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MORPHOLOGICAL RESPONSES OF *MYRIOPHYLLUM EXCALBESCENS* FERN. TO DIFFERENT RED: FAR-RED LIGHT RATIOS

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RIVARD P. G. and HODDINOTT J. *Morphological responses of* Myriophyllum excalbescens *Fern. to different red:far-red light ratios.* BIOTRONICS **18**, 9–14, 1989. This study investigates the influence of the red: far-red (R: FR) light ratio supplied by artificial light sources on the form of *Myriophyllum excalbescens* Fern. plants growing in aquaria in a controlled environment chamber. In the high R: FR light 85% of turions broke dormancy, while 65% broke dormancy in low R: FR light. In the low R: FR light plants had a lower specific leaf area and leaf area ratio than in high R: FR light. *Myriophyllum* thus showed morphological responses to the R: FR ratio of light that parallel those shown by terrestrial plants.

Key words: *Myriophyllum excalbescens* Fern.; red: far-red ratio; growth; leaf morphology.

INTRODUCTION

Water absorbs far-red light more strongly than red light and with increasing depth in the water column the red: far-red (R:FR) ratio of natural light increases (*14*). The R:FR ratio of light influenced the development of heterophylly in the aquatic plant *Hippuris vulgaris*, low ratios being associated with the production of aerial form leaves and high ratios with submerged form leaves (*1*), and end of day irradiance with far-red light (low R:FR ratio) enhanced mean internode length in *H. vulgaris* (*14*). Terrestrial plants may show less obvious alterations in leaf form in response to the R:FR ratio. *Phaseolus vulgaris* produced leaves of higher specific leaf weight (SLW) (i.e. lower specific leaf area (SLA)) and shorter stems in higher R:FR ratios (*6*). Bud development was promoted in high ratios in *Lolium multiflorum* where there was an increase in the number of tillers produced (*2*). However, it has also been reported that heterophylly in *H. vulgaris* is due to leaf abscisic acid level with no role for the incident R:FR ratio (5).

Myriophyllum excalbescens produces leaves of a single form. It was grown in aquaria in a controlled environment chamber providing uniform conditions with

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the exception of different R:FR ratios to allow the investigation of the influence of the R:FR ratio on leaf development. The observations allowed comparisons to be made to responses by heterophyllous aquatic plants and terrestrial ones. The major changes observed were in specific leaf area (SLA) and leaf area ratio (LAR) which increased in higher R:FR ratios.

MATERIALS AND METHODS

Dormant turions of *Myriophyllum excalbescens* Fern. were collected from Narrow Lake, Alberta (54° 55′ N, 113° 37′ W), in November 1985. Twenty shoots of 10 cm length were planted in each of two $1.0 \times 0.5 \times 0.5$ m aquaria placed on either side of a black cloth hanging vertically across the center line of an EGC growth chamber. On one side of the cloth light was provided by General Electric F96T10CW cool white fluorescent tubes (red (R) treatment), on the other side light was provided from a 2:1 ratio of cool white tubes and Sylvania F96T12/232/VHO far-red emitting fluorescent tubes (far-red (FR) treatment). Aquarium height was adjusted to provide 210 μmol m^{-2} s^{-1} of photosynthetically active radiation (PAR) at the water surface. The spectral distribution of the two light sources was measured with a Tectum QSM-2500 quanta spectrometer (Fig. 1). The photoperiod was 12 h with a constant 20°C temperature.

After 40 days growth, stems were cut from the distal ends of the turions and stored at 4°C in a 4% formaldehyde solution for 10 days. The stems were then rinsed with tap water to remove epiphytes. The surface area of leaves and stems was estimated by a colorimetric method (*3*). Fresh weight was measured after blotting the plant parts with absorbant paper, and dry weight was measured following drying at 80°C to constant weight. Specific leaf area ((SLA) leaf area/leaf weight),

