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Research Article

EFFECT OF CERTAIN PHYSICAL FACTORS ON SEED GERMINATION OF CERTAIN SPECIES OF *AMARANTHUS* FOUND IN RAJASTHAN

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ABSTRACT
In the present investigation an attempt was made to study the effect of certain physical factors on seed germination of *Amaranthus*. Studied plants showed different response to U.V. radiation,Light quality and Light duration. Among all species UV treatment were most beneficial for *A. hybridus* subsp. *hybridus* var. *hybridus*. Regarding light quality the red light has best response in seed germination of *A. palmeri* and *A. spinosus.* Green wavelength have best response for seed germination as well as radicle length of *A. hybridus* subsp. *hybridus* var. *hybridus*. Blue wavelength have promotory effect in hypocotyl length of *A. palmeri* and *A. hybridus* subsp. *hybridus* var. *hybridus* whereas deleterious effect in germination, as well as in seedling growth of *A. hybridus* subsp. *cruentus* var. *paniculatus.* Best results were obtained in dark followed by yellow wavelength in *A. hybridus* subsp. *cruentus* var. *paniculatus* for seed germination as well as seedling growth. In case of yellow wavelength, radicle of *A. spinosus* have promotory effect. Photoperiodic responses reveals that 36 hours of light duration gave the gradually increased percentage seed germination, as well as seedling growth in *A. spinosus* and *A. hybridus* subsp. *hybridus* var. *hybridus* and in percentage seed germination of *A. hybridus* subsp. *cruentus* var. *paniculatus* too. In *A. palmeri* light duration of 36 hours showed promotory effect on percentage seed germination and seedling growth. Percentage seed germination and seedling growth of *A. palmeri* at 48 hours of photoperiod showed most inferior effects than the control.

Key Words: *Amaranthus, Seed Germination, Photoperiod, UV Light*

INTRODUCTION
Amaranths (*Amaranthus* species) are a new crop but one with a past history. *Amaranthus* species have been grown for centuries for vegetable and grain in different parts of the World. Amaranth is consumed as vegetable in Africa, Caribbean, China, Greece, India, Italy, Nepal and South Pacific Islands (Stallknecht and Schulz-Schaeffer, 1993). Grain amaranths are distributed widely throughout Asia. In Afghanistan and Persia, the grain amaranths are found scattered throughout in the melon and tobacco fields (Atkinson, 1891). It is cultivated in the mountain areas in China and Manchuria where its seeds are called "*tien-shutze*" or millet from heaven.This crop is important and most widespread in India. It has been grown all over along the Himalayas, from Kashmir to Bhutan and also on South Indian hills. In the Kulu Valley (the Punjab) the grain is known as "*siriara*" or "*scol*" and about 2,000 acres are grown annually. In the upper Sutlez valley, in Himachal Pradesh, the amaranth is called "*tulsi*" and in the border district of Kinnaur the local name "*kalgi*" and "*dankhar*". At present, it is also an important crop in the plains of India, especially in parts of Gujarat where it is known as "*rajgirah*". Isolated crop fields are also seen in the North Indian Plains, chiefly as a mixed crop with vegetables, such as chillies, brinjal, etc. In the North Indians plains, its common names are "*sil*" or "*chaulai*" (Singh 1961).

MATERIALS AND METHODS
In the present investigation germination studies were carried out with the seeds of *A. spinosus, A. hybridus* subsp. *cruentus* var. *paniculatus, A. viridis, A. palmeri* and *A. hybridus* subsp. *hybridus* var. *hybridus*. Seeds were collected from different sites located in Jaipur and stored in glass stoppered bottles.

After a preliminary selection for uniformity (criteria being the size and colour of the seeds), the seeds were surface sterilized with 0.1% $HgCl_2$ for two minutes and repeatedly washed with distilled water (Mishra, 1968). The seeds were subjected to given the following physical pretreatments.

UV-Radiations

The source of ultra-violet rays was a Philips ultraviolet tube light of TUV 30W with wave length of 2537°A. Irradiation was made from a distance of 30 cm from the source for 5,10,15, 20 and 30 minutes after which the Petri plates containing seeds were kept in dark for 24 hours to prevent any photoreactivation.

