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Research Article

ASSESSMENT OF VARIATIONS IN MORPHOLOGY AND GROWTH OF THREE VARIETIES OF COWPEA UNDER ELEVATED ULTRAVIOLET-B RADIATION

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ABSTRACT
The growth parameters studied in three varieties of cowpea *viz.*, GOWMATHI, FOLA and NS-634 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). Leaves were less in number (16.16 to 54.54 %) under UV-B exposure in all the varieties of cowpea. UV-B irradiation reduced the total leaf area and leaf area index (LAI) throughout the growth period, the maximum being 91.06 % and 71.66 % in NS-634 on 60 DAS. The specific leaf weight (SLW) was reduced (47.61 %) severely in GOWMATHI on 15 DAS after UV-B exposure. Fresh weight of leaves under UV-B stress decreased by 22 to 87.57 % with maximum reduction shown by FOLA on 45 DAS. The dry weight of foliage decreased (31.50 to 92.13 %) in all stages of UV-B exposed plants with GOWMATHI and FOLA recording heavy reduction. UV-B exposure reduced root (6.25 to 46.42 %) and shoot length (6 to 55.53 %) and S / R ratio (6 to 35.02 %) till 60 DAS, the major reduction being in NS-634. Fresh and dry biomass of roots (2.12 to 95.40 %) and shoots (7.57 to 94.27 %) were inhibited by UV-B treatment with the maximum sensitivity shown by GOWMATHI. The relative growth rate (RGR) was lowered (33.56 to 97.42 %) in all UV-B irradiated plants at all stages of growth. However, FOLA and NS-634 showed an enhancement (65 to 103%) in RGR over control on 60 DAS.

Keywords: *Ultraviolet-B, Cowpea, Three Varieties, Morphology, Growth*

INTRODUCTION
Plant growth and survival are controlled by the environment. Even if one environmental factor is less or more than the optimum level, it will turn into a growth limiting factor. An abiotic stress like ultraviolet-B (UV-B) radiation introduced during the active growth period of a crop, would create changes on the gross morphology through metabolic processes, as the crop struggles to compromise the adverse effects and grow normally (Rajendiran, 2001). Supplementary UV-B damages the foliage (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) inhibits growth (Rajendiran and Ramanujam, 2003; Rajendiran and Ramanujam, 2004; Kokilavani and Rajendiran, 2014o), suppresses yield (Kokilavani and Rajendiran, 2014e) and reduces 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) in a variety of crops. According to Caldwell *et al.*, (1998) 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. This has been blamed as the major defect leading to overstating the damaging influence of UV-B (Jordan, 1997) as plants under natural day light

conditions with high PAR (photosynthetically active radiation) are affected very little (Adamse and Britz, 1992). The present work gains importance as the three varieties of cowpea *viz.*, GOWMATHI, FOLA and NS-634 were grown under field conditions (*in situ*) allowing the interaction of PAR and other environmental factors with UV-B radiation.

MATERIALS AND METHODS

Cowpea (*Vigna unguiculata* (L.) Walp.) belonging to the family Fabaceae which is a nitrogen fixing grain legume was chosen for the study. Viable seeds of the three varieties of cowpea *viz.* GOWMATHI, FOLA and NS-634 (Namdhari Seeds) 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 cowpea 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 al.*, 1983) were calculated using the following formulae.

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

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

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

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

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 ten varieties of cowpea 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 ten varieties of cowpea, dendrograms were draw to derive the interrelationship between them and presented in tables and plates.

RESULTS AND DISCUSSION

The responses of three varieties of cowpea *viz.* GOWMATHI, FOLA and NS-634 in control and supplementary UV-B irradiation under *in situ* condition were assessed in terms of growth on 15, 30, 45 and 60 DAS and yield performances at the final stage (60 DAS). Under UV-B stress there were fewer leaves only (16.16 to 54.54 %) in all the three varieties of cowpea and the number of leaves decreased with age. However plants under normal ambience had more number of leaves. Supplementary UV-B irradiation reduced the total leaf area throughout the growth period, the maximum being 91.06 % on 60 DAS in NS-634 (Table 1 to 4; Plate 1). The LAI was reduced by UV-B exposure to a larger extent, the maximum being 71.66 % over control on 60 DAS in NS-634. The SLW in UV-B irradiated decreased with age. An average decrease ranging from 7.29 to 47.61 % was observed on 15, 30, 45 and 60 DAS in all the three varieties of cowpea. However, the pattern of SLW reduction (47.61 %) was very severe in GOWMATHI on 15 DAS. UV-B stress decreased the fresh weight of leaves by 22 to 87.57 %, with the maximum reduction being in FOLA on 45 DAS. However, FOLA which suffered heavily (87.57 %) on 45 DAS recovered from UV-B stress (9.70 %) on 60 DAS. The dry weight of foliage decreased by 31.50 to 92.13 % in all stages of UV-B exposed plants. UV-B stressed GOWMATHI and FOLA recorded heavy reduction (Table 1 to 4).

On prolonged exposure to UV-B the leaves of all the three varieties of cowpea 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 bronzing and 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.

Growth of all the varieties of cowpea was progressively inhibited by the UV-B radiation. UV-B exposure reduced root length significantly by 6.25 to 46.42 % on all stages of growth till 60 DAS (Table 5 to 8; Plate 5). UV-B stressed FOLA showed maximum reduction of root growth which progressively decreased from 46.42 % on 30 DAS to 14.43 % on 60 DAS.

However, it recovered after 45 DAS. Shoot length of UV-B stressed plants decreased by 6 to 55.53 % within 30 DAS and continued so till 60 DAS with 38.50 % reduction. NS-634 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 6 to 35.02 % in GOWMATHI, FOLA and NS-634, the maximum decrease being in NS-634. However, S / R ratio showed an increase of 3.36 to 29.79 % over control on 15 DAS in FOLA and NS-634. NS-634 showed a low value (21.72 %) below control while GOWMATHI and FOLA recorded an increase in S / R ratio by 5.08 and 3.36 % on 60 DAS respectively.

