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EFFECT OF ARTIFICIAL SHADING ON GROWTH AND MORPHOGENESIS OF *RAUVOLFIA SERPENTINA* BENTH. EX. KURZ AND *R. TETRAPHYLLA* L.

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Abstract

Context: Plants behaviour is greatly influenced by light intensity, quality and photoperiods. *Rauvolfia serpentina* Benth. ex. Kurz and *R. tetraphylla* L. grow well during April to September with longer daylength and maximum light intensity. Growth of both the species continues during rest months with slow rate. From their overall performance in their normal habitat *R. serpentina* seems to appear that it can tolerate some shading as against *R. tetraphylla*.

Objective: To study the growth behaviour of *R. serpentina* and *R. tetraphylla* under three different light intensities i.e. full open sun, partial shade and shade in a glasshouse.

Materials and Methods: Experiments were done on three light regimes measured with the help of luxmeter, i.e. full light under natural condition with 100% light under netted cloth cover with 90% and diffused light under muslin cloth with 70% Seedlings were raised in earthenware pots. The harvesting was started after 2 weeks after transference of the plants to their appropriate light intensities. The performance of species was judged with respect to mean dry weight accumulation, leaf area increase, relative growth rate, leaf area ratio, specific leaf area, leaf weight ratio, net assimilation rate and α.

Results: In both species dry weight and leaf area increased steadily in successive harvests but *R. serpentina* and *R. tetraphylla* appear to behave differently in their response to different light regimes. *R. serpentina* grows well in partial shade and full light as against *R. tetraphylla* which does well in full light than in partial shade. *R. serpentina* always maintained an edge over *R. tetraphylla*.

Conclusion: Both species showed the value of α more than one in most regimes. It means that they are morphogenetically well balanced and are ready for flowering.

Keywords: Artificial shading, Growth, Morphogenesis, *Rauvolfia serpentine*, *R. tetraphylla*.

Introduction

Plants behaviour is greatly influenced by the light intensity, quality and photoperiods. Responses of the species against variations in light amount received during growth and development often reflect their survival strategies in the community. Briggs *et al.* (1920) was the pioneer for analysing the effect of light intensity on growth and yield of plants. Hunt *et al.* (1984) have noted that upto 300 calories cm^2/day of radiation has an enhancing effect on the growth of the plant. However excessive light and heat reduce photosynthetic activity through photoinhibition apparatus (Powel 1984, Osmond 1994). Evans and Hughes (1961) worked out effect of artificial shading on *Impatiens parviflora*. Pandey and Sinha (1977) have extensively studied the effect of artificial shading on *Crotalaria juncea* L. and *Crotalaria sericea* Retz. Dale and Causton (1992) investigated the effect of shading on *Veronica chamaedrys*, *V. montana* and *V. officinalis*. Jalaluddin and Siddique (2003) worked out the shading effect on growth of three populations of *Cassia tora* L.

Rauvolfia serpentina Benth. ex. Kurz and *R. tetraphylla* L. grow well during April to September with longer daylength and maximum light intensity. Growth of both the species continues during rest months with slow rate. From their overall performance in their normal habitat *R. serpentina* seems to appear that it can tolerate some shading as against *R. tetraphylla*. Hence *R. serpentina* and *R. tetraphylla* grown under three light regimes have been compared with well established growth parameters with a view to investigating their morphogenetic behaviour to fluctuating light climates.