Light Quality and Duration

The source of continuous light was two tube lights of 40 watts each set at a distance of 60 cm from the petri plates. Total intensity of tube lights was 120 Lux. Different wavelengths, i.e. dark, green, red, blue and yellow were produced by wrapping the petri plates with double cellophane papers of the respective colours. Control was wrapped in double white cellophane paper. Petri plates were then kept under a light source for 10 days.

Photoperiod

Photoperiodic effect was seen by keeping the Petri plates containing seeds under light for 3,6,12,18 and 24 hours and then in diffuse light under laboratory conditions. The source of light and distance are the same as mentioned above. Three replicates of 10 seeds were used in every case.

RESULTS

Effect of UV Radiation

The data with regard to the effect of ultraviolet radiations are given in Table 1. In *A. hybridus* supsp. *cruentus* var. *paniculatus,* ultraviolet radiations were found to be beneficial for seed germination and seedling growth, where 10 minutes exposure had promotory effect, the maximum germination (73.33%) and radicle (1.88 cm) and hypocotyl length (1.75 cm) were observed whereas in the control it was found to be 70%, 1.75 cm and 1.65 cm, respectively. Among all the UV exposure treatments only 10 minutes exposure was effective and thereafter it was negative effect with increasing exposure. Data were significant for all treatment.

Effect of UV radiations on seed germination and seedling growth *of A.palmeri* are presented in Table 2. Seed germination increased up to 10 minutes exposure in comparison to control, thereafter it declined. Seedling growth increased at all exposures except 15 minutes exposure to UV. Statistical analysis reveals that all results were highly significant.

Results in respect of *A. spinosus* are showed in Table 3. Increasing UV exposure show promotory effect on seed germination and hypocotyl length. Best results were observed for germination and hypocotyl length at 30 minutes exposure where 50 % of seed germination and length of hypocotyl increased up to 1.87 cm. For radicle length (2.23 cm) best results were obtained at 5 minutes exposure. All the data were superior than the control. Statistically data were highly significant except among treatments where it were not significant. In *A. hybridus* subsp. *hybridus* var. *hybridus* the seeds responded to 15-20 minutes UV exposure for germination. All the treatments had negative effect on radicle length but positive for hypocotyl length. Statistical analysis shows that data regarding exposure of control, 5,10,15,20 and 30 minutes were highly significant and among treatments too the data were significant (Table 4).

Effect of light quality

***A. hybridus* subsp. *hybridus* var. *paniculatus* Linn.:** Seed germination was maximum in dark followed by yellow light quality where 73.33 and 66.67 per cent germination were recorded (Table 5). For radicle length best performance was observed in dark followed by green and yellow where recorded radicle length were 2.03, 1.69 and 1.66 cm, respectively. The same trend was also observed for hypocotyl l where 2.23, 1.68 and 1.53 cm length were recorded. Among all light qualities blue light showed most of poor

response where results were inferior to control. Statistical analysis shows that data all forlight qualities including control is highly significant whereas treatments are not significant.

***A. palmeri* Wats.:** In *A. palmeri* regarding light qualities response, the most superior results were found under red light for seed germination (70%), green light for radicle length (3.83 cm) and blue light for hypocotyl length (2.96 cm). For seed germination, other than red light all were inferior to control (60%). In respect of radicle green light followed by dark, blue and red light gave lengths of 3.83, 3.50, 3.00 and 2.83 cm, respectively which were superior to the control (2.25 cm). In hypocotyl length, all data were superior to control (1.74 cm). Regarding statistical analysis results were found to be highly significant (Table 6).

***A. spinosus* Linn.:** The results along with relevant statistical analysis are given in Table 7. Seed germination, radicle length and hypocotyl length were enhanced by different wave lengths of light. The maximum enhancement regarding seed germination and hypocotyl length were found under red light where it was 70% and 1.89 cm, respectively. Radicle length (2.52 cm) was maximum in yellow light in comparison to the controls and the results were statistically highly significant.

***A. hybridus* subsp. *hybridus* var. *hybridus* Linn.:** Effect of light quality in *A. hybridus* subsp. *hybridus* var. *hybridus* on various ecological parameters are presented in Table 8. Results of seed germination showed that only green light had promotory effect while yellow light most deleterious effect, where only 13.33% germination were recorded when compared to control (43.33%). Response of all light qualities towards radicle length were highly inferior to the control, (3.63 cm) and for hypocotyl, the length was maximum (2.48 cm) in blue light followed by red, green, dark and yellow as compared to the control (1.63 cm). Statistically all results were found to be highly significant except for green light quality.

