DESCRIPTION OF LIGHT QUALITY PARAMETERS IN CONTROLLED ENVIRONMENT RESEARCH

Cerny, T. A.
Department of Horticulture Clemson University

Rajapakse, N. C.
Department of Horticulture Clemson University

Rieck, J. R.
Department of Experimental Statistics Clemson University

出版情報：BIOTRONICS. 29, pp.17-21, 2000-12. Biotron Institute, Kyushu University
バージョン：
権利関係：

BIOTRONICS **29**, 17–21, 2000

DESCRIPTION OF LIGHT QUALITY PARAMETERS IN CONTROLLED ENVIRONMENT RESEARCH

T. A. CERNY[1], N. C. RAJAPAKSE[1] and J. R. RIECK[2]

[1]*Department of Horticulture, Clemson University, Clemson, SC 29634, USA.*
[2]*Department of Experimental Statistics, Clemson University, Clemson, SC 29634, USA.*

(Received July 2, 2000; accepted September 25, 2000)

CERNY T. A., RAJAPAKSE N. C. and RIECK J. R. *Description of light quality parameters in controlled environment research.* BIOTRONICS **29**, 17–21, 2000. The R : FR ratios and phytochrome photoequilibrium estimates (ϕ_e) are often used to correlate plant responses to various light quality environments. However, R : FR ratios and ϕ_e vary with wavelength selection and the estimation method used for ϕ_e calculation. Interpretation of plant responses based on R : FR ratio should be done carefully as illustrated in the example shown in the research described in this paper. Lack of standardized bandwidth selection makes it difficult to compare data. Although standardized light quality parameters are needed, the task is complicated by spectral distribution patterns of various light sources. Therefore, providing complete spectral distribution in addition to quantitative light quality parameters should be reported.

Key words: spectral filters; phytochrome photoequilibrium; R: FR ratio; photomorphogenesis

Quality of light exerts diverse effects on plant growth and development through photomorphogenesis. In general, most photomorphogenic processes are controlled by wavelengths in the blue (B : 400–500 nm), red (R : 600–700 nm) and far-red (FR : 700–800 nm) regions. In photomorphogenesis, photons in these wavelengths are perceived by biological photoreceptors present in plants. Provided that minimum levels are received, photomorphogenic processes are not influenced by intensity of photons. Upon absorption of photons in these regions, photoreceptors induce signals that can lead to specific plant responses.

Phytochrome is the most widely studied of these photoreceptors that controls photomorphogenesis. Phytochrome can absorb wavelengths from 300–800 nm with maximum absorption in R region (600–700 nm) with peak absorption at 660 nm and FR region (700–800) with peak absorption at 730 nm of the spectrum. The pigment exists in two interconversional forms: the R light and FR light absorbing, P_r and P_{fr} forms, respectively. The P_{fr} form is assumed to be the physiologically active form that triggers a variety of physiological responses. Upon prolonged exposure to a given light environment, an *in vivo* photoequilibrium develops between P_{fr} and P_{total}. This ratio is defined as phytochrome photoequilibrium (ϕ). Methods to estimate ϕ from spectral properties of a light source and optical properties of purified phytochrome have been described by several researchers.

Photon ratios between the R and FR regions of the spectrum (R : FR ratio) and *in vitro* estimates of $\phi(\phi_e)$ have commonly been used to quantitatively describe the light environment. Despite the interest in lighting in controlled environments and photomorphogenesis, standardized numerical parameters for expressing light quality cannot be found in the literature.