Fresh weight of roots increased with age in all treatments. But the biomass accumulation in root was inhibited by UV-B treatment by 2.12 to 95.40 % on 30 DAS, the maximum reduction being in GOWMATHI. On 30, 45 and 60 DAS all the varieties of cowpea did not show any recover as the reduction continued to reach 44.27 to 80.53 %.

A general decrease of 7.57 to 94.27 % in shoot fresh weight of UV-B treated plants was observed with the maximum sensitivity shown by GOWMATHI. 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 94.72 % in GOWMATHI on 30 DAS. A gradual reduction in the root biomass content starting from 26.92 to 35.82 % on 15 DAS and reaching 47.35 to 83.69 % on 60 DAS, the maximum being in GOWMATHI was caused by UV-B treatment. UV-B exposure suppressed dry weight of shoot by 34.79 to 54.04 % on 15, reaching a maximum of 38.57 to 85.60 % on 60 DAS over control.

The severity of UV-B stress was experienced by GOWMATHI at all stages of growth. Plant dry weight increased with age in all varieties of cowpea but after UV-B stress, it fell below control by 34.75 to 50.92 % on 15 DAS and 26 to 35 % on 60 DAS (Table 5 to 8).

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).

Table 1: Changes in foliage of three varieties of 15 DAS *Vigna unguiculata* (L.) Walp. 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)
GOWMATHI	Control	2	164.260	0.502	0.231	2.592	0.166
	UV-B	2	63.676	0.451	0.121	2.005	0.083
FOLA	Control	2	403.92	0.396	0.159	2.742	0.187
	UV-B	2	142.56	0.343	0.114	2.136	0.105
NS-634	Control	2	362.419	0.564	0.136	2.321	0.133
	UV-B	2	107.844	0.380	0.114	2.861	0.083

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Table 2: Changes in foliage of three varieties of 30 DAS *Vigna unguiculata* (L.) Walp. 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)
GOWM	Control	3	553.21	0.646	0.164	2.462	0.245
ATHI	UV-B	3	98.20	0.488	0.124	1.160	0.094
FOLA	Control	3	739.23	0.768	0.147	2.650	1.004
	UV-B	2	102.96	0.512	0.123	0.725	0.128
NS-634	Control	6	822.19	0.961	0.094	1.331	0.378
	UV-B	5	121.96	0.654	0.081	0.331	0.068

Table 3: Changes in foliage of three varieties of 45 DAS *Vigna unguiculata* (L.) Walp. 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)
GOWM	Control	5	910.8	0.724	0.127	3.660	0.657
ATHI	UV-B	5	519.75	0.685	0.098	2.719	0.450
FOLA	Control	5	941.32	1.167	0.192	7.017	2.075
	UV-B	3	158.76	0.623	0.178	0.872	0.222
NS-634	Control	7	803.88	1.137	0.197	4.635	1.004
	UV-B	7	333.23	1.082	0.139	1.072	0.206

Table 4: Changes in foliage of three varieties of 60 DAS *Vigna unguiculata* (L.) Walp. 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)
GOWM	Control	7	1481.04	1.124	0.163	8.489	4.386
ATHI	UV-B	4	203.63	0.945	0.148	1.901	0.345
	Control	7	1746.36	1.260	0.184	11.366	6.179
FOLA	UV-B	5	1135.53	1.055	0.160	10.263	3.608
NS-634	Control	11	1132.56	2.132	0.180	4.538	2.811
	UV-B	5	101.178	0.604	0.158	2.347	1.320

Table 5: Changes in growth parameters of three varieties of 15 DAS *Vigna unguiculata* (L.) Walp. 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
GOWMATHI	Control	8	19.5	2.43	1.664	2.435	4.100	0.067	0.309	0.377	-
	UV-B	6.8	12.8	1.88	0.191	1.266	1.457	0.043	0.142	0.185	-
FOLA	Control	5.7	24.7	4.33	2.805	2.740	5.54	0.052	0.392	0.430	-
	UV-B	3.5	19.7	5.62	2.920	1.726	4.647	0.038	0.197	0.249	-
NS-634	Control	6	25	4.16	2.874	2.724	5.538	0.055	0.273	0.328	-
	UV-B	5	23.5	4.7	2.813	1.939	4.813	0.035	0.178	0.214	-

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Table 6: Changes in growth parameters of three varieties of 30 DAS *Vigna unguiculata* (L.) Walp. 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
GOWMATHI	Control	10	30	3	3.157	4.753	7.910	0.135	0.180	1.240	0.034
	UV-B	8.5	24	2.82	0.145	0.272	0.417	0.034	0.105	0.214	0.004
FOLA	Control	16.8	46	2.73	0.769	6.103	6.734	0.211	2.959	3.170	0.057
	UV-B	9	29.5	3.27	0.631	2.903	3.672	0.125	0.384	0.509	0.020
NS-634	Control	10	98.5	9.85	1.618	3.894	5.513	0.089	1.517	1.606	0.045
	UV-B	7.5	43.8	6.4	0.162	1.869	2.031	0.051	0.392	0.443	0.001

Table 7: Changes in growth parameters of three varieties of 45 DAS *Vigna unguiculata* (L.) Walp. 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
GOWMATHI	Control	16	54	3.37	0.627	8.003	8.631	0.236	1.410	1.647	0.008
	UV-B	15	39	2.6	0.459	7.048	7.508	0.223	1.000	1.223	0.004
FOLA	Control	18	121	6.72	1.579	12.362	13.942	0.610	3.341	3.952	0.006
	UV-B	14	103	7.35	0.638	2.903	3.542	0.186	0.657	0.844	0.014
NS-634	Control	13	112	8.61	0.732	9.748	10.481	0.365	2.024	2.389	0.011
	UV-B	9	85.5	9.5	0.212	2.616	2.829	0.080	0.466	0.546	0.006