Effect of Photoperiods

***A. hybridus* subsp. *cruentus* var. *paniculatus*. (L.) Thell.:** The data regarding the effect of different light durations are given in Table 9. Among the light durations, it was observed that seed germination percentage increased gradually with increasing exposure of light duration up to 36 hours where it was 56.66%. For hypocotyl length, 48 hours duration was optimum while others were also than control (1.44 cm). In respect of radicle length, duration of 36 hours was most superior (2.08 cm) whereas 12 hours was most inferior (1.40 cm) in comparision to the control. Statistically data for all were highly significant.

***A. palmeri* Wats.:** The data on photoperiodic effect on *A. palmeri* are presented in Table 10.Results revealed that seed germination percentage and seedling growth were found maximum under 36 hours of photoperiod. However, other treatments were not effective and inferior to the control. Highly negative response were found at 48 hours of photoperiod where only 3.33% germination was observed. All treatments *vis a vis* photoperiods were statistically highly significant but photoperiods, among themselves photoperiod of 48 hours duration was not significant.

***A. spinosus* Linn.:** Results on the response of light duration on seed germination in *A. spinosus* are presented in Table 11. Among different photoperiods it has been observed that seed germination percentage, radicle and hypocotyl length increased gradually up to 36 hours exposure light duration as compared to the control. Among all 36 hours light duration showed the best results followed by 48, 60, 24 and least in 12 hours. Among these, best response regarding seed germination, radicle and hypocotyl length were recorded as 76.67%, 2.55 cm and 1.99 cm, respectively whereas in the control they were only 36.67%, 1.12 cm and 0.97 cm, respectively. Statistically all the data for different treatments were significant.

***A. hybridus* subsp. *hybridus* var. *hybridus* Linn.:** Data on effect of certain treatments on germination behaviours are showed in table 12. The results are more or less similar to *A. spinosus*. The maximum percentage of seed germination, radicle and hypocotyl length, were observed at 36 hours photoperiod.While minimum 20% at 60 hours of photoperiod, which is lower than the control (33.33%). Radicle and hypocotyl length were more thane the control. Statistical analysis show that data for photoperiod of 12,24,36,46 and control were highly significant except 60 hours and among photoperiods were not significant.

Table 1: Effect of U.V. radiation on seed germination (percentage), radicle length (cm) and hypocotyl length (cm) of *A. hybridus* subsp. *cruentus* var. *paniculatus*

U.V. Radiation (in minutes)	Percentage germination	Radicle length (cm)	Hypocotyl length (cm)
Control	70.00	1.75	1.65
5	50.00	1.02	0.95
10	73.33	1.88	1.77
15	60.00	1.34	1.52
20	50.00	1.49	1.37
30	46.67	1.47	1.40

Analysis of variance

Source of variation	DF	SS	MSS	F-ratio
Within Control U.V.	2	9329.7950	4664.8975	47.78**
Within 5 Min. U.V	2	4804.2942	2402.1471	24.45**
Within 10 Min. U.V	2	10226.9016	5113.4508	52.05**
Within 15 Min. U.V	2	6861.7193	3430.8596	34.92**
Within 20 Min. U.V	2	4718.4340	2359.2170	24.02**
Within 30 Min U.V	2	4091.8133	2045.9066	20.82**
Between treatments	5	691.3739	345.6869	3.52*
Error	36	3536.4052	98.2334	-

Table 2: Effect of U.V. Radiation on seed germination (percentage), radicle length (cm) and hypocotyl length (cm) of *A. palmeri*

U.V. Radiation (in minutes)	Percentage germination	Radicle length (cm)	Hypocotyl length (cm)
Control	60.00	2.45	1.78
5	80.00	2.58	1.79
10	63.33	2.69	1.96
15	53.33	2.35	1.75
20	50.00	2.82	2.87
30	33.33	3.91	2.01