The objectives of this paper are to report the difficulties in correlating plant response with commonly used quantitative light quality parameters (R : FR ratio

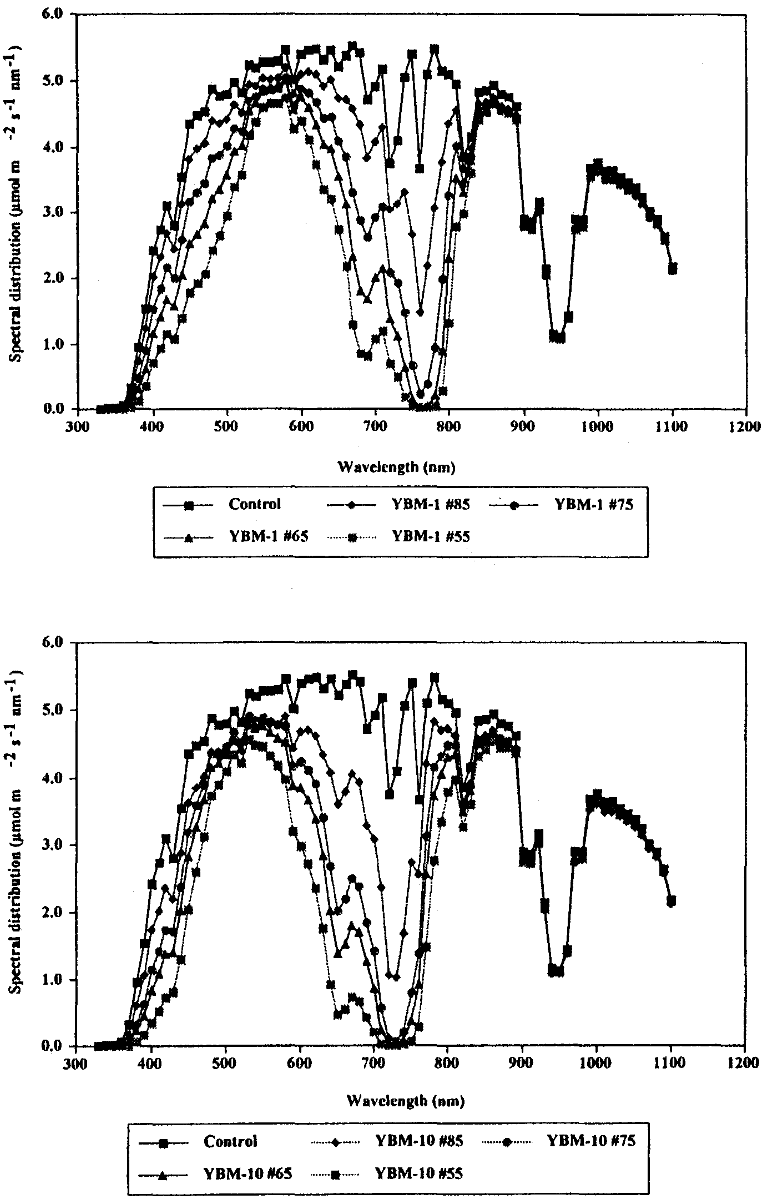

Fig. 1. Light transmission characteristics of YBM-1 (top) and YBM-10 (bottom).

and ϕ) and the need for a coordinated effort of scientists in developing standardized quantitative light quality parameters.

In collaboration with Mitsui Chemicals, Inc., (Tokyo, Japan) we are making efforts to develop photoselective greenhouse covers that can remove FR light from the greenhouse as a non-chemical alternative for height control of greenhouse crops. For initial trials, Mitsui Chemicals, Inc. developed photoselective greenhouse covers with two different FR light absorbing dyes, YBM-1 and YBM-10, which intercepted FR wavelengths with maximum interception at 760 nm and 730 nm, respectively (Figure 1). To determine an optimum dye concentration for future use we initially tested greenhouse covers with five dye concentrations from each of the dyes. We constructed growth chambers (1 m×0.8 m×0.8 m) covered with each of the experimental materials. As the dye concentration in the covers increased, light transmission decreased. Therefore, growth chambers were covered with neutral density shade cloth to adjust the irradiance to be equal among all experimental chambers. Plant growth inside these chambers was tested with several species but only data from bell pepper are presented to demonstrate the objective.