Table 8: Changes in growth parameters of three varieties of 60 DAS *Vigna unguiculata* (L.) Walp. 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
GOWMATHI	Control	19	86	4.52	5.459	17.127	22.596	1.570	8.545	10.115	0.052
	UV-B	17.6	83.6	4.75	1.062	5.471	6.533	0.256	1.230	7.486	0.005
FOLA	Control	19.4	173	8.91	3.673	21.065	25.278	1.452	10.864	12.316	0.032
	UV-B	16.6	153	9.21	2.046	19.968	22.014	0.581	7.428	8.010	0.065
NS-634	Control	16.4	180.5	11.00	2.388	13.261	15.650	0.576	6.697	7.274	0.032
	UV-B	12.8	111	8.67	0.966	5.251	6.217	0.303	3.132	4.436	0.053

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

Varieties	GOWMATHI	FOLA	NS-634
GOWMATHI	100%	23.26%	19.37%
FOLA	23.26%	100%	31.73%
NS-634	19.37%	31.73%	100%

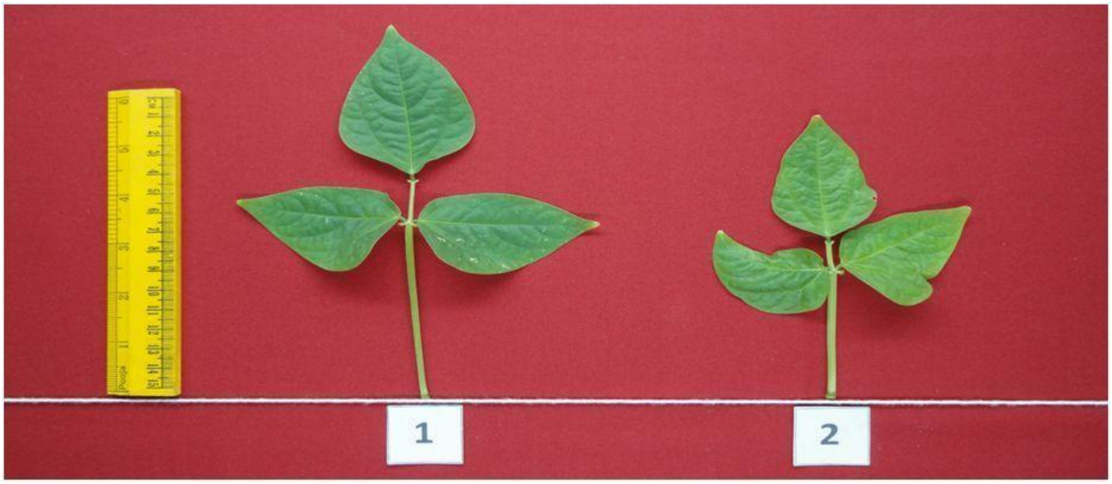

Figure 1: GOWMATHI

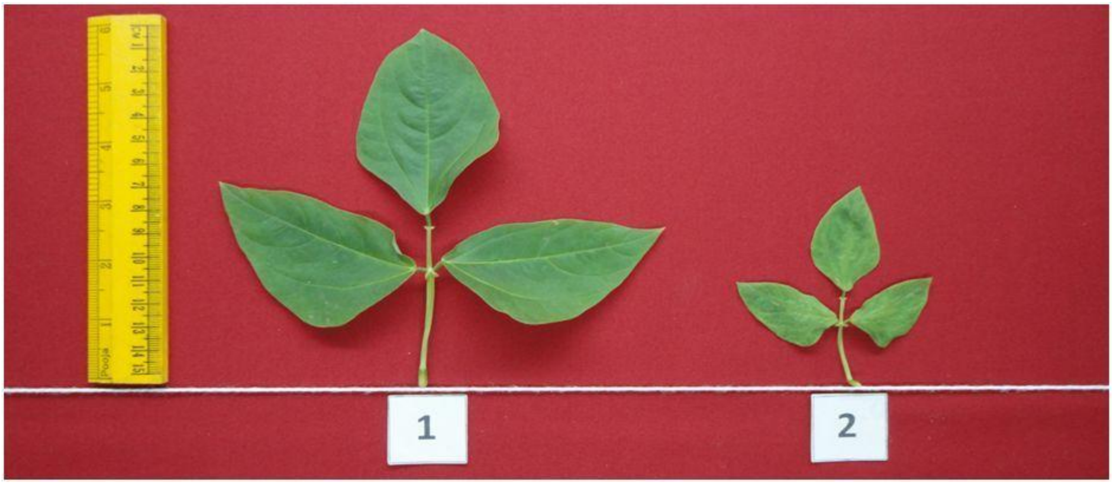

Figure 2: FOLA

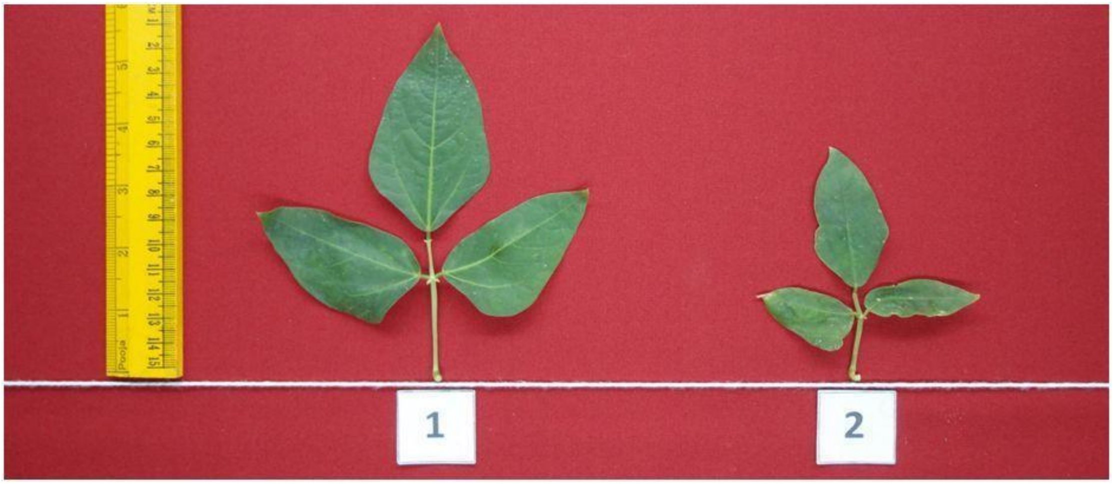

Figure 3: NS-634

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

Plate 2: Types of foliar injury caused by elevated UV-B radiation in *Vigna unguiculata* (L.) Walp. var. GOWMATHI on 30 DAS

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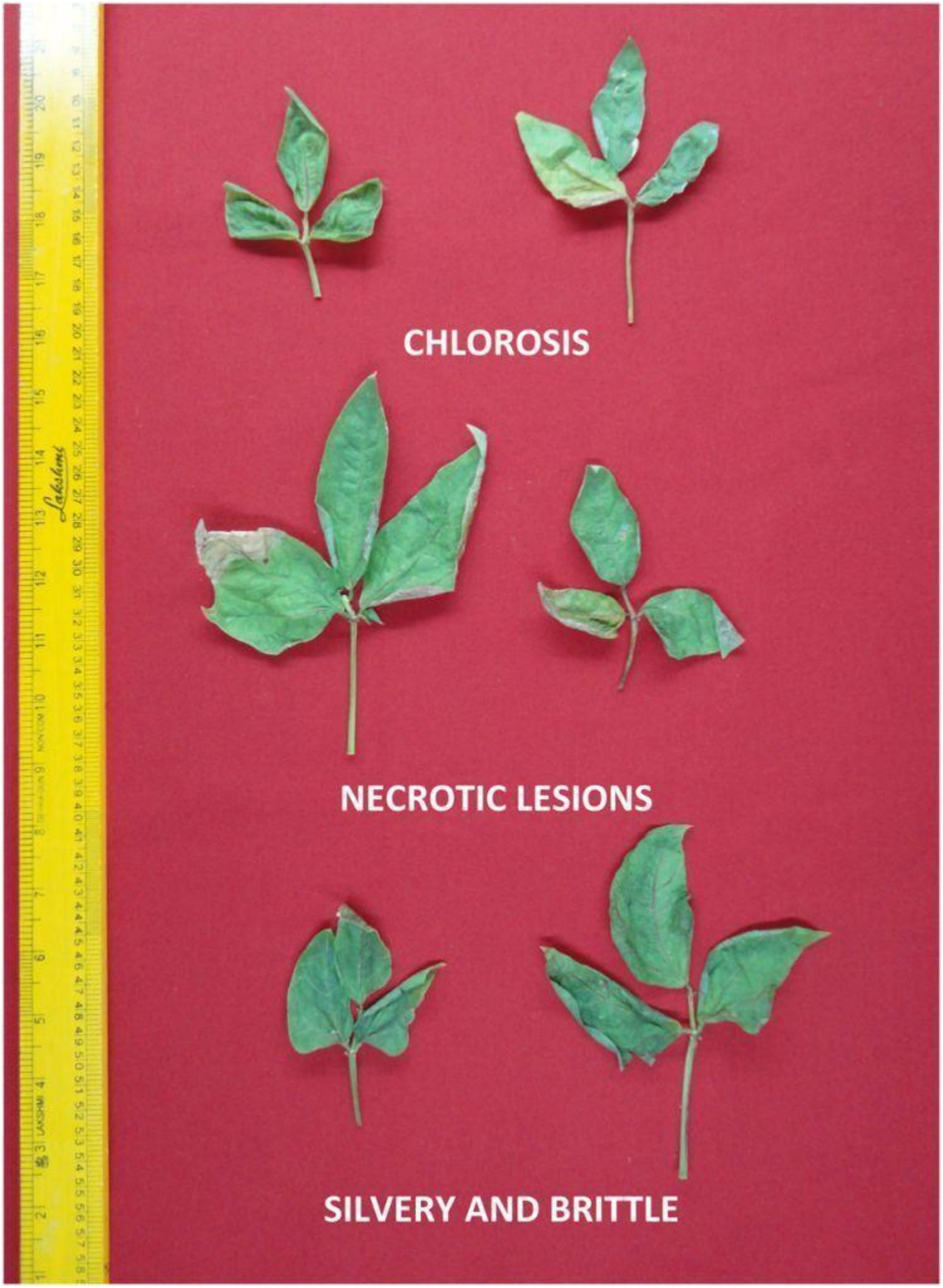

Plate 3: Types of foliar injury caused by elevated UV-B radiation in *Vigna unguiculata* (L.) Walp. var. FOLA on 30 DAS