Analysis of variance

Source of variation	DF	SS	MSS	F-ratio
Within Control U.V.	2	6727.5819	3363.7909	60.23**
Within 5 Min. U.V	2	12111.8112	6055.9056	108.43**
Within 10 Min. U.V	2	7445.2322	3722.6161	66.65**
Within 15 Min. U.V	2	5260.1646	2630.0823	47.09**
Within 20 Min. U.V	2	4447.5056	2223.7528	39.82**
Within 30 Min U.V	2	1850.4937	925.2468	16.56**
Between treatments	5	1116.3657	558.1828	9.99 **
Error	36	2010.4958	55.8471	-

** Significant ; ** Highly significant*

Table 3: Effect of U.V. radiation on seed germination (percentage), radicle length (cm) and hypocotyl length (cm) of *A. spinosus*

U.V. Radiation (in minutes)	Percentage germination	Radicle length (cm)	Hypocotyl length (cm)
Control	36.67	1.18	0.97
5	36.67	2.23	1.42
10	40.00	1.35	1.55
15	40.00	1.62	1.67
20	43.33	1.78	1.79
30	50.00	2.04	1.87

Analysis of variance

Source of variation	DF	SS	MSS	F-ratio
Within Control U.V.	2	2533.1250	1266.5625	16.27**
Within 5 Min. U.V	2	2428.8676	1214.4338	15.61**
Within 10 Min. U.V	2	2972.2650	1486.1325	19.10**
Within 15 Min. U.V	2	2942.2168	1471.1084	18.91**
Within 20 Min. U.V	2	3452.5280	1726.2640	22.18**
Within 30 Min U.V	2	4616.0434	2308.0217	29.66**
Between treatments	5	148.0781	29.6156	00.38^{NS}
Error	36	2800.8238	77.8006	-

Table 4: Effect of U.V. radiation on seed germination (percentage), radicle length (cm) and hypocotyl length (cm) of *A. hybridus* subsp *hybridus* var. *hybridus*

U.V. Radiation (minutes)	Percentage germination	Radicle length (cm)	Hypocotyl length (cm)
Control	43.33	3.63	1.63
5	40.00	2.98	1.80
10	40.00	3.06	1.81
15	46.67	3.69	2.40
20	73.33	2.91	2.14
30	33.33	2.80	2.05

Analysis of variance

Source of variation	DF	SS	MSS	F-ratio
Within Control U.V.	2	3318.9800	1659.4900	28.70**
Within 5 min. U.V	2	2831.1128	1415.5564	24.48**
Within 10 min. U.V	2	2824.3894	1412.1947	24.42**
Within 15 min. U.V	2	3807.3362	1903.6681	32.92**
Within 20 min. U.V	2	10028.5449	5014.2724	86.73**
Within 30 min U.V	2	1911.4938	955.7469	16.53**
Between treatments	5	998.7998	199.7599	3.45*
Error	36	2081.3144	57.8142	-

*NS Non significant; * Significant ; ** Highly significant*

Table 5: Effect of light quality on seed germination (percentage), radicle length (cm) and hypocotyl length (cm) of *A. hybridus* subsp. *cruentus* var. *paniculatus*

Light Quality	Percentage germination	Radicle length (cm)	Hypocotyl length (cm)
Control	53.33	1.39	1.35
Dark	73.33	2.03	2.23
Green	43.33	1.69	1.68
Red	50.00	1.47	1.44
Blue	40.00	0.95	0.91
Yellow	66.67	1.66	1.53

Analysis of variance

Source of variation	DF	SS	MSS	F-ratio
Within Control light quality	2	5400.0324	2700.0162	19.17**
Within Dark light quality	2	10140.3620	5070.1810	36.01**
Within Green light quality	2	3469.1673	1734.5836	12.32**
Within Red light quality	2	4713.5587	2356.7793	16.73**
Within Blue light quality	2	3052.9322	1526.4661	10.84**
Within Yellow light quality	2	8467.8013	4233.9006	30.06**
Between light qualities	5	940.7623	188.1524	1.33^{NS}
Error	36	5068.9617	140.8044	

Table 6: Effect of light quality on seed germination (percentage), radicle length (cm) and hypocotyl length (cm) of *A. palmeri*

Light Quality	Percentage Germination	Radicle length (cm)	Hypocotyl length (cm)
Control	60.00	2.25	1.74
Dark	46.67	3.50	2.48
Green	26.67	3.83	2.80
Red	70.00	2.83	2.50
Blue	53.33	3.00	2.96
Yellow	56.67	2.13	2.70

