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SPECTRAL TRANSMISSION CURVES FOR A BEECH (FAGUS SYLVATICA L.) CANOPY

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SUMMARY

Measurements were made at eighteen sites within a beechwood on a calm, uniformly overcast day in August, 1971. The sites varied in total incoming radiation (visible plus infra-red), being placed at various points on a light gradient from a clearing to deep canopy shade. Readings of spectral intensity were recorded from 380 nm to 1100 nm both inside and outside the wood. Transmission curves were then plotted for all sites. These showed a relative increase in transmission in the green (550 nm) and far red/near infra-red (beyond 700 nm) wavebands. When normalised, the transmission increment beyond 700 nm was shown to vary between sites, becoming less marked as total incoming radiation increased.

1. INTRODUCTION

General variations in the transmission of deciduous canopies with wavelength from 365–740 nm have been well established by such workers as ATKINS, POOLE & STANBURY (1937), ANDERSON (1964), COOMBE (1957), EVANS (1939, 1969), FEDERER & TANNER (1966), and ROBERTSON (1966). Recently, however, STOUTJESDIJK (1972a, 1972b) has published spectral transmission curves for temperate and tropical forests for the 400 nm–1100 nm and 400 nm–900 nm wavebands, respectively. These data confirm previous hypotheses, showing a striking increase in transmission beyond 700 nm which is maintained to 900 nm or 1100 nm. Also confirmed is the characteristic transmission curve for the visible region, slight minima being found between 425 nm and 475 nm and at 675 nm, with a maximum at 550 nm. This is as expected and can be explained by the absorption and reflection spectra for deciduous leaves (MOSS & LOOMIS 1952, BILLINGS & MORRIS 1951). Within the visible spectrum a certain amount of radiation will be absorbed in all wavebands, but at 440 nm and 670 nm, the peaks of the photosynthesic action spectra, absorption is strongest. Other wavebands will be subjected to a greater amount of transmission and reflection by the canopy. At 550 nm absorption is at a minimum, and the amount of radiation reflected and transmitted will be high. Similarly, beyond 700 nm in the far red and near infra-red wavebands, absorption is low and these wavelengths therefore figure prominently in the woodland light climate.

The aim of the present work was to investigate the spectral composition of light at a number of sites in the same woodland, and a comparison has been made with Stoutjesdijk's curves in geometric terms. The variation in transmissivities between sites with different total light intensities is demonstrated.

2. THE WOODLAND SITE

Measurements were made on a transect from the edge of a clearing where felling had taken place, to a typically dark site within the wood. The wood itself was a mature natural beechwood, The Rough, on the South Downs, near Arundel, Sussex, England (NGR TQ003094). The canopy was composed almost entirely of beech (*Fagus sylvatica* L.) with a widely scattered understorey of yew (*Taxus baccata* L.). Ash (*Fraxinus excelsior* L.) was rarely present. The field layer was dominated by bramble.

3. METHODS

As different sites were being compared it would have been desirable to take readings simultaneously, at all sites and, for the calculation of transmissivities, at a point outside the wood. However, as this was not practicable, it was decided to standardize the measurements at each site as far as possible. Consequently readings were taken:

a) within two hours of midday (1100–1500 hrs. BST), in order to eliminate variations in light intensity and quality due to the rapidly changing angle of the sun to the zenith.

b) with reference to a horizontal surface, and at a constant height from the ground,

c) under stable light conditions.

This latter condition required either a totally clear or uniformly overcast sky. Measurements were made under both light regimes on a number of days, but eventually the data for one calm overcast day, 15 August, 1971, met the required conditions of constant, undepleted values. On alternative overcast days the cloud thickness outside the wood appeared to vary considerably throughout the day with resulting marked variation at the control site. On clear sunny days there was always a slight breeze disturbing the tree canopy and consequently a rapidly moving light pattern over the woodland floor. The stability of the light climate outside the wood was assessed from readings taken with a Casella Bimetallic Actinograph which continuously recorded total light intensity (280 nm–3000 nm) at the control site.

An Isco Spectroradiometer was used to determine quantity of radiation at selected waveband intervals. A range of 380 nm–1100 nm was considered, 380 nm–735 nm being specified by the makers as the "visible" range, whilst 735 nm–1100 nm was specified as "infra-red radiation". Measurements were made at 25 nm intervals in the former and 50 nm intervals in the latter range. Total radiation (visible plus infra-red) was obtained by summing the area under the curve of intensity vs. wavelength. The spectral composition of daylight was determined at the control site outside the wood approximately every half-hour and varied little on the day in question. Eighteen sites were finally considered.