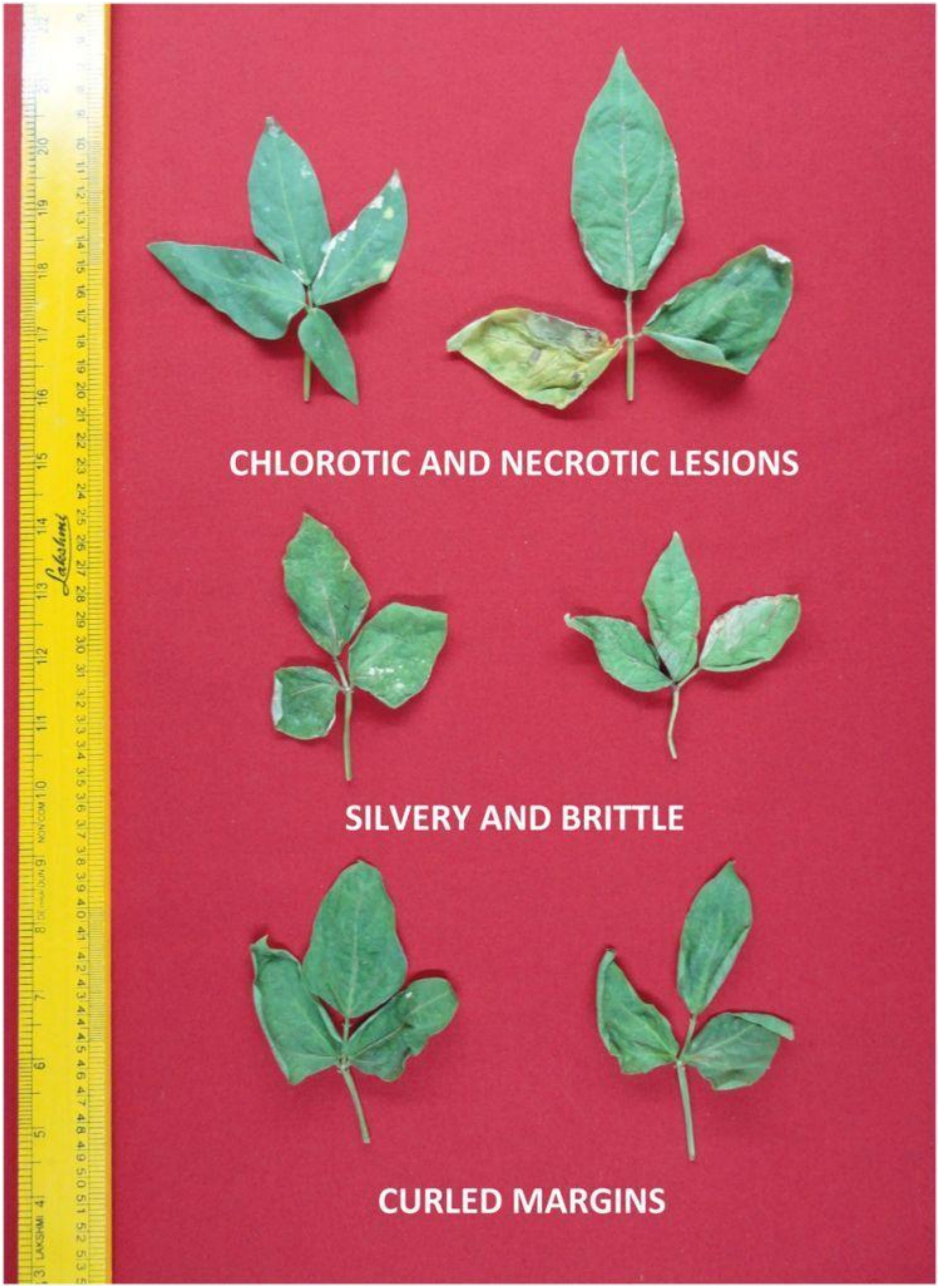

Plate 4: Types of foliar injury caused by elevated UV-B radiation in *Vigna unguiculata* (L.) Walp. var. NS-634 on 30 DAS

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Figure 1: GOWMATHI - 45 DAS 60 DAS Control UV-B