Analysis of variance

Source of variation	DF	SS	MSS	F-ratio
Within Control light quality	2	6727.5819	3363.7909	112.67**
Within Dark light quality	2	3816.5616	1908.2808	63.91**
Within Green light quality	2	1092.0466	546.0233	18.28**
Within Red light quality	2	9067.7222	4533.8611	151.86**
Within Blue light quality	2	7042.4493	3521.2246	117.94**
Within Yellow light quality	2	5886.6066	2943.3033	98.58**
Between light qualities	5	1257.2693	251.4538	8.42**
Error	36	1074.7894	29.8552	-

*NS – Non significant ; ** Highly significant*

Table 7: Effect of light quality on seed germination (percentage), radicle length (cm) and hypocotyl length (cm) of *A. spinosus*

Light Quality	Percentage germination	Radicle length (cm)	Hypocotyl length (cm)
Control	23.33	1.18	0.97
Dark	43.33	1.43	1.77
Green	33.33	1.29	1.63
Red	70.00	1.48	1.89
Blue	66.66	1.63	1.86
Yellow	46.67	2.52	1.22

Analysis of variance

Source of variation	DF	SS	MSS	F-ratio
Within Control light quality	2	990.6362	495.3181	24.25**
Within Dark light quality	2	3482.4028	1741.2014	85.23**
Within Green light quality	2	2031.1422	1015.5711	49.71**
Within Red light quality	2	9332.7602	4666.3801	228.42**
Within Blue light quality	2	8428.8593	4214.4296	206.30**
Within Yellow light quality	2	4015.1348	2007.5674	98.27**
Between light qualities	5	1753.7743	350.7548	17.16**
Error	36	735.4375	20.4286	-

Table 8: Effect of light quality on seed germination (percentage), radicle length (cm) and hypocotyl length (cm) of *A. hybridus* subsp. *hybridus* var. *hybridus*

Light Quality	Percentage germination	Radicle length (cm)	Hypocotyl length (cm)
Control	43.33	3.63	1.63
Dark	33.33	3.26	1.89
Green	66.67	3.15	2.01
Red	33.33	2.81	2.41
Blue	16.67	2.70	2.48
Yellow	13.33	1.98	1.83

Analysis of variance

Source of variation	DF	SS	MSS	F-ratio
Within Control light quality	2	3318.9800	1659.4900	98.24**
Within Dark light quality	2	1894.3366	947.1683	56.07**
Within Green light quality	2	35.3194	17.6597	1.04^{NS}
Within Red light quality	2	1888.4960	944.2480	55.90**
Within Blue light quality	2	396.1944	198.0972	11.72**
Within Yellow light quality	2	261.3221	130.6610	7.73**
Between light qualities	5	1050.8370	210.1674	12.44**
Error	36	608.0743	16.8909	-

*NS Non significant; ** Highly significant*

Table 9: Effect of photoperiods on seed germination (percentage), radicle length (cm) and hypocotyl length (cm) of *A. hybridus* subsp. *cruentus* var. *paniculatus*

Photoperiods (in hours)	Percentage germination	Radicle length (cm)	Hypocotyl length (cm)
Control	30.00	2.00	1.44
12	43.33	1.40	1.78
24	53.33	1.89	1.55
36	56.66	2.08	1.70
48	40.00	2.00	2.39
60	46.67	1.69	1.75

Analysis of variance

Source of variation	DF	SS	MSS	F-ratio
Within control photoperiod	2	1599.9984	799.9992	9.37**
Within 12 hours photoperiod	2	3484.9462	1742.4731	20.41**
Within 24 hours photoperiod	2	5328.7339	2664.3669	31.22**
Within 36 hours photoperiod	2	6001.1754	3000.5877	35.16**
Within 48 hours photoperiod	2	2858.4160	1429.2080	16.74**
Within 60 hours photoperiod	2	4040.1108	2020.0554	23.67**
Between photoperiods	5	461.1790	92.2358	1.08^{NS}
Error	36	3072.1125	85.3364	-

Table 10: Effect of photoperiods on seed germination (percentage), radicle length (cm) and hypocotyl length (cm) of *A. palmeri*

Photoperiods (in hours)	Percentage germination	Radicle length (cm)	Hypocotyl length (cm)
Control	46.66	2.24	1.76
12	13.33	2.23	1.48
24	16.66	1.82	1.07
36	53.33	2.36	1.77
48	03.33	0.83	0.67
60	33.33	1.98	1.61

Analysis of variance

Source of variation	DF	SS	MSS	F-ratio
Within control photoperiod	2	3989.4699	1994.7349	117.19**
Within 12 hours photoperiod	2	264.195	132.0975	7.76**
Within 24 hours photoperiod	2	464.445	232.2225	13.64**
Within 36 hours photoperiod	2	5257.7538	2628.8769	154.45**
Within 48 hours photoperiod	2	13.3888	6.9444	0.41^{NS}
Within 60 hours photoperiod	2	1989.7522	994.8761	58.45**
Between photoperiods	5	2132.5780	426.5156	25.06**
Error	36	612.7454	17.0207	-

*NS Non significant; ** Highly significant*

Table 11: Effect of photoperiods on seed germination (percentage), radicle length (cm) and hypocotyl length (cm) of *A. spinosus*

Photoperiod (in hours)	Percentage germination	Radicle length (cm)	Hypocotyl length (cm)
Control	36.67	1.12	0.97
12	53.33	2.27	1.65
24	60.00	2.34	1.76
36	76.67	2.55	1.99
48	66.66	2.35	1.89
60	63.33	2.17	1.73

Analysis of variance

Source of variation	DF	SS	MSS	F-ratio
Within control photoperiod	2	2537.8370	1268.9185	19.54**
Within 12 hours photoperiod	2	5278.3304	2639.1652	40.64**
Within 24 hours photoperiod	2	6716.1314	3358.0657	51.71**
Within 36 hours photoperiod	2	11070.1872	5535.0936	85.24**
Within 48 hours photoperiod	2	8332.4360	4166.2180	64.16**
Within 60 hours photoperiod	2	7535.3080	3767.6540	58.02**
Between photoperiods	5	1033.5748	206.7149	3.18*
Error	36	2337.6491	64.9346	-

Table 12: Effect of photoperiods on seed germination (percentage), radicle length (cm) and hypocotyl length (cm) of *A. hybridus* subsp. *hybridus* var. *hybridus*

Photoperiod (in hours)	Percentage germination	Radicle length (cm)	Hypocotyl length (cm)
Control	33.33	3.07	1.70
12	33.33	3.06	1.94
24	36.67	3.64	2.06
36	50.00	4.06	3.39
48	46.67	3.93	2.35
60	20.00	3.18	1.78

Analysis of variance

Source of variation	DF	SS	MSS	F-ratio
Within control photoperiod	2	1918.2214	959.1107	8.46**
Within 12 hours photoperiod	2	1903.2481	951.6241	8.40**
Within 24 hours photoperiod	2	2290.4276	1145.2138	10.11**
Within 36 hours photoperiod	2	4380.0181	2190.0090	19.33**
Within 48 hours photoperiod	2	3793.4664	1896.7332	16.74**
Within 60 hours photoperiod	2	616.7100	308.3550	2.72^{NS}
Between photoperiods	5	647.2491	129.4498	1.14^{NS}
Error	36	4078.2297	113.2841	-

*NS Non significant; *Significant; ** Highly significant*

DISCUSSION

Some reports are available on seed germination in different species of *Amaranthus*. Myers (1996) found that in Amaranths percentage of seed germination and speed of germination decline when temperature is reduced to 21°/10°C regime and germination percentage greatly reduced at 18°/15°C or below. The seeds normally sprout within 24 hours at warmer temperatures. Seeds planted in mid-April failed to germinate. In all planting from mid-May onwards amaranth germination was achieved satisfactorily (Singh and Whitehead, 1996). According to Wagoner (1983), most *Amaranthus* species and cultivars germinate when the soil temperature reaches 18°C or above. Webb *et al*. (1984) found that temperature around 25°C was optimum for germination.

In *Amaranthus dubius* great variability in seed characteristics and germination responses were found when comparing different populations (Wulff, 1988). In *A. retroflexus,* Mc Williams *et al.* (1968) found a latitudinal cline in North America for seed size and germination requirements. Frost and Cavers (1975) showed that seeds of *A. powelli* collected from different populations in Ontario varied in their germination requirements. The germination requirements of the seeds are also adjusted as to open more avenues for the success of *A. spinosus* (Mukherjie, 1965). Summer seeds of *A. spinosus* germinate soon after the rain when the temperature is still high. If they fail to do so the storage in soil helps them to germinate during winters at a low temperature (Gopal, 1974; Mayer and Mayber, 1963).

Wulff (1988) investigated intraspecific variation in germination requirements and growth in *A. dubius.* It was observed that differences in seed size and temperature may affect seedling growth and survival probabilities. McWilliams *et al.* (1968) studied variation in seed weight and germination in populations of *A. retroflexus.* It was observed that highest germination occurred at 35°C which may be set as an optimum temperature for germination. Zangerl and Bazzaz (1984) found that environmental gradients influence the variation in the population of *A. retroflexus* and *Abutilon theophrasti.*

Study of photoperiodic responses show that *Amaranthus caudatus* is a short day species. It flowered under 8 hrs photoperiods, failed to flower under continuous illumination and under the natural long days of Spring (mostly 12 to 14 hrs). Plants of *A. caudatus* are remarkably sensitive in their flowering response to short photoperiods (Fuller, 1949). Allard and Garner (1940) reported briefly the photoperiodic responses of *Celosia argentea, C. cristata* (both indeterminate), *Gomphrena globosa* (determinate), *Amaranthus hybridus* (indeterminate) and *Amaranthus* species (indeterminate), all of the Amaranthaceae and *Spinacea oleracea* (long day) of the Chenopodiaceae.

A perusal of the above account elegantly show that on the one hand *Amaranthus* is an outstandingly important genus not only from the point of view of its vast economic importance as a grain crop for man and as a nutritious green, leguminous-cum-carbohydrate rich and palatable fodder for cattles and which has attracted attention of a large number of workers in the field, on the other hand studies on this important genus in a vast country like India have been meagre in respect of seed germination. In view of this it was decided to carry out effect of certain physical factors such as light quality and duration and UV-radiations on seed germination of Amaranths. In the present investigation, the effect of the pretreatment of different light qualities, photoperiods, UV radiations, micronutrients and growth regulators have been studied on seed germination, radicle and hypocotyl length and the results are discussed below.

Role of Physical Factors

Ultraviolet Radiations: UV radiations are known to produce excitation of biological molecules and are also powerful mutagenic agents. Rupert and Harm (1966) and Vyas and Agarwal (1970) reported that ultraviolet irradiations resulted in a decreased percentage of germination in *Dalbergia sissoo*. Pandey (1969) found maximum germination in *Anagallis arvensis* under 10 minutes exposure to ultraviolet radiations. Similar results were observed in *Commiphora wightii* (Sharma, 1993) and in *Boswellia serrata* (Sharma, 1998). Goel (1990) reported that in *Ephedra foliata* UV rays have inhibitory effect on germination of seeds except 20 minutes exposure. In the present investigations maximum germination was found in *A. hybridus* subsp. *cruentus* var. *paniculatus,* there was 3% increase at 10 minute exposure,

in *A. spinosus,* 13% at 30 minute exposure, in *A. palmeri* 20% at 5 minute exposure and in *A. hybridus* subsp. *hybridus* var. *hybridus* 30% at 20 minute exposure giving best response in comparison to the control. Regarding seedling growth 5,10,15 and 20 minutes expsoure were found suitable for *A. spinosus, A. hybridus* subsp. *cruentus* var. *paniculatus, A. hybridus* subsp. *hybridus* var. *hybridus* and *A. palmeri,* respectively. This shows that there is difference in the requirement of UV radiation for different species of *Amaranthus*.