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Materials and Methods

Experiments were done on three light regimes measured with the help of luxmeter, i.e. full light under natural condition with 100% light as T_1, under netted cloth cover with 90% as T_2 and diffused light under muslin cloth with 70% as T_3. Shading conditions were prepared with mosquito net and muslin cloth covering over iron frames (2m x 1m x 1.5m). Seeds of *R. serpentina* and *R. tetraphylla* were procured from Falka of Katihar District and Purnea and experiments were conducted in Department of Botany, Patna University. They after scarification were treated with 0.1% $HgCl_2$. Seedlings were raised in earthenware pots with 25 cm top and 15 cm base diameter having a depth of 30 cm filled with a mixture of field soil, farmyard manure and sandy soil (5:3:2 v/v). The pots were watered every alternate day. After thinning and the seedling to only one per pot, they were left to stabilize. The harvesting was started after 2 weeks after transference of the plants to their appropriate light intensities. Weekly harvests were made from each light regime. Three plants with their roots intact constituted the harvest sample for each species at each of the three light intensities. Soil particles adhering to the roots were carefully washed off with fine jet of water ensuring against any loss of rootlets. Roots, stems and leaves were separated and pressed between folds of blotting paper to remove moisture after which outlines of laminar portions of the leaves were drawn on graph paper for determining leaf areas. The plant parts were then dried at 80°C in an oven for 48 h and cooled over fused calcium chloride in desiccators for next 48 h before weighing. The primary recorded data were dry weight of roots, stem and leaves together with leaf areas. From these the following parameters were calculated; (i) Dry weight increase between harvests, in mg. (ii) Leaf area increase between harvests, in cm^2. (iii) Relative growth rate (RGR), using the formula $R = \frac{Log_e W_2 - Log_e W_1}{t_2 - t_1}$, where W_1 and W_2 are mean weights in mg of harvest times t_1 and t_2 respectively. (iv) Leaf area ratio (LAR), calculated at the ratio of mean total leaf area in cm^2 to mean plant dry weight in mg. (v) Specific leaf area (SLA), calculated as $\frac{\text{Leaf area}(cm^2)}{\text{Leaf wt.(mg)}}$. (vi) Leaf weight ratio (LWR), as leaf dry weight over plant dry weight in mg. (vii) Net assimilation rate (NAR), calculated from the formula. $NAR = \frac{Log_e LA_2 - Log_e LA_1}{t_2 - t_1} \times \frac{W_2 - W_1}{LA_2 - LA_1}$, where W_1, LA_1 and W_2, LA_2 are mean dry weights and mean leaf areas at harvest times t_1 and t_2. (viii) α (of Whitehead and Myerscough 1962), calculated from the formula $\alpha = \frac{Log_e W_2 - Log_e W_1}{Log_e LA_2 - Log_e LA_1}$.

Results

Mean dry weight of whole plant in mg has been given in Table 1 and Fig. 1. *R. serpentina* showed highest mean dry weight accumulation in T_2 regime while lowest in T_3 regime. In *R. tetraphylla*, there was similar trend in dry weight accumation in T_1 and T_2 regimes upto third harvest but it was highest in fourth harvest of T_2 regime. *R. serpentina* accumulates higher dry weight in all the treatments as against *R. tetraphylla*. The analysis of variance supports the conclusion.

The results of leaf area (Table 2) showed that it rises steadily in successive harvests. The mean leaf areas are higher in 90% illumination and least at 70% intensity in both the species. *R. serpentina* shows highest RGR in T_1 and T_2 regimes in first harvest. In second harvest the RGR decreased but again it was maintained in last harvest.

In *R. tetraphylla* the result is different one. In 1-2 harvest interval it was highest in T_3 regime and more or less similar in T_1 and T_2 regimes in 2-3 and 3-4 harvest intervals. There was similar RGR in T_2 regime (Table 3).

The value of NAR was similar in T_1 and T_2 regimes in both the species. The basic difference is 2-3 harvests interval. In *R. tetraphylla* the value of NAR increased from first harvest to second harvest interval while in *R. serpentina* it decreased in T_1 and T_2 regime. Thus both the species selected are behaving differently (Fig. 4). LAR shows a general increase with reduction in light intensity in both the species. In T_3 regime the value was highest. After first harvest, the values decreased but still higher as against T_1 regime in both the species (Table 4 and Fig. 2).

