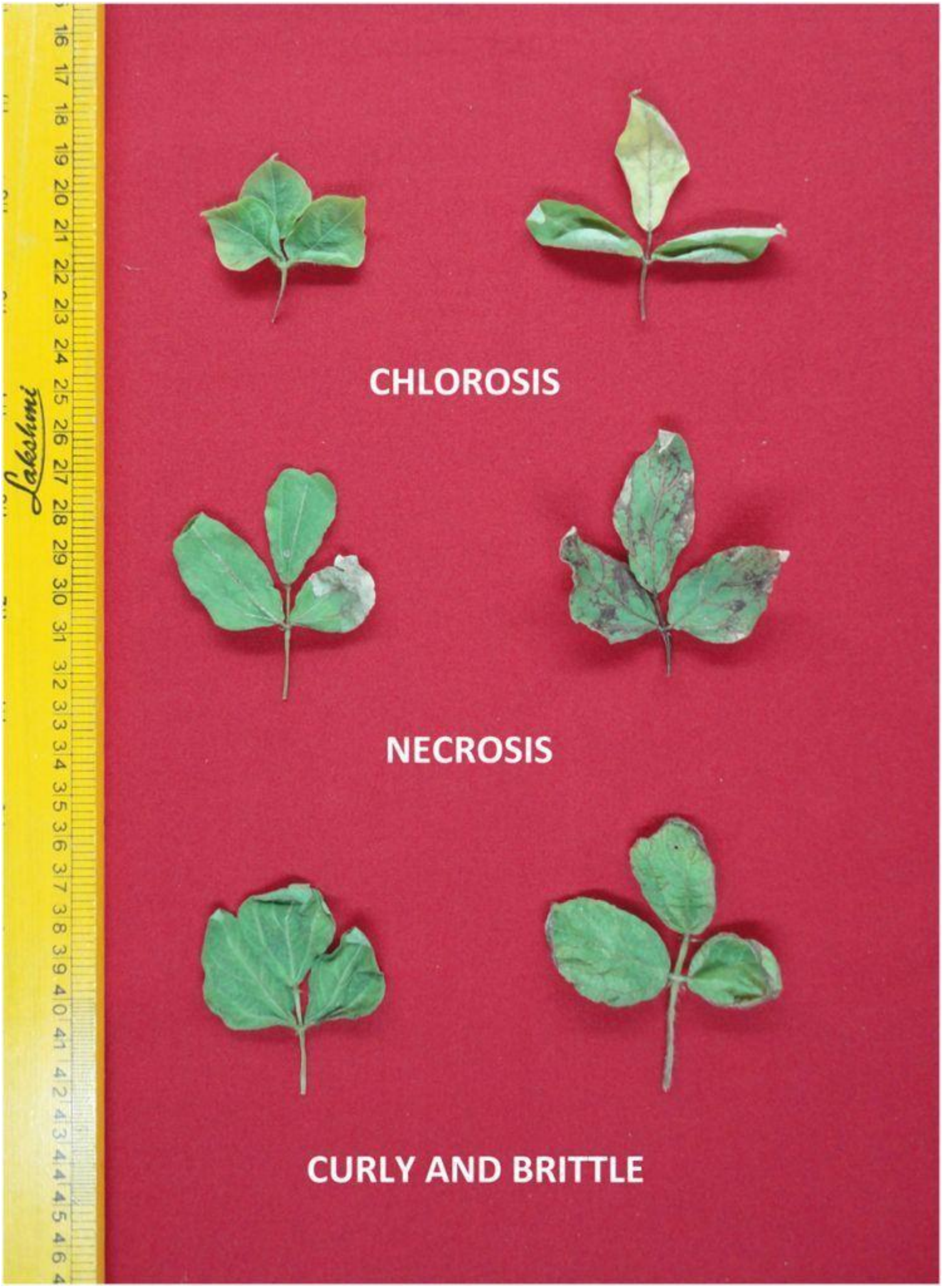

Plate 2: Types of foliar injury caused by elevated UV-B radiation in *Vigna mungo* (L.) Hepper var. VAMBAN-3 on 30 DAS

