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Insolation in monsoonal wet tropics and transmission/reflection coefficients of leaves of some plantation crops

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सार — केरल के मानसूनी नम कटिबन्धीय क्षेत्रों के कोट्टाम्परम्ब 11° 15′ उत्तर तथा 75° 52′ पूर्व तथा माध्य समुद्र तल से 80 मी० ऊपर में जिन दिनों उच्च आर्द्रता उपलब्ध होती है उस अवधि में सूर्यातपन (0.15 से 3.0 μ मी०) 120 से 150 तक 500 डब्लू मी०$^{-2}$ से 60 डब्लू मी०$^{-2}$ तक कम हो जाता है। इसका कारण है कि मानसून के दिनों में आकाश मेघाच्छादित होता है। तदानुसार, निकटवर्ती अवरक्त विकिरण (0.71–4.0 μ मी०) 220 डब्लू मी०$^{-2}$ से 35 डब्लू मी०$^{-2}$ तक कम हो जाता है तथा प्रकाश संश्लेषी प्रदीप्ति (0.36–0.75 μ मी०) 45 से 8 क्लक्स तक कम हो जाती है। कोट्टांपरम्ब में विकिरण ऊर्जा के वितरण तथा आर्द्रता उपलब्धी के अध्ययन से पता चलता है कि लम्बे समय तक इनमें से एक भी उपस्थित रहे तो इस क्षेत्र में प्रकाश-संश्लेषण तथा वनस्पति के जीवभार के उत्पादन में बाधा आती है।

इस लेख में नौ रोