4 Non-photosynthetic Responses to Light Quality

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4.1 Introduction

In nature, survival is dependent on the sensitivity with which an organism can perceive its environment. One environmental resource obviously of prime importance to plants is light, its optimum harvest by photosynthesis being essential for the survival of both the individual organism and the species. Photosynthetic optimisation has been rendered possible through the evolution of highly sensitive perception mechanisms by which many different aspects of the continuously variable and always complex radiation environment may be detected. The information gathered from the environment by these mechanisms allows the plant to adapt, or acclimate, to the light conditions by appropriately modulating its metabolism or development. The non-photosynthetic responses to light quality – namely, photomorphogenesis, phototropism and photoperiod-
ism – which form the subject of this chapter are the physiological manifestations of the environmental perception mechanisms.

The origins of our present knowledge and understanding of photomorphogenesis, phototropism and photoperiodism can be traced at least to the early part of this century, but the presently emergent appreciation of the functions of these phenomena in plants growing under natural conditions has awaited the development of reliable instrumentation for the analysis and simulation of natural light spectra. Clearly, there is an abundant literature. The work discussed below is limited to that which has a direct bearing on the natural environment and in which the light environment is accurately defined. As this is, apparently, the first review of non-photosynthetic responses to light quality, it seems essential to set out in detail the spectral variation encountered in nature, and the responses to such variation as it is simulated in the controlled environment. The photoreceptors are given only minor attention here, since the detailed discussion which they deserve will appear in the later Photomorphogenesis volume of the Encyclopedia.

### 4.2 The Natural Light Environment (cf. also Chaps. 1 and 2, this Vol.)

#### 4.2.1 Daylight

At solar elevations of greater than 10° the global radiation between 400 nm and 800 nm has a characteristically uniform spectrum which is made up from direct sunlight and diffuse skylight. This is daylight. When the solar disk has less than 10° elevation the spectrum of the global radiation between 400 nm and 800 nm is radically altered by atmospheric processes. We have called this period twilight (see below). The spectral distribution of direct sunlight at the Earth’s surface (Fig. 4.1a) is a result of attenuation of the direct solar beam in the Earth’s atmosphere by ozone absorption, Rayleigh scattering, Mie scattering, and absorption by oxygen and water molecules (Gates 1966; Robinson 1966; Henderson 1977). Scattering produces diffuse skylight (Fig. 4.1b), which is rich in blue light due to Rayleigh scattering.

A typical spectral distribution for daylight under a clear midsummer sky is shown in Fig. 4.1c. Cloud cover and dust/haze (Mie particles) produce two frequently-encountered variations of this typical spectral distribution. Clouds appear to act as non-selective diffusing filters, which reflect a considerable proportion of direct sunlight. The resulting spectrum shows an increase in the proportion of blue (scattered) light, but very little change at the longer wavelengths (600–800 nm) (Fig. 4.1d) (Taylor and Kerr 1941; Hull 1954; Robertson 1966; Holmes and Smith 1977a). Holmes and Smith (1977a) found

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1 The spectra for Figs. 1, 3 and 4 must unfortunately be presented in relative units (normalised to 1 at 600 nm), because it is not feasible to convert the published data to absolute photon units (µmol m⁻² s⁻¹). However, we have included an approximate photon fluence rate per nm at 600 nm in the figure legends.