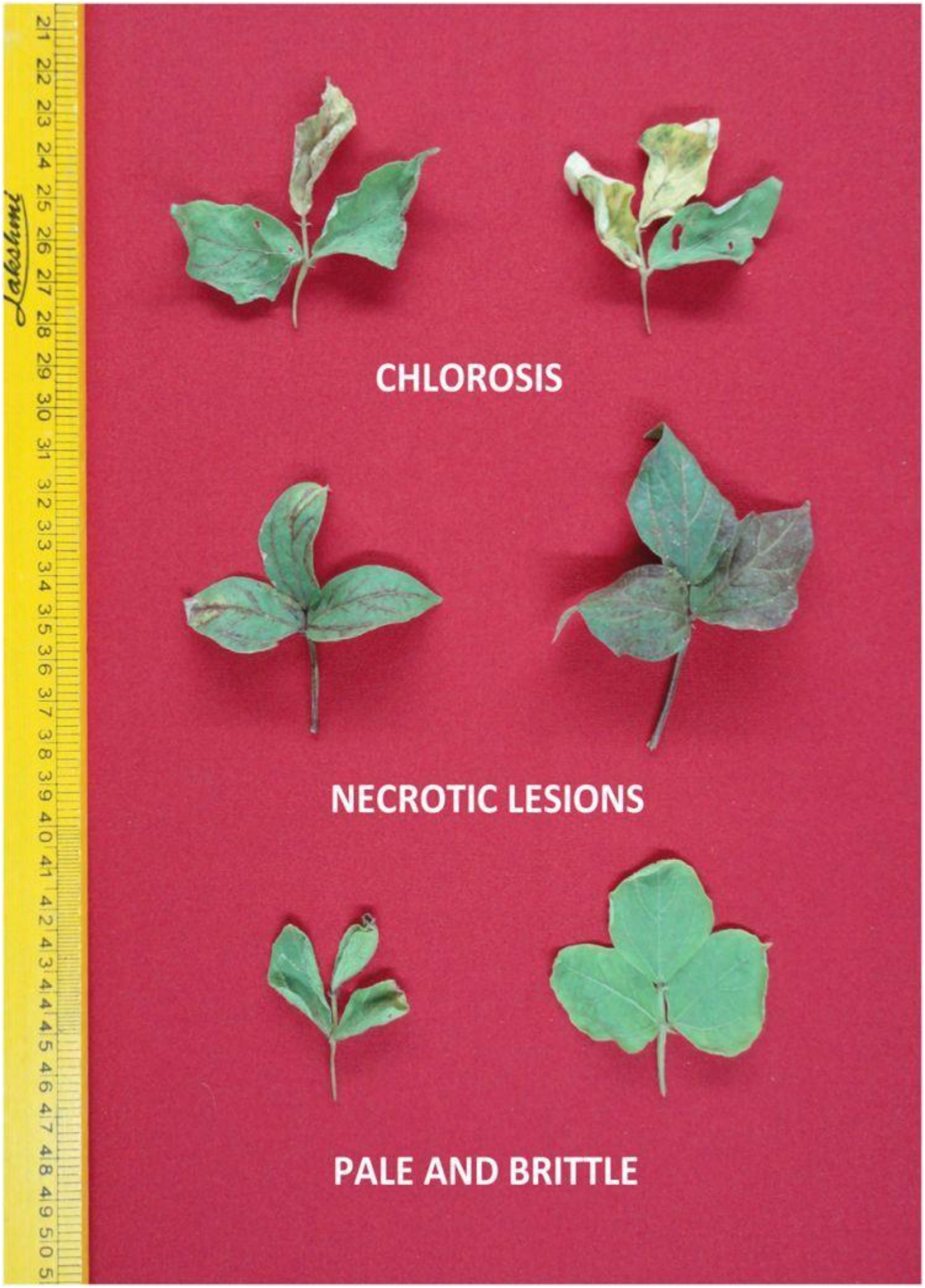

Plate 3: Types of foliar injury caused by elevated UV-B radiation in *Vigna mungo* (L.) Hepper var. NIRMAL-7 on 30 DAS

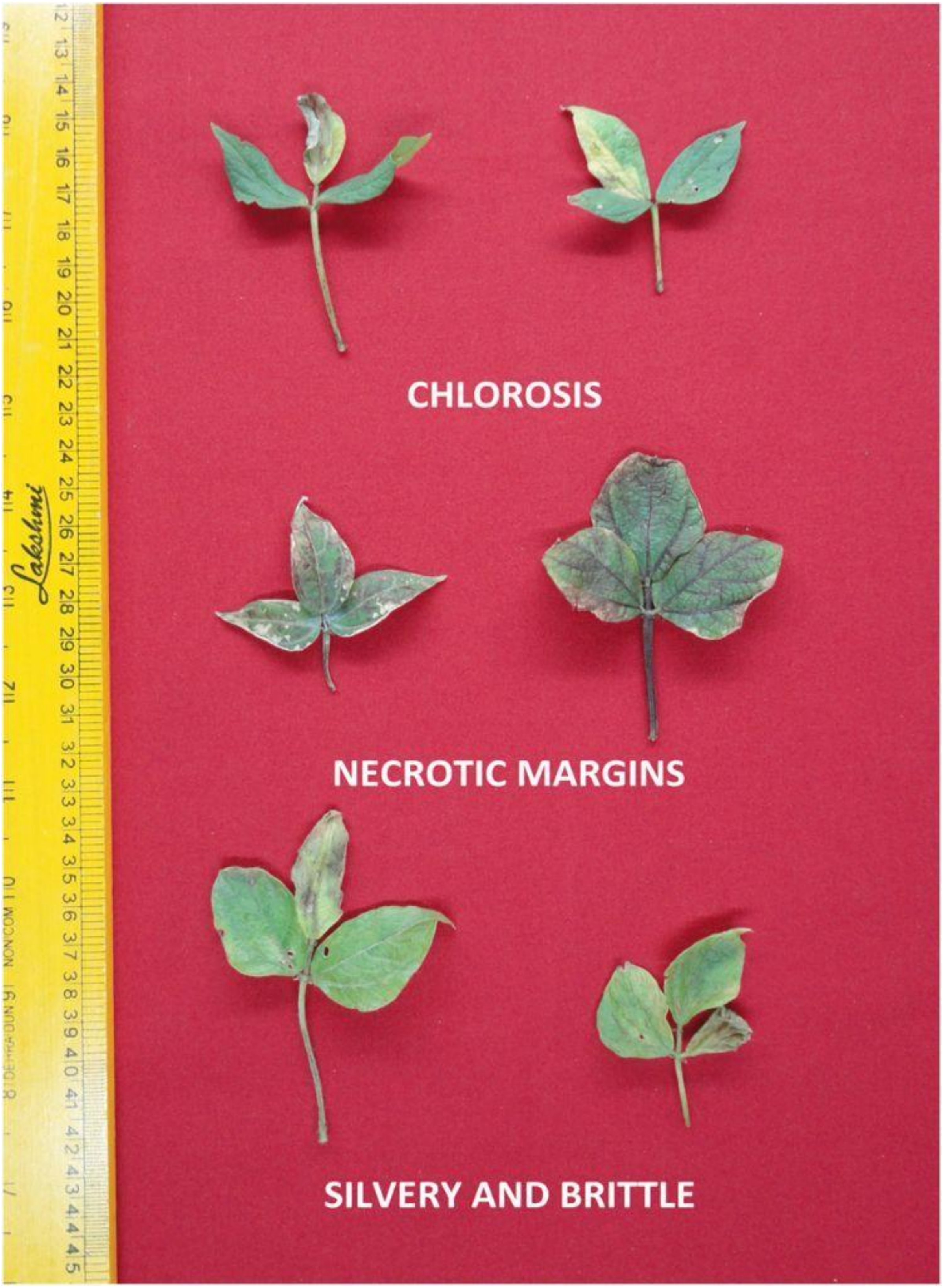

Plate 4: Types of foliar injury caused by elevated UV-B radiation in *Vigna mungo* (L.) Hepper var. T-9 on 30 DAS

Figure 1: VAMBAN-3 - 45 DAS 60 DAS Control UV-B

Figure 2: NIRMAL-7 - 45 DAS 60 DAS Control UV-B

Figure 3: T-9 - 45 DAS 60 DAS Control UV-B

Plate 5: The control and supplementary UV-B stressed plants of three varieties of *Vigna mungo* (L.) Hepper on 45 and 60 DAS. (1: Control, 2: UV-B)

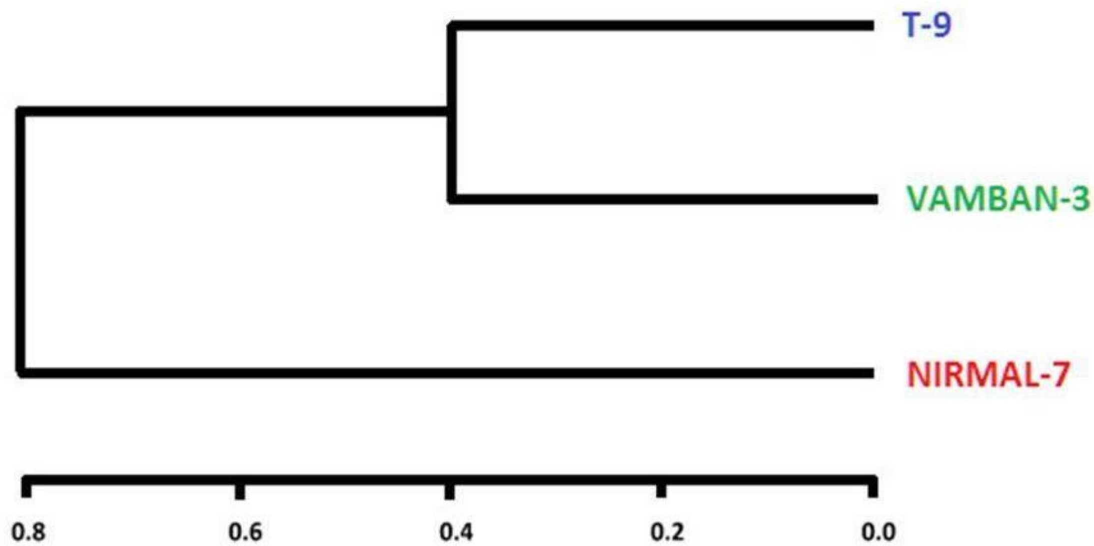

Plate 6: Dendrogram showing the interrelationship between the three varieties of *Vigna mungo* (L.) Hepper in growth parameters under control and supplementary UV-B - *In situ*

A gradual reduction in the root biomass content starting from 10.45 to 57.40 % on 15 DAS and reaching 69.64 to 80.83 % on 60 DAS, the maximum being in T-9 was caused by UV-B treatment. UV-B exposure suppressed dry weight of shoot by 18.69 to 38.80 % on 15, reaching a maximum of 51.51 to 87.26 % on 60 DAS over control.

The severity of UV-B stress was experienced by VAMBAN-3 at all stages of growth. Plant dry weight increased with age in all varieties of black gram but after UV-B stress, it fell below control by 18.69 to 38.80 % on 15 DAS and 53.12 to 85.28 % on 60 DAS (Table 5 to 8).

Table 1: Changes in foliage of three varieties of 15 DAS *Vigna mungo* (L.) Hepper under control and supplementary UV-B exposed conditions – *In situ*

Varieties	**Treatment**	**Number of leaves**	**Total leaf area (cm^2)**	**Leaf area index**	**Specific leaf weight (g^{-2})**	**Fresh weight of foliage (g)**	**Dry weight of foliage (g)**
VAMBAN-3	Control	2	102.828	0.362	0.259	0.325	0.074
	UV-B	2	32.947	0.312	0.159	0.279	0.045
NIRMAL-7	Control	1	102.828	0.362	0.358	0.279	0.065
	UV-B	1	17.16	0.201	0.201	0.087	0.075
T-9	Control	2	104.544	0.429	0.221	0.190	0.088
	UV-B	2	29.7	0.378	0.152	0.128	0.063

Table 2: Changes in foliage of three varieties of 30 DAS *Vigna mungo* (L.) Hepper under control and supplementary UV-B exposed conditions – *In situ*

Varieties	**Treatment**	**Number of leaves**	**Total leaf area (cm^2)**	**Leaf area index**	**Specific leaf weight (g^{-2})**	**Fresh weight of foliage (g)**	**Dry weight of foliage (g)**
VAMBAN-3	Control	5	415.8	0.588	0.828	0.642	0.528
	UV-B	4	83.16	0.540	0.437	0.141	0.134
NIRMAL-7	Control	3	130.917	0.464	0.362	0.233	0.210
	UV-B	5	65.445	0.320	0.270	0.155	0.148
T-9	Control	4	233.164	0.485	0.525	0.223	0.209
	UV-B	3	58.924	0.452	0.373	0.026	0.025

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Table 3: Changes in foliage of three varieties of 45 DAS *Vigna mungo* (L.) Hepper under control and supplementary UV-B exposed conditions – *In situ*

Varieties	Treatment	Number of leaves	Total leaf area (cm^2)	Leaf area index	Specific leaf weight (g^{-2})	Fresh weight of foliage (g)	Dry weight of foliage (g)
VAMB	Control	6	733.425	0.840	0.26	1.910	0.449
AN-3	UV-B	4	148.5	0.762	0.15	0.245	0.129
NIRM	Control	5	435.6	0.962	0.321	1.748	0.405
AL-7	UV-B	3	76.058	0.327	0.278	0.345	0.081
T-9	Control	6	498.326	0.775	0.285	1.539	0.436
	UV-B	4	22.086	0.745	0.176	0.989	0.252

Table 4: Changes in foliage of three varieties of 60 DAS *Vigna mungo* (L.). Hepper under control and supplementary UV-B exposed conditions – *In situ*

Varieties	Treatment	Number of leaves	Total leaf area (cm^2)	Leaf area index	Specific leaf weight (g^{-2})	Fresh weight of foliage (g)	Dry weight of foliage (g)
VAMB	Control	15	3049.2	1.834	1.196	3.107	2.234
AN-3	UV-B	12	217.8	0.572	0.762	0.404	0.276
NIRM	Control	14	1085.37	2.730	1.554	4.451	1.353
AL-7	UV-B	7	619.905	2.612	0.620	1.004	0.552
T-9	Control	9	915.868	1.348	1.317	1.865	0.951
	UV-B	7	350.380	0.888	0.821	0.240	0.153

Table 5: Changes in growth parameters of threevarieties of 15 DAS *Vigna mungo* (L.) Hepper under control and supplementary UV-B exposed conditions – *In situ*