Table 1. Effect of artificial shading on mean dry wt. (mg) increase

Species	Harvests	Treatments		
		T_1	T_2	T_3
R. serpentina	1	32.0	36.2	25.0
	2	50.0	56.5	35.6
	3	65.1	76.8	52.0
	4	100.9	112.2	71.2
R. tetraphylla	1	30.0	30.0	20.0
	2	42.1	42.0	31.0
	3	65.1	65.0	46.0
	4	83.5	99.9	60.5

ANOVA

Source	Degree of freedom	Sum of square	Mean squares	Variance ratio
Species (Sp.)	1	403.43	403.43	48.33**
Treatment (Tr.)	2	2089.84	1044.92	125.19**
Harvest (Har.)	3	11791.80	3930.59	470.93**
Sp. x Tr.	2	27.05	13.52	1.62
Sp. x Har.	3	71.94	23.98	2.87
Tr. x Har.	6	504.08	84.01	10.06**
Residual	6	50.07	8.34	
Total	23	14938.24		

** Significant at 1% level

Table 2. Effect of artificial shading on leaf area (cm^2)

Species	Harvests	Treatments		
		T_1	T_2	T_3
R. serpentina	1	110.1	123.69	99.7
	2	164.2	192.19	119.5
	3	181.8	237.60	174.3
	4	275.9	344.0	206.8
R. tetraphylla	1	107.3	109.5	74.4
	2	154.2	154.1	109.5
	3	181.8	181.5	158.1
	4	223.1	267.2	178.3

ANOVA

Source	Degree of freedom	Sum of square	Mean squares	Variance ratio
Species (Sp.)	1	4558.93	4558.93	36.90**
Treatment (Tr.)	2	15047.94	7523.96	60.91**
Harvest (Har.)	3	67763.81	22587.94	182.86**
Sp. x Tr.	2	1065.37	532.68	4.31
Sp. x Har.	3	1338.75	446.50	3.61
Tr. x Har.	6	4351.50	725.25	5.87*
Residual	6	741.12	123.52	
Total	23	94867.44		

* Significant at 5% level, ** Significant at 1% level

Table 3. Effect of artificial shading on relative growth rate

Species	Harvests	Treatments		
		T_1	T_2	T_3
R. serpentina	1-2	0.44	0.44	0.35
	2-3	0.27	0.31	0.38
	3-4	0.43	0.38	0.32
R. tetraphylla	1-2	0.34	0.34	0.43
	2-3	0.44	0.43	0.40
	3-4	0.24	0.43	0.27

ANOVA

Source	Degree of freedom	Sum of square	Mean squares	Variance ratio
Species (Sp.)	1	0.000005	0.000005	0.00007
Treatment (Tr.)	2	0.00341	0.00171	0.248
Harvest (Har.)	2	0.00615	0.00307	0.446
Sp. x Tr.	2	0.00363	0.00182	0.264
Sp. x Har.	2	0.02443	0.01222	1.775
Tr. x Har.	4	0.01022	0.00256	0.371
Residual	4	0.02753	0.00688	
Total	17	0.07538		

Table 4. Effect of artificial shading on leaf area ratio

Species	Harvests	Treatments		
		T_1	T_2	T_3
R. serpentina	1	3.44	3.42	3.98
	2	3.28	3.40	3.36
	3	2.79	3.09	3.35
	4	2.73	3.07	2.90
R. tetraphylla	1	3.58	3.65	3.72
	2	3.66	3.67	3.53
	3	2.79	2.79	3.44
	4	2.67	2.67	2.95

ANOVA

Source	Degree of freedom	Sum of square	Mean squares	Variance ratio
Species (Sp.)	1	0.004	0.004	0.161
Treatment (Tr.)	2	0.337	0.168	6.821*
Harvest (Har.)	3	2.511	0.837	33.925**
Sp. x Tr.	2	0.028	0.014	0.163
Sp. x Har.	3	0.145	0.048	1.166
Tr. x Har.	6	0.268	0.045	1.809
Residual	6	0.148	0.025	
Total	23	3.441		

Table 5. Effect of artificial shading on specific leaf area

Species	Harvests	Treatments		
		T_1	T_2	T_3
R. serpentina	1	6.17	6.51	5.57
	2	6.87	7.04	6.02
	3	7.02	7.64	6.78
	4	7.24	8.00	7.01
R. tetraphylla	1	5.96	6.02	4.80
	2	6.56	6.85	5.73
	3	7.02	7.09	5.99
	4	7.15	7.79	6.39