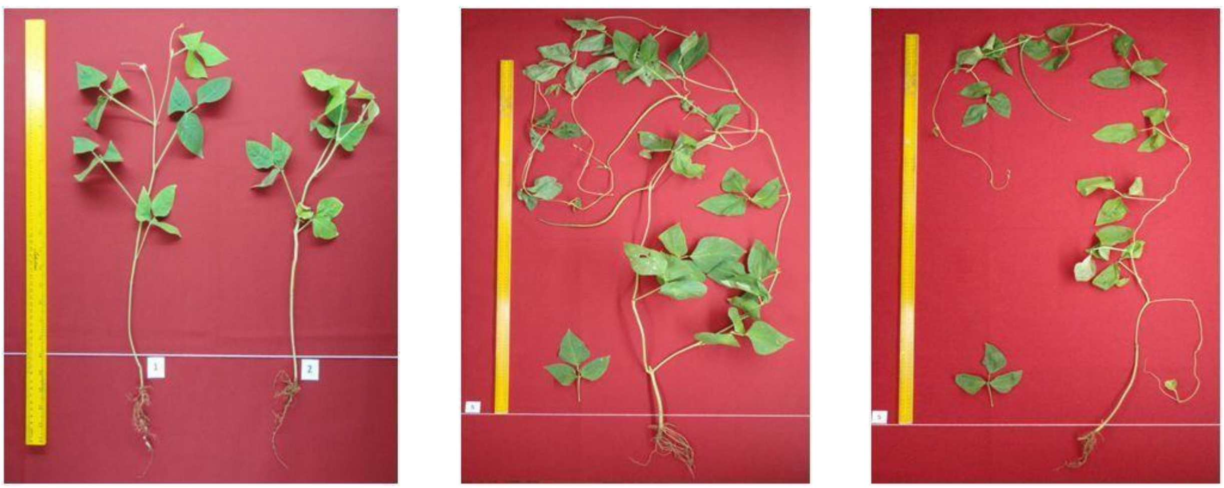

Figure 2: FOLA - 45 DAS 60 DAS Control UV-B

Figure 3: NS-634 - 45 DAS 60 DAS Control UV-B

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

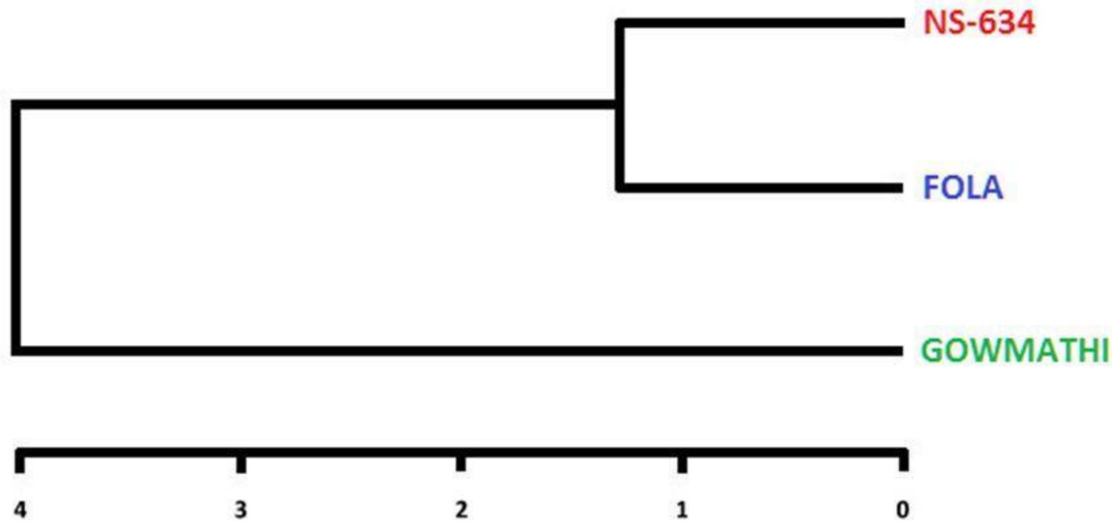

Plate 6: Dendrogram showing the interrelationship between the three varieties of *Vigna unguiculata* (L.) Walp. in growth parameters under control and supplementary UV-B - *In situ*

The relative growth rate (RGR) was lowered (33.56 to 97.42 %) in all UV-B irradiated plants except in FOLA and NS-634 which showed an enhancement in RGR as the values were significantly higher (65 to 103%) over control on 60 DAS. However, RGR was reduced in GOWMATHI with age as it reached 90.34 % reduction on 60 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. However Rajendiran *et al.*, (2015g) in *Portulaca oleracea* L. reported enhanced RGR after UV-B exposure.
The growth parameters studied in three varieties of cowpea 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. The similarity index between FOLA and NS-634 was the highest with a value of 31.73 % and these two varieties remained as one group showing close relationship. The response of GOWMATHI to elevated UV-B irradiation was unique to it and was totally isolated from the rest of the varieties (Table 9; Plate 6).

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REFERENCES
Adamse P and Britz SJ (1992). Amelioration of UV-B damage under high irradiance I. role of photosynthesis. *Photochemistry and Photobiology* **56** 645 - 650.
Arulmozhi D and Rajendiran K (2014a). Effect of supplementary ultraviolet-B radiation on nodulation and nitrogen metabolism in *Lablab purpureus* L. var. Goldy. *International Journal of Advanced Biological Research* **4**(3) 343-346.
Arulmozhi D and Rajendiran K (2014b). Supplementary ultraviolet-B induced reduction in nodulation and nitrogen metabolism in hyacinth bean. *International Journal of Geology, Earth and Environmental Sciences* **4**(2) 73-77.

Arulmozhi D and Rajendiran K (2014c). Effect of elevated ultraviolet-B irradiation on the nodulation and nitrogen metabolism in *Vigna unguiculata* (L.) Walp. cv. COFC-8. *International Journal of Food, Agriculture and Veterinary Sciences* **4**(2) 184-188.

Bhat TM and Kudesia R (2011). Evaluation of Genetic Diversity in Five Different Species of Family Solanaceae using Cytological Characters and Protein Profiling. *Genetic Engineering and Biotechnology Journal* **2011** 1- 8.

Britz SJ and Adamse P (1994). UV-B induced increase in specific leaf weight of cucumber as a consequence of increased starch content. *Photochemistry and Photobiology* 60: 116 - 119.

Caldwell MM, Bjorn LO, Bornman JF, Flint SD, Kulandaivelu G, Teramura AH and Tevini M (1998). Effects of increased solar ultraviolet radiation on terrestrial ecosystems. *Photochemistry and Photobiology* **46** 40 - 52.

Everstt B (1985). *Clustering Analysis* (John Wiley and Sons, New York).

Huang S, Dai Q, Peng S, Chavez AO, Miranda MLL, Visperas RM and Vergara BS (1997). Influence of supplementary ultraviolet-B on indole acetic acid and calmodulin in the leaves of rice (*Oryza sativa* L.). *Plant Growth Regulation* **21** 59 - 64.

Jain VK, Dhingra GK and Ambrish K (1999). Changes in productivity and biomass partitioning in field grown mungbean with response to supplementary UV-B radiation. In: *Plant Physiology for Sustainable Agriculture*, edited by Srivastava GC, Singh K and Pal M (Pointer Publishers, Jaipur, India) 301 - 308.

Jordan BR (1997). Effects of UV-B radiation on plants - An overview. In. UV radiation and its Effects: An update. Report of a workship sponsored by the National Science Strategy Committee tor Climate Change. *The Royal Society of New Zealand* **49** 27 - 28.