Photon flux distribution inside each chamber was measured with a LI-1800 spectroradiometer fitted with a LI-1800-10 remote cosine sensor. The R : FR ratios, both broad and narrow band, were calculated as the photon flux ratio between 600 and 700 nm (R) and 700 and 800 nm (FR) and photon ratio between

Table 1. Comparison of R: FR ratio (based on wavelength selection for R and FR) and phytochrome photoequilibrium estimates (ϕ_e) of light transmitted through YBM-1 and YBM-10 material and bell pepper plant height.

Filter	Plant ht (cm)	R : FR ratio		ϕ_e^X
		BB[Z]	NB[Y]	
Control	22.1±0.72	1.1	1.3	0.72
YBM-1 #85	17.2±0.51	1.5	1.5	0.75
YBM-1 #75	13.9±0.33	2.5	2.0	0.78
YBM-1 #65	13.9±0.23	3.8	2.9	0.81
YBM-1 #55	12.0±0.16	6.0	4.6	0.83
r		0.965	0.917	0.947
Control	14.5±0.21	1.1	1.3	0.72
YBM-10 #85	11.2±0.26	1.4	3.2	0.77
YBM-10 #75	10.0±0.19	1.6	19.2	0.80
YBM-10 #65	9.9±0.16	1.5	42.7	0.81
YBM-10 #55	9.6±0.26	1.2	46.6	0.82
r		0.475	0.980	0.964

[Z]BB=Broad band R : FR based on R=600-700 nm and FR=700-800 nm.
[Y]NB=Narrow band R : FR ratio based on R=655-665 nm and FR=725-735 nm.
[X]ϕ_e=Calculated as described by Sager et al., 1988.