ANOVA

Source	Degree of freedom	Sum of square	Mean squares	Variance ratio
Species (Sp.)	1	0.851	0.851	47.876**
Treatment (Tr.)	2	4.834	2.417	135.930**
Harvest (Har.)	3	6.767	2.256	126.856**
Sp. x Tr.	2	0.217	0.108	6.103*
Sp. x Har.	3	0.053	0.018	0.998
Tr. x Har.	6	0.186	0.031	1.741
Residual	6	0.107	0.018	
Total	23	13.015		

* Significant at 5% level, ** Significant at 1% level

Table 6. Effect of artificial shading on leaf weight ratio

Species	Harvests	Treatments		
		T_1	T_2	T_3
R. serpentina	1	0.56	0.52	0.72
	2	0.48	0.48	0.56
	3	0.40	0.40	0.49
	4	0.37	0.38	0.41
R. tetraphylla	1	0.60	0.61	0.77
	2	0.56	0.54	0.61
	3	0.40	0.39	0.57
	4	0.37	0.34	0.46

ANOVA

Source	Degree of freedom	Sum of square	Mean squares	Variance ratio
Species (Sp.)	1	0.008	0.008	12.125*
Treatment (Tr.)	2	0.066	0.033	47.711**
Harvest (Har.)	3	0.205	0.068	98.402**
Sp. x Tr.	2	0.001	0.0006	0.879
Sp. x Har.	3	0.004	0.0013	1.826
Tr. x Har.	6	0.010	0.0017	2.441
Residual	6	0.009	0.0007	
Total	23	0.303		

* Significant at 5% level, ** Significant at 1% level

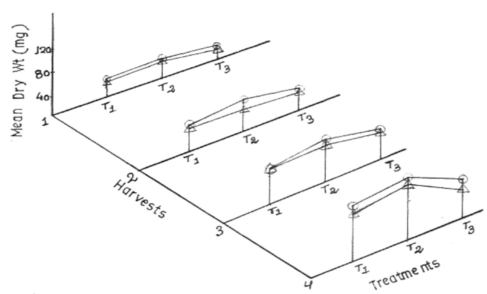

Fig. 1. Effect of artificial shading on mean dry wt. increase.T_1, Full sunlight; T_2, 90% light intensity; T_3, 70% light intensity, *O=R. serpentina; ∆= R. tetraphylla*

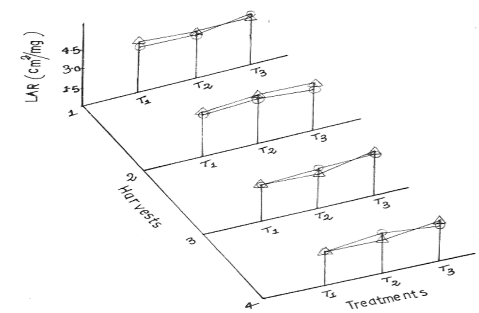

Fig. 2. Effect of artificial shading on LAR. T_1, Full sunlight; T_2, 90% light intensity; T_3, 70% light intensity, *O=R. serpentina; ∆= R. tetraphylla*

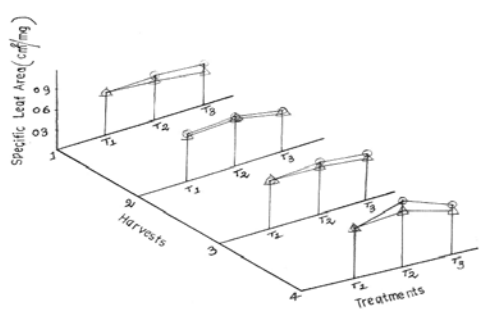

Fig. 3. Effect of artificial shading on SLA. T_1, Full sunlight; T_2, 90% light intensity; T_3, 70% light intensity, *O=R. serpentina; ∆= R. tetraphylla*