4. RESULTS

From the data obtained, transmission curves were calculated for the eighteen sites. The total intensity of radiation (from 380 nm–1100 nm) at these sites varied from 360 μW cm^{-2} in the darkest part of the wood, to 2700 μW cm^{-2} at the edge of the clearing. *Fig. 1* (A-E) shows transmission curves for five of these sites, selected on the basis of a fairly constant increase in total radiation of

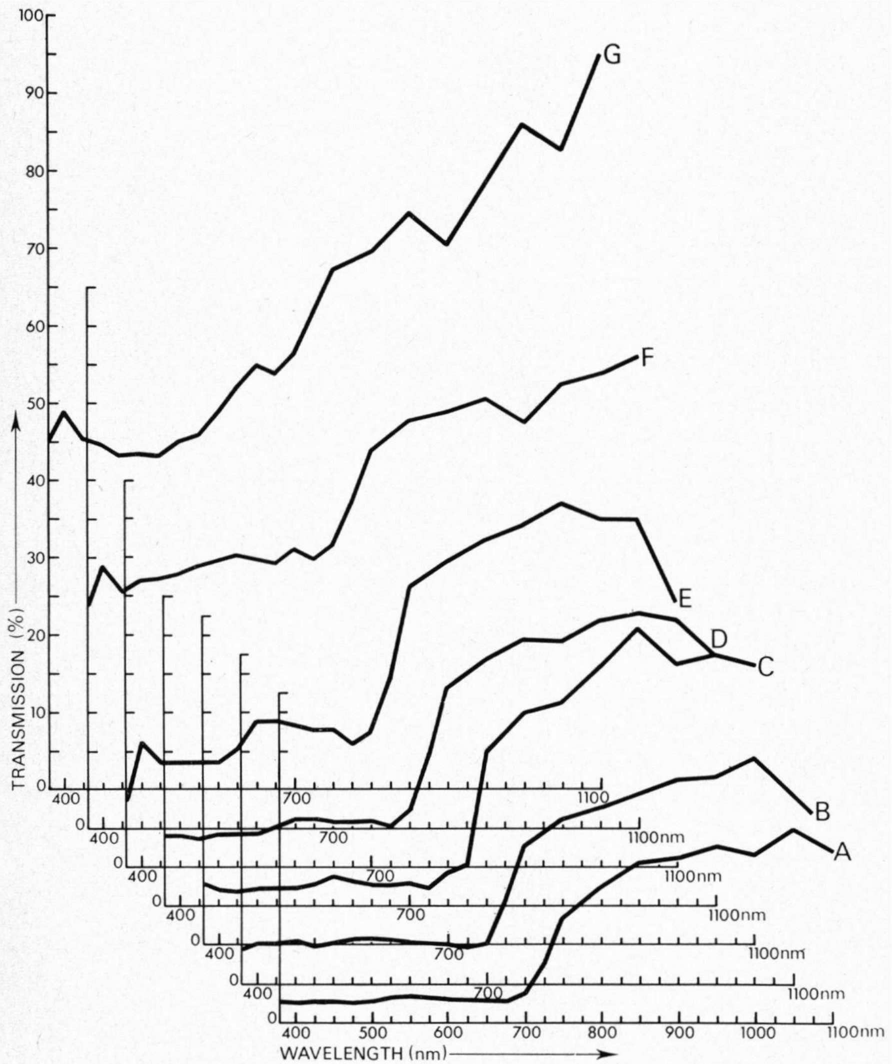

Fig. 1. Transmission curves for seven representative sites.