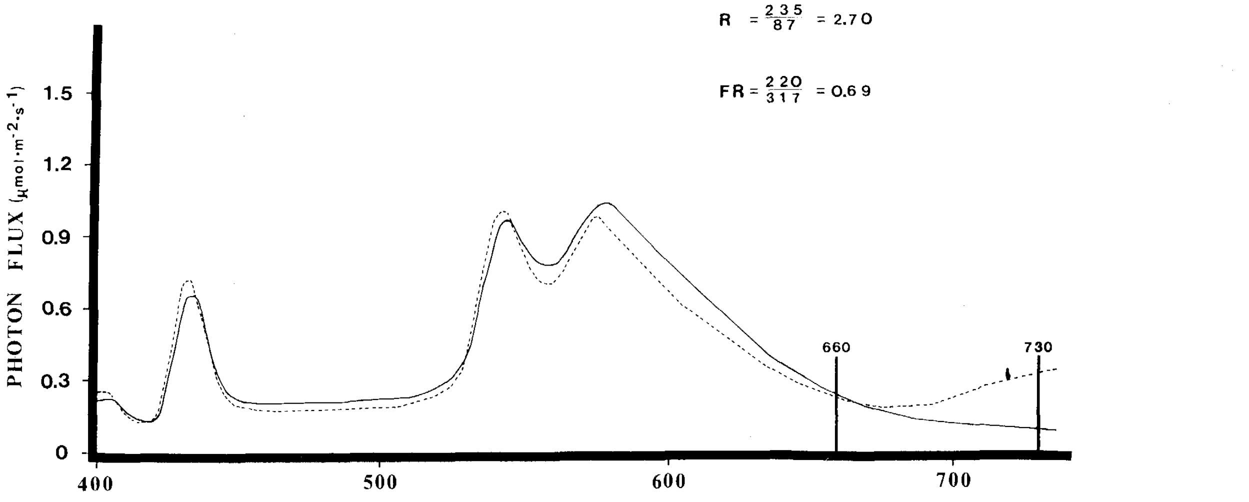

Fig. 1. The spectral quality of the red (R ——) and far-red (FR ······) rich light treatments in the controlled environment chambers. The enclosed values are for the 660: 730 nm quantum flux ratios.

leaf area ratio ((LAR) leaf area/plant weight) and leaf weight ratio ((LWR) leaf weight/plant weight) were then calculated (*8*). Total stem length (TSL) and mean internodal length (MIL) between the leaf whorls were also determined.

Data was analysed by STATPRO (*18*) which performed tests of significant differences ($P<0.05$) between treatment means using the Student's t test. If variables were significant, the program described the variation in a population parameter when it was added to a multiple linear regression model (*12*, *20*). Tests to differentiate between means were chosen to identify discrete differences between population treatments, while multiple linear regression tests were performed to test if differences due to treatments were significant in describing a change in one or many parameters along a continuous measurement gradient (*4*, *10*).

RESULTS AND DISCUSSION

Of the 20 turions planted, 85% of the R and 65% of the FR treated ones broke dormancy by the end of the growth period. It is known that exposure to FR can suppress germination of *Lycopersicon* seeds (*16*) and lateral bud growth on *Xanthium* shoots (*15*). The partial inhibition of the release from dormancy of *M. excalbescens* turions by FR light is consistent with its inhibitory effects on terrestrial plants.

Among all the morphological parameters measured, a significant difference was only seen between light qualities in the stem fresh weight to dry weight ratio (Table 1, FWS/DWS). Although that was the only difference due to treatments, it is proposed that covariance of one or more parameters masked our ability to detect light treatment effects. Analyses by multiple linear regression determined which of the parameters investigated best described variation in the estimates of SLA, LAR and LWR (Table 2). For SLA and LAR the leaf fresh weight/dry weight ratio coupled with the variation described by the light treatments were the only two measures of significance in the model. A negative slope for the effect of the light treatments (using $R=0$ and $FR=1$ as dummy variables) showed that the magnitude of SLA and LAR were higher for R than for FR. Light treatments affected SLA and LAR after the covariation due to leaf fresh weight/dry weight ratio had been identified. The LWR was also well described by the leaf fresh weight/dry weight ratio and the MIL. However, light treatments did not affect the LWR relationship and, in fact, LWR increased with a decrease in both leaf fresh weight/dry weight ratio and MIL.

Since R: FR ratios become very high with increasing water depth, it has been proposed that plants perceive R:FR as an index of depth (*13*, *14*, *19*). Investigations on terrestrial plants have shown convincing evidence that the R:FR ratio is important in acclimation to the depth of canopy shade. Seedlings of herbaceous plants in low ratios may show increased petiole length (*11*), reduced leaf area (*7*), increased stem dry weight (*9*) and reduced branching (*17*).