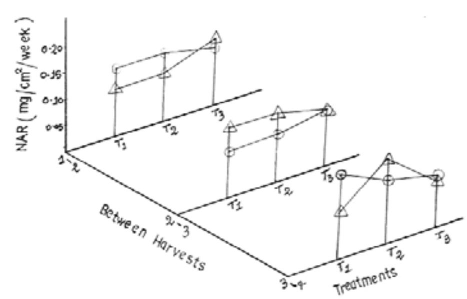

Fig. 4. Effect of artificial shading on NAR. T_1, Full sunlight; T_2, 90% light intensity; T_3, 70% light intensity, *O=R. serpentina; ∆= R. tetraphylla*

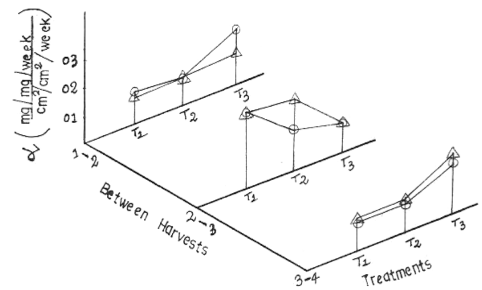

Fig. 5. Effect of artificial shading on α . T_1, Full sunlight; T_2, 90% light intensity; T_3, 70% light intensity, *O=R. serpentina; ∆= R. tetraphylla*

LAR is maintained by SLA and LWR. SLA has been presented in Table 5 and Fig. 3. It is more or less similar in T_1 and T_2 regimes of *R. serpentina* and *R. tetraphylla*. It showed increasing trend from first to fourth harvest in both the species. The higher SLA indicates thinner leaf to receive more and more solar radiation. *R. serpentina* maintained an edge over *R. tetraphylla*.

LWR has been presented in Tables 6. It is highest in T_3 regime of both the species. It means maximum amount of photosynthetic material is being transported to leaf from other parts of the plants. Thus, they are not adapted well in this regime. The least amount of LWR is shown by fourth harvest of T_1 and T_2 regimes. It means that plants are adapted in partial shade (90% light) and full light. It should be noted that *R. tetraphylla* shows higher LWR values in comparison to *R. serpentina*. It means former is not adapting well in 70% light intensity.

Both species showed the value of α more than one in most regimes. It means that they are morphogenetically well balanced and are ready for flowering (Fig. 5). The results are not fully supported by analysis of variance where major factors and interactions are non-significant. Harvest and Interaction of Tr. x Har. are only significant at 5% level

Discussion

The maximum RGR in many species at T_3 regime (lower intensities) has also been seen by Evans and Hughes (1962) and Myerscough and Whitehead (1967). Thus, both species behave in general as plants requiring high light intensity but *R. serpentina* shows adaptability to shading in terms of dry weight, leaf area and RGR. Similar is the behaviour in *C. juncea* and *C. sericea* reported by Pandey and Sinha (1977). Blackman and Wilson (1951) pointed out that the relationship between LAR and log relative light intensity was linear and they used the slope of the line as a measure of sensitivity of LAR to shading. Accordingly they defined a shade plant as one in which a reduction in light intensity, causes a rapid rise in LAR from an initially low value in full day light. A large LAR is an important asset in such a species in enabling it to out grow its competitors quickly, even though its emergence from the shaded layer may expose it to the risk of desiccation if a drought should occur (Blackman and Wilson 1951). The reduction of LAR with ageing has been observed as a usual feature in *Crotalaria* species (Pandey and Sinha 1977). Comparisons of values of LAR are, however, made difficult by autogenetic drifts and Njoku (1959) has reported categories of plants characterised by high, intermediate and low intrinsic levels of LAR. The results are partially supported by analysis of variance (Table 3) where treatment is significant at 5% level while harvest at 1% level.

LWR values are highest in T_3 regime for both species. It suggests a greater consumption of assimilates for further growth of leaves. The least amount of LWR shown in fourth harvest of T_1 and T_2 regimes indicate that plants are adapted in partial shade (90% light) and full light. If comparisons are made, *R. tetraphylla* is more disturbed in 70% light intensity as against *R. serpentina*. The results of the present experiments, especially those for *R. serpentina*, conform that the species has characteristics of a partial shade adapted plant.

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