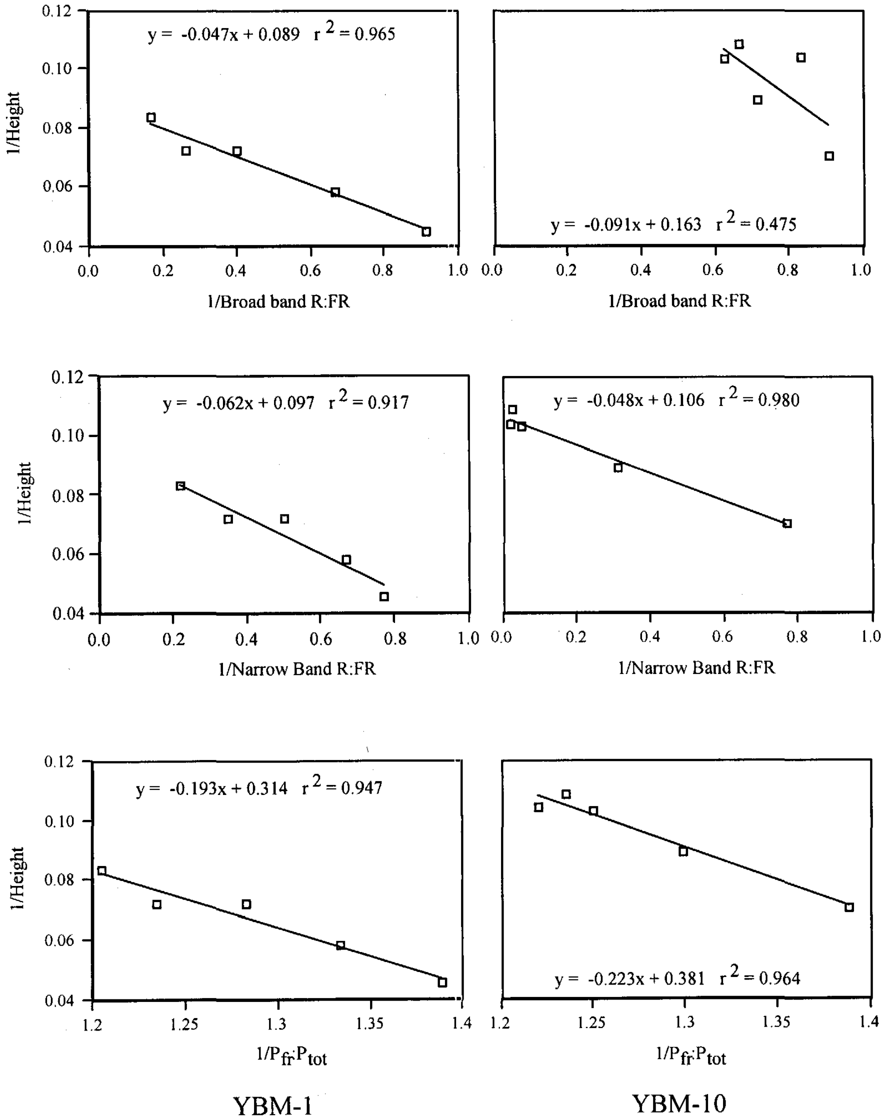

Fig. 2. Relationship between inverse height and inverse broad band R: FR, narrow band R: FR and ϕ.

655 and 665 (R) and 725 and 735 nm (FR), respectively. Phytochrome photoequilibrium was calculated as described by Sager et al. (*4*).

Table 1 shows the R: FR ratios, ϕ_e, and height of bell pepper plants grown inside chambers made of the two types of covers. In YBM–1 chambers, the broad band R: FR ratio increased from 1.1 to 6.0 as the dye concentration increased, however, in YBM–10 chambers broad band R: FR ratio increased to 1.6 and then decreased. In YBM–10 chambers, the broad band R: FR ratio was similar between the control and the chamber with the highest dye concentration. Narrow band R: FR ratio increased as the dye concentration increased in both the YBM–1 and YBM–10 chambers but narrow band R: FR ratios were smaller in YBM–1 chambers than in YBM–10 chambers. The ϕ_e increased as the dye concentration increased in both materials.

Height of bell pepper plants decreased as the dye concentration increased in both types of chambers. Correlation values are based on inverse height and inverse R: FR ratios and ϕ_e. In the YBM-1 chambers plant height correlated well ($R^2>0.91$) with both narrow and broad band R: FR ratios or ϕ_e (Figure 2). However, in YBM-10 chambers, plant height correlated well only with narrow band R: FR ratios and ϕ_e ($R^2>0.96$). The correlation between plant height and broad band R: FR ratio was lower ($R^2<0.50$). Similar results were observed with tomato, watermelon and chrysanthemum *(1, 2)*.

Although most researchers use R: FR ratios to quantify light quality parameters, our results show that R: FR ratios vary with the bandwidth selection. Therefore, interpretation of plant responses based on R: FR ratio should be done carefully. In our data plant response had a more consistent correlation with ϕ_e than with R: FR ratios. However, in a previous paper we reported the problem of correlating plant response with ϕ because of the variation in phytochrome parameters used *(3)*.

Interpreting plant responses under modified light environments is difficult due to lack of reliable quantitative light quality measurements. Although R: FR ratios provide a quantitative expression of light quality, lack of standardized band width selection makes it difficult to compare data. Phytochrome photoequilibrium estimates provide a better quantitative parameter than R: FR ratios but this can also provide misleading estimates when both R and FR are absent. Although a standard light quality parameter is needed this task is complicated by spectral distribution patterns of various light sources. Therefore, even if a standardized parameter is used, providing complete spectral distribution is needed.

REFERENCES

1. Cerny T. A., Rajapakse N. C. and Oi R. (1999) Recent developments in photoselective greenhouse covers. *Proc. Natl. Agr. Plastics Congr.* **28**, 75–80.
2. Rajapakse N. C., Young R. E. and Oi R. (1998) Plant growth regulation by photoselective greenhouse covers. *Proc. Natl. Agr. Plastics Congr.* **27**, 23–29.
3. Rajapakse N. C. and Kelly J. W. (1994) Problems of reporting spectral quality and interpreting phytochrome-mediated responses. *HortScience* **29**, 1404–1407.
4. Sager J. C., Smith W. O., Edwards, J. L. and Cyr K. L. (1988). Photosynthetic efficiency and phytochrome photoequilibria determination using spectral data. *Transactions of ASAE* **31**, 1882–1887.