The data in Table 2 imply that *M. excalbescens* in low R:FR ratios responded in a similar manner to canopy shaded terrestrial plants with decreased leaf size as estimated by SLA and LAR.

The study indicates how use can be made of flourescent tubes with specific

Table 1. A comparison between means of treatments of red (R) and far-red (FR) enriched light for various morphological parameters of *Myriophyllum excalbescens*

Parameter	Light	Mean	Units	Standard error
Mean internode length (MIL)	R	0.830	cm	0.028
	FR	0.898		0.049
Number of whorls	R	17.7		1.56
	FR	18.8		1.34
Total shoot length (TSL)	R	16.7	cm	1.17
	FR	18.8		1.13
Fresh weight leaves (FWL)	R	0.681	g	0.070
	FR	0.699		0.106
Fresh weight stem (FWS)	R	0.197	g	0.022
	FR	0.297		0.044
Fresh weight shoot (FWSL)	R	0.878	g	0.086
	FR	0.996		0.144
Dry weight leaves (DWL)	R	0.189	g	0.104
	FR	0.087		0.011
Dry weight stem (DWS)	R	0.027	g	0.003
	FR	0.028		0.004
Dry weight shoot (DWSL)	R	0.216	g	0.105
	FR	0.115		0.015
Leaf area	R	85.51	cm^2	11.816
	FR	63.36		11.519
Stem area	R	11.90	cm^2	2.456
	FR	7.13		0.966
Shoot area	R	97.42	cm^2	12.822
	FR	70.48		12.161
Leaf area ratio (LAR)	R	319.7	cm^2 g^{-1}	33.9
	FR	273.4		34.2
Stem area ratio (SAR)	R	48.9	cm^2 g^{-1}	11.4
	FR	31.1		2.7
Shoot area ratio (SLAR)	R	368.6	cm^2 g^{-1}	41.3
	FR	304.5		35.3
Leaf weight ratio (LWR)	R	0.791		0.023
	FR	0.757		0.024
Shoot weight ratio (SWR)	R	0.209		0.023
	FR	0.243		0.024
Specific leaf area (SLA)	R	416.3	cm^2 g^{-1}	49.2
	FR	370.4		53.8
Specific stem area	R	226.2	cm^2 g^{-1}	48.9
	FR	131.5		9.7
FWL/DWL	R	6.99		0.78
	FR	8.34		1.13
FWS/DWS**	R	7.42		0.23
	FR	10.93		0.80
FWSL/DWSL	R	6.95		0.72
	FR	8.74		0.78

** Denotes a significant difference between treatment means for the same parameter at $P<0.01$.

Table 2. Multiple linear regression analyses of three estimates of *Myriophyllum excalbescens* morphology where Field variables significantly describe variation at $P<0.05$

Specific leaf area (SLA)

Source of variation	DF	SS	MS	F	R^2
Total	19	4.88E+05			
Regression	2	2.98E+05	1.48E+05	13.29	0.61
Residual	17	1.90E+04			

Field	Beta coefficient	Standard error	Partial F
Intercept	127.38		
FWL/DWL	41.32	8.16	25.65
Treatment	−102.02	48.64	4.40

Leaf area ratio (LAR)

Source of variation	DF	SS	MS	F	R^2
Total	19	2.19E+05			
Regression	2	1.04E+05	5.19E+04	7.62	0.47
Residual	17	1.16E+05	6.82E+03		

Field	Beta coefficient	Standard error	Partial F
Intercept	155.27		
FWL/DWL	23.52	6.36	13.66
Treatment	−78.17	37.93	4.25

Leaf weight ratio (LWR)

Source of variation	DF	SS	MS	F	R^2
Total	19	0.105			
Regression	2	0.080	0.040	27.36	0.76
Residual	17	0.025	0.001		

Field	Beta coefficient	Standard error	Partial F
Intercept	1.11		
FWL/DWL	−0.02	0.003	48.89
Mean internode lengh (MIL)	−0.21	0.069	9.28

light emission characteristics to study photomorphogenesis in aquatic plants in controlled environment chambers.

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