Varieties	Treatment	Root length (cm)	Shoot length (cm)	Shoot / root ratio	Root fresh wt. (g)	Shoot fresh wt. (g)	Plant fresh wt. (g)	Root dry wt. (g)	Shoot dry wt. (g)	Plant dry wt. (g)	Relative growth rate
VAMB	Control	4.51	16.72	3.88	0.180	0.634	0.799	0.022	0.110	0.132	-
AN-3	UV-B	4.32	15.73	3.33	0.107	0.619	0.742	0.019	0.090	0.109	-
NIRM	Control	6.53	13.52	2.57	0.138	0.679	0.818	0.021	0.123	0.145	-
AL-7	UV-B	5.12	12.56	2.05	0.047	0.297	0.344	0.009	0.075	0.084	-
T-9	Control	7.65	20.06	2.85	0.109	0.551	0.660	0.023	0.164	0.188	-
	UV-B	6.52	16.08	2.46	0.094	0.516	0.111	0.016	0.114	0.130	-

Table 6: Changes in growth parameters of three varieties of 30 DAS *Vigna mungo* (L.) Hepper under control and supplementary UV-B exposed conditions – *In situ*

Varieties	Treatment	Root length (cm)	Shoot length (cm)	Shoot / root ratio	Root fresh wt. (g)	Shoot fresh wt. (g)	Plant fresh wt. (g)	Root dry wt. (g)	Shoot dry wt. (g)	Plant dry wt. (g)	Relative growth rate
VAMB	Control	7.5	23.5	3.13	0.179	1.480	1.659	0.113	0.866	0.979	0.057
AN-3	UV-B	7	21	3	0.056	0.321	0.378	0.034	0.236	0.271	0.026
NIRM	Control	6	25	4.16	0.113	0.713	0.826	0.058	0.383	0.441	0.036
AL-7	UV-B	5	20	4	0.041	0.312	0.354	0.032	0.264	0.297	0.032
T-9	Control	8	26	3.25	0.767	0.661	1.428	0.092	0.395	0.487	0.027
	UV-B	6	16	2.66	0.042	0.085	0.127	0.059	0.075	0.135	0.001

Table 7: Changes in growth parameters of three varieties of 45 DAS *Vigna umungo* (L.) Hepper under control and supplementary UV-B exposed conditions – *In situ*

Varieties	Treatment	Root length (cm)	Shoot length (cm)	Shoot / root ratio	Root fresh wt. (g)	Shoot fresh wt. (g)	Plant fresh wt. (g)	Root dry wt. (g)	Shoot dry wt. (g)	Plant dry wt. (g)	Relative growth Rate
VAMBAN-3	Control	11.12	34.32	3.98	1.104	3.719	4.859	0.266	0.893	1.160	0.059
	UV-B	8.53	33.96	3.09	0.886	1.494	2.380	0.110	0.356	0.467	0.004
NIRMAL-7	Control	10.52	38.22	4.02	0.941	4.576	5.517	0.185	1.068	1.254	0.030
	UV-B	9.51	27.74	2.63	0.710	1.161	1.872	0.073	0.281	0.354	0.018
T-9	Control	16.58	32.46	2.78	1.022	3.600	4.622	0.217	0.933	1.151	0.047
	UV-B	9.56	26.57	1.96	0.763	2.392	3.156	0.104	0.590	0.694	0.024

Table 8: Changes in growth parameters of three varieties of 60 DAS *Vigna mungo* (L.) Hepper under control and supplementary UV-B exposed conditions – *In situ*

Varieties	Treatment	Root length (cm)	Shoot length (cm)	Shoot / root ratio	Root fresh wt. (g)	Shoot fresh wt. (g)	Plant fresh wt. (g)	Root dry wt. (g)	Shoot dry wt. (g)	Plant dry wt. (g)	Relative growth Rate
VAMBAN-3	Control	9.52	67.61	7.11	4.257	12.830	17.087	1.391	6.718	8.110	0.056
	UV-B	5.81	38.22	6.58	0.604	2.218	5.822	0.337	0.855	4.010	0.016
NIRMAL-7	Control	18.32	33.74	1.94	0.843	11.460	12.303	0.358	3.669	4.027	0.048
	UV-B	17.51	33.01	1.81	0.225	4.834	5.059	0.108	1.779	1.888	0.033
T-9	Control	16.20	42.63	2.63	1.191	5.996	7.187	0.512	2.159	2.672	0.024
	UV-B	14.91	36.51	2.44	0.182	1.879	2.062	0.098	0.853	1.951	0.009