Kokilavani V and Rajendiran K (2013). Ultraviolet-B induced changes in the leaf epidermal and anatomical characteristics of *Vigna mungo* L. var. KM-2. *International Journal of Science and Nature* **5**(1) 126-130.

Kokilavani V and Rajendiran K (2014a). Changes in leaf architecture of *Vigna unguiculata* (L.) Walp. cv. BCP-25 after exposure to elevated ultraviolet-B radiation. *International Journal of Science and Nature* **5**(3) 542-546.

Kokilavani V and Rajendiran K (2014b). Ultraviolet-B induced changes in the leaf architecture of *Cucumis sativus* L. var. CO 1. *International Journal of Geology, Earth and Environmental Sciences* **4**(2) 208-215.

Kokilavani V and Rajendiran K (2014c). Alterations in leaf architecture of *Ocimum sanctum* L. under elevated ultraviolet-B stress. *Global Journal of Bio-Science and Biotechnology* **3**(4) 374-378.

Kokilavani V and Rajendiran K (2014d). Ultraviolet-B induced changes in the leaf epidermal and anatomical characteristics of *Vigna mungo* L. var. KM-2. *International Journal of Advanced Biological Research* **5**(1) 126-130.

Kokilavani V and Rajendiran K (2014e). Effect of supplementary UV-B radiation on the yield of ten varieties of cowpea. *International Journal of Geology, Earth and Environmental Sciences* **4**(3) 65-73.

Kokilavani V and Rajendiran K (2014f). Influence of elevated Ultraviolet-B radiation on foliar organisation in *Vigna unguiculata* (L.) Walp. c.v. CW-122. *International Journal of Innovative Research and Review* **2**(4) 53-60.

Kokilavani V and Rajendiran K (2014g). Evaluation of the impact of Ultraviolet-B radiation on the foliar epidermal and anatomical characteristics of *Vigna unguiculata* (L.) Walp. c.v. COVU-1. *International Journal of Innovative Research and Review* **2**(4) 61-68.

Kokilavani V and Rajendiran K (2014h). Variation in leaf architecture of *Vigna unguiculata* (L.) Walp. c.v. COFC-8 induced by supplementary UV-B exposure. *International Journal of Innovative Research and Review* **2**(4) 69-76.

Kokilavani V and Rajendiran K (2014i). Ultraviolet-B induced reduction in nodulation in ten varieties of cowpea. *International Journal of Innovative Research and Review* **2**(4) 77-82.

Kokilavani V and Rajendiran K (2014j). Efficacy of *Vigna unguiculata* (L.) Walp. cv. Vamban leaves to withstand supplementary ultraviolet-B irradiation. *International Journal of Geology, Earth and Environmental Sciences* **4**(3) 203-210.

Kokilavani V and Rajendiran K (2014k). Anatomical and epidermal alterations in the leaves of *Vigna unguiculata* (L.) Walp. cv. CO-6 due to UV-B exposure. *International Journal of Geology, Earth and Environmental Sciences* **4**(3) 211-218.

Kokilavani V and Rajendiran K (2014l). A survey on the adaptive mechanism in leaf architecture of *Vigna unguiculata* (L.) Walp. cv. KM-1 under ultraviolet-B radiation. *International Journal of Food, Agriculture and Veterinary Sciences* **4**(3) 50-57.

Kokilavani V and Rajendiran K (2014m). Modifications in leaf architecture of *Vigna unguiculata* (L.) Walp. cv. COVU-2 to defend from ultraviolet-B radiation. *International Journal of Food, Agriculture and Veterinary Sciences* **4**(3) 65-72.

Kokilavani V and Rajendiran K (2014n). Analysis of the UV-B induced changes in morphology, anatomy and epidermis of *Vigna unguiculata* (L.) Walp. cv. CO-1 leaves. *International Journal of Food, Agriculture and Veterinary Sciences* **4**(3) 87-94.

Kokilavani V and Rajendiran K (2014o). Influence of elevated ultraviolet-B radiation on the morphology and growth of ten varieties of cowpea. *International Journal of Food, Agriculture and Veterinary Sciences* **4**(3) 171-189.

Kokilavani V and Rajendiran K (2015a). Variations in foliar morphology and anatomy of *Vigna unguiculata* (L.) Walp. c.v. CO-3 after supplementary ultraviolet-B exposure. *International Journal of Advanced Biological Research* **5**(1) 23- 28.

Kokilavani V and Rajendiran K (2015b). Study of leaf architecture of *Vigna unguiculata* (L.) Walp. cv. Puduvai under elevated ultraviolet-B radiation. *International Journal of Advanced Biological Research* **5**(1) 34-39.

Kulandaivelu G, Maragatham S and Nedunchezhian N (1989). On the possible control of ultraviolet - B induced response in growth and photosynthetic activities in higher plants. *Physiologia Plantarum* **76** 398-404.

Mark SM and Tevini M (1997). Effects of solar UV-B radiation on growth, flowering and yield of central and southern European bush bean cultivars (*Phaseolus vulgaris* L.). *Plant Ecology* **128** 114 - 125.

Maskay N (1998). Single linkage clustering. In: *Encyclopedia of Biostatistics*, edited by Armintage P and Cotton T (Wiley, New York) **5** 4121- 4122.

Pearce RB, Brown RK and Blaser RE (1968). Photosynthesis of *Alfalfa* leaves as influenced by age and environment. *Crop Science* **8** 677 - 680.

Racey GD, Glerum C and Hutchinson RE (1983). The practicability of top root ratio in nursery stock characterization. *The Forestry Chronicle* **59** 240 - 243.

Rajendiran K (2001). Amelioration of Ultraviolet-B radiation impacts in green gram by Triadimefon. PhD. Thesis, Pondicherry University.