Light quality: The seeds of most plants are stimulated by light and germination is benefited but in others it is retarded. For example *Lactuca sativa* will not germinate without light stimulation. In contrast many Liliaceae and Cucurbitaceae germinate better in darkness. The physiological explanation of light influence of germination is rendered specially obscure by the fact that so many other environmental factors influence the relationship. The effect of light on seed germination can be reversed by temperature manipulation or by supplying oxygen, nitrate or weak acids. These complex interrelationship have caused much confusion in the literature on this subject. According to Wulff (1988) in *Amaranthus dubius* seeds produced by different individuals growing in close proximity differ in weight, in total germination percentage and rate, in the response to temperatures and in the proportion requiring light to germinate. Differences *dissecta,* an arid zone species, the highest percentage germination was under red light within the first 24 hours. Sharma (1998) in *Boswellia sarrata* and Verma and Tandon (1984) in *Pinus kesiya* showed that a red radiations enhanced seed germination and seedling growth whereas far-red radiations were inhibitory. In the present investigations in *A. palmeri* and *A. spinosus,* 10 and 46% increase of germination over control was observed under red light and in *A. hybridus* subsp. *hybridus* var. *hybridus* yellow light enhanced 22% germination. Kaul (1972) observed that in *Alternanthera sessilis* red, blue and orange light are more favourable than white, green and far red, our results in *A. palmeri* and *A. spinosus* were similar to Kaul (1972). Taylorson and Hendricks (1969), reported dark germination of *A. retrofleuxs* seed at 35°C which increased after several days of prechilling at 20°C or lower. Irradiation with far red light for short periods during the early hours of prechilling period at 10° inhibited subsequent dark germination at 35°C. Our results indicate that *A. spinosus* is not sensitive to different spectra of wavelengths and can germinate in absence of light.

There are only a few reports of biological activity of blue light (Evenari, 1965; Neumann and Stein, 1957; Black and Wareing, 1960; Stephen, 1928). Chawan and Sen (1973) reported that red and blue lights were inhibitory to seed germination in *Sida grewioides* whereas no spectral sensitivity was found in *Sida spinosa.* There are certain species in which germination is inhibited by light although the number of such species is considerably smaller. Thus, from the above account it is clear that with regard to germination, species respond differently to various wavelengths. However, in the investigated species of *Amaranthus* red, green and dark portions of the spectrum was promoting seed germination. Mukherjie (1965), Gopal (1974) have also shown that the germination requirements of the seeds of *A. spinosus* are adjusted as to open more advances for the success. The seeds do not show dormancy and can germinate at higher temperature. Chadoeuf-Hannel and Taylorson (1985) reported that seeds of *Amaranthus albus* develop an enhanced sensitivity to the far red absorbing form to phytochrome after prolonged imbibition at temperature > 32°C. The enhanced sensitivity developed at 40°C could be reversed by subsequent treatment at 20°C and similarly re-established by repeating at 40°C treatment. Work of Taylorson and Hendricks (1971) in *A. retroflexus* indicated that enhanced responsiveness to red irradiation could be attributed to an accelerated synthesis of phytochrome.

Photoperiods: Visible radiations have been known to influence seed germination. The effect of light upon germination is due to photic and chemical stimuli within the seed. It plays an important role in the germination of seeds in the desert region. Depending on the species it may accelerate or retard germination. The influence of light on germination of dispersal units has been termed 'photoblastism' (Evenari, 1956; Mukherjee and Chatterjee, 1970). Light sensitive seeds are termed as 'positive' photoblastic whereas which do not require light as 'photoblastic neutral'. According to Wulff (1988), seeds collected from five *Amaranthus dubius* plants of the same population were weighed and tested in

continuous light or darkness at three different temperatures in controlled conditions. Different seed families differed in weight, germination percentages and rate and responded differently to an increase in temperature from 25 to 38°C. Fuller (1949) reported that *Amaranthus caudatus* is a short day species. It flowered under 8 hour photoperiod, failed to flower under continuous illumination and under the natural long days of Spring (Mostly 12 to 14 hrs.). Gopal (1974) studied the photoperiodic response of *Amaranthus spinosus* which shows it to be a day natural plant exhibiting quantitative response. The maximum observed vegetative growth and flowering at 11 and 12 hours photoperiod support the field observations that the plants flower in nature mostly during mid-summer and early winter when the natural day length also varies between 11 and 12 hours. At other times, the plants continue to flower since the photoperiod is no important a factor.

In respect of light duration treatment, seeds of *A. palmeri, A. hybridus* subsp. *cruentus* var. *paniculatus, A. spinosus* and *A. hybridus* subsp. *hybridus* var. *hybridus* showed promotion in percentage germination and seedling growth with gradual increase of light duration up to 36 hours only as compared to the controls. According to Sharma (1998), maximum percentage of seed germination in *Boswellia serrata* occurred under continuous light. The role of light on seed germination has been reviewed rather extensively by many workers (Toole *et al.,* 1956; Evenari, 1956, 1965; Borthwick *et al.,* 1969 and Crocker, 1936).

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