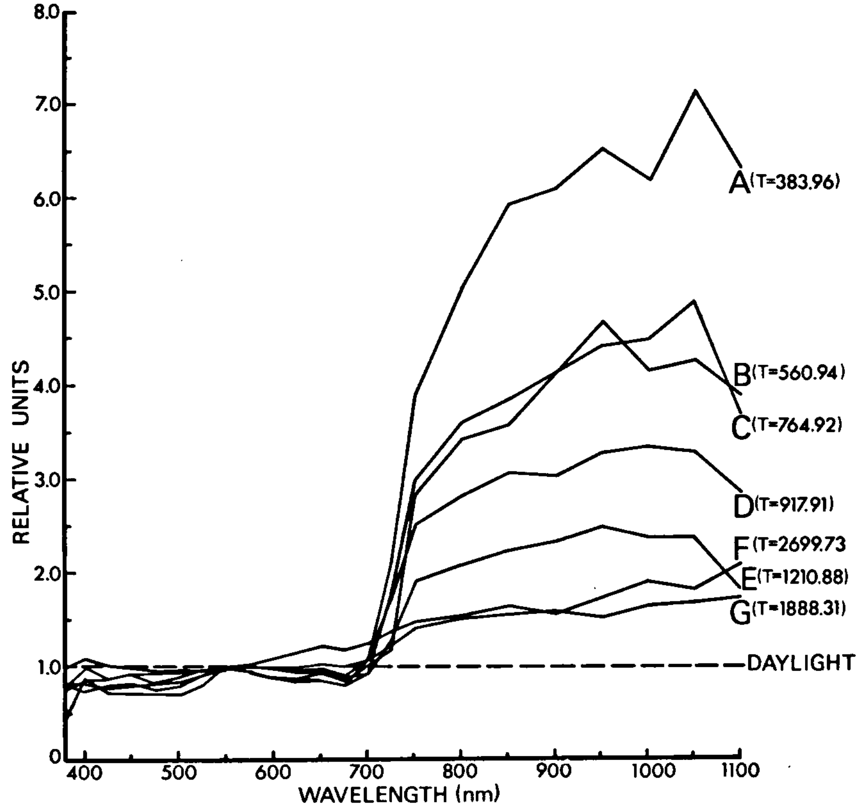

Fig. 2. Transmission curves with transmissivities expressed as a percentage of outside light and standardised to 1.0 at 550 nm. T = total light intensity (visible plus near infra-red radiation) in $\mu W/cm^{-2}$.

approximately 200 $\mu W\ cm^{-2}$, and are typical of the remaining transmission curves. *Fig. 1* (F and G) shows curves for two sites with high total intensity. *Fig. 2* shows these seven transmission curves standardized to 1.0 at 550 nm in order show graphically any difference in the relative transmissivities between sites.

5. DISCUSSION

It can be seen from *fig. 1* (A-G) that at all sites the transmission beyond 700 nm is proportionately greater than for the shorter wavelengths. Also shown are the weak maximum at 550 nm and slight minima at 675 nm and, less noticeably, at 475 nm, corresponding approximately to the principal absorption bands of chlorophyll. Stoutjesdijk's spectral transmission curves are thus confirmed, although quantitatively the transmissions obtained for each wavelength are much higher than those found in a temperate beechwood at Oostvoorne, where values as low as 0% were encountered. Further evidence is thus offered of the spectrally selective action of a deciduous canopy in filtering incoming radiation from 380 nm–1100 nm.

When the transmission curves are standardized (*fig. 2*), the geometrical differences in the transmission curves are apparent. If the total light intensities (T in *fig. 2*) are considered, there appears to be a progressive "flattening" of the curves as the brighter sites are approached – the transmission in each wavelength is becoming more constant as the sites approximate more closely to daylight. (This is represented in *fig. 2*, in relative units, as a straight line with an intercept of 1.0). Proportionately, the greatest amounts of infra-red radiation are found at the darkest sites and therefore, as total radiation decreases, so the relative amount of infra-red radiation increases.

This may be explained as follows: at the darker sites, where total light intensity is low, a dense leaf canopy is implied. Here selective filtering of incoming radiation by the tree canopy will be at a maximum and radiation in the physiologically useful wavelengths will have been absorbed most strongly by a large number of leaves. Remaining wavebands such as green (550 nm), far red and near infra-red will therefore be transmitted and reflected to a greater degree than at brighter sites where the leaf canopy is less dense. The relative amount of radiation in a given wavelength will thus vary according to the thickness of the leaf canopy above. This has previously been hypothesised and indeed becomes obvious when it is realised that deciduous leaves will selectively filter incoming radiation. Atkins, Poole and Stanbury made measurements at different sites within the same wood, but only from 425 nm–700 nm and, of necessity, with somewhat insensitive instruments; Coombe considered only two sites in a *Castanea* wood and measured light from 365 nm–730 nm. There appears to have been no previous empirical evidence offered for the differences in spectral composition with varying degrees of shade in deciduous woodlands beyond 730 nm.

6. CONCLUSIONS

It has often been predicted that the altered spectral composition of light within a woodland may influence various plant physiological processes. In particular, the increased percentage of far red and near infra-red light could cause inhibition of seed germination (STOUTJESDIJK 1972a), elongation of stems (VAN DER VEEN & MEIJER 1962) and influence initiation of flowering. However, the effects cannot be predicted until both the understorey light climate itself, and the plant responses to various wavelengths have been determinded in some detail. The methods selected here for the measurement of radiation, therefore, need to be extended to take into account daily and seasonal light variation in a complex situation. Later papers will examine variation in transmissivities under these various conditions in more detail and the way in which these are related to the growth of enchanter's nightshade (*Circaea lutetiana* L.).

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