Rajendiran K and Ramanujam MP (2000). Growth and biochemical responses of black gram (*Vigna mungo* L. Hepper cv. T-9) to supplementary UV-B radiation. *State level seminar on Environmental Pollution and Bioremediation, PSGR Krishnammal College Coimbatore* Abstract 10.

Rajendiran K and Ramanujam MP (2003). Alleviation of ultraviolet-B radiation-induced growth inhibition of green gram by triadimefon. *Biologia Plantarum* **46** 621-624.

Rajendiran K and Ramanujam MP (2004). Improvement of biomass partitioning, flowering and yield by triadimefon in UV-B stressed *Vigna radiata* (L.) Wilczek. *Biologia Plantarum* **48** 145-148.

Rajendiran K, Ariswary D, Arulmozhi D and Kokilavani V (2015a). Screening of explants of ultraviolet-B exposed *Amaranthus dubius* Mart. Ex. Thell. for *in vitro* propagation. *International Journal of Food, Agriculture and Veterinary Sciences* **5**(2) 33-45.

Rajendiran K, Iswarya R, Arulmozhi D and Kokilavani V (2015b). Evaluation of ultraviolet-B stressed explants of *Macrotyloma uniflorum* (Lam.) Verdc. For *in vitro* propagation. *International Journal of Innovative Research and Review* **3**(2) 19-31.

Rajendiran K, Julie Soniya F, Vijayalakshmi R and Kokilavani V (2015c). *In vitro* propagation of ultraviolet-B stressed *Momordica charantia* L. *International Journal of Geology, Earth and Environmental Sciences* **5**(2) 92-104.

Rajendiran K, Periyalakshmi D, Vijayalakshmi R and Kokilavani V (2015d). *In vitro* propagation of explants from ultraviolet-B stressed *Spinacia oleracea* L. *International Journal of Innovative Research and Review* **3**(2) 32-44.

Rajendiran K, Priyadarsini V, Sudaroli Sudha J and Kokilavani V (2015e). *In vitro* propagation of *Trigonella foenum-graecum* (L.) Ser. after supplementary UV-B irradiation. *International Journal of Food, Agriculture and Veterinary Sciences* **5**(2) 46-57.

Rajendiran K, Riswan A, Sudaroli Sudha J and Kokilavani V (2015f). *In vitro* propagation of *Benincasa hispida* (Thunb.) Cogn. explants after enhanced UV-B exposure. *International Journal of Innovative Research and Review* **3**(2) 45-56.

Rajendiran K, Shanmathy M, Sudaroli Sudha J and Kokilavani V (2015g). Assessment of ultraviolet-B tolerance in *Portulaca oleracea* L. for *in vitro* propagation. *International Journal of Biotechnology* **4**(2) 32-42.

Rajendiran K, Vidya S, Gowsalya L and Thiruvarasan K (2015h). Impact of supplementary UV-B radiation on the morphology, growth and yield of *Vigna mungo* (L.) Hepper var. ADT-3. *International Journal of Food, Agriculture and Veterinary Sciences* **5**(2) 104-112.

Sudaroli Sudha J and Rajendiran K (2013a). Effect of elevated UV-B irradiation on the nodulation and nitrogen metabolism in *Sesbania grandiflora* (L.) Pers. *International Journal of Science and Nature* **4**(4) 664 - 667.

Sudaroli Sudha J and Rajendiran K (2013b). Effect of elevated UV-B irradiation on the nodulation and nitrogen metabolism in *Vigna unguiculata* (L.) Walp. c.v. BCP-25. *International Journal of Food, Agriculture and Veterinary Sciences* **3**(3) 77 - 81.

Sudaroli Sudha J and Rajendiran K (2014a). Impact of ultraviolet-B radiation on nodulation and nitrogen metabolism in *Vigna unguiculata* (L.) Walp. cv. COVU-1. *International Journal of Geology, Earth and Environmental Sciences* **4**(2) 224-230.

Sudaroli Sudha J and Rajendiran K (2014b). Ultraviolet-B induced reduction in nodulation and nitrogen metabolism in *Vigna mungo* (L.) Hepper var. T-9. *Global Journal of Bioscience and Biotechnology* **3**(4) 370 - 373.

Sudaroli Sudha J and Rajendiran K (2014c). Ultraviolet-B induced reduction in nodulation and nitrogen metabolism in *Vigna unguiculata* (L.) Walp. cv. CO-1. *Global Journal of Bioscience and Biotechnology* **4**(3) 10 - 14.

Sullivan JH, Teramura AH and Dillenburg LR (1994). Growth and photosynthetic responses of field-grown sweetgum (*Liquidalmbar styraciflua*) seedlings to UV-B radiation. *American Journal of Botany* **81** 826 - 832.

Tevini M and Teramura AH (1989). UV-B effects on terrestrial plants. *Photochemistry and Photobiology* **50** 479 - 487.

Vijayalakshmi R and Rajendiran K (2014a). Impact of ultraviolet-B radiation on nodulation and nitrogen metabolism in *Cyamopsis tetragonoloba* (L.) Taub. var. PNB. *International Journal of Geology, Earth and Environmental Sciences* **4**(2) 78 - 82.

Vijayalakshmi R and Rajendiran K (2014b). Impact of ultraviolet-B radiation on nodulation and nitrogen metabolism in *Phaseolus vulgaris* L. cv. Prevail. *International Journal of Advanced Biological Research* **4**(3) 339 - 342.

Vijayalakshmi R and Rajendiran K (2014c). Effect of elevated ultraviolet-B irradiation on the nodulation and nitrogen metabolism in *Vigna unguiculata* (L.) Walp. cv. CW-122. *International Journal of Food, Agriculture and Veterinary Sciences* **4**(2) 189-193.

Williams RF (1946). The physiology of plant growth with special reference to the concept of net assimilation rate. *Annals of Botany* **10** 41 - 42.