Table 9: The similarity indices in growth parameters of three varieties of *Vigna mungo* (L.) Hepper under supplementary UV-B exposed conditions – *In situ*

Varieties	VAMBAN-3	NIRMAL-7	T-9
VAMBAN-3	100%	52.6%	50.6%
NIRMAL-7	52.6%	100%	52.7%
T-9	50.6%	52.7%	100%

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), *Phaseolus vulgaris* (Mark and Tevini 1997), *Vigna mungo* (Rajendiran and Ramanujam 2000) and *Vigna radiata* (Rajendiran and Ramanujam 2003). Similar reductions in growth parameters were reported by Kokilavani and Rajendiran (2014o) in ten varieties of cowpea, Rajendiran *et al.*, (2015a) in *Amaranthus dubius* Mart. Ex. Thell., Rajendiran *et al.*, (2015b) in *Macrotyloma uniflorum* (Lam.) Verdc., Rajendiran *et al.*, (2015c) in *Momordica charantia* L., Rajendiran *et al.*, (2015d) in *Spinacia oleracea* L., Rajendiran *et al.*, (2015e) in *Trigonella foenum-graecum* (L.) Ser., Rajendiran *et al.*, (2015f) in *Benincasa hispida* (Thunb.) Cogn. and Rajendiran *et al.*, (2015h) in *Vigna* *mungo* (L.) Hepper var. ADT-3 after enhanced UV-B exposure. 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). However *Portulaca oleracea* L. plants were taller and healthy than controls after UV-B irradiation (Rajendiran *et al.,* 2015g).

The relative growth rate (RGR) was lowered (11.11 to 93.22 %) in all UV-B irradiated plants compared with control till 60 DAS. However, RGR was reduced to the maximum in VAMBAN-3 as it reached 93.22 % reduction on 45 DAS (Table 5 to 8). Similar inhibitions of RGR by UV-B were observed by Jain *et al.,* (1999) in mungbean, by Kokilavani and Rajendiran (2014o) in ten varieties of cowpea, Rajendiran *et al.,* (2015a) in *Amaranthus dubius* Mart. Ex. Thell., Rajendiran *et al.,* (2015b) in *Macrotyloma uniflorum* (Lam.) Verdc., Rajendiran *et al.,* (2015c) in *Momordica charantia* L., Rajendiran *et al.,* (2015d) in *Spinacia oleracea* L., Rajendiran *et al.,* (2015e) in *Trigonella foenum-graecum* (L.) Ser., Rajendiran *et al.,* (2015f) in *Benincasa hispida* (Thunb.) Cogn. after enhanced UV-B exposure. On the contrary, Rajendiran *et al.,* (2015g) in *Portulaca oleracea* L. reported enhanced RGR after UV-B exposure.

The growth parameters studied in three varieties of black gram after *in situ* supplementary UV-B irradiation showed variations in the plant height, number of leaves, total leaf area, fresh weight, dry weight and relative growth rate after exposure to supplementary UV-B radiation *in situ* during different stages of growth. Under UV-B exposure, T-9 was severely while plant growth was best in VAMBAN-3 followed by NIRMAL-7. The similarity index between VAMBAN-3 and T-9 was the least with a value of 50.6 % (Table 9; Plate 6). These two varieties remained as one group and showed close relationship with NIRMAL-7 with a similarity index 52 %. The response of NIRMAL-7 to elevated UV-B irradiation was unique to it and was totally isolated from the rest of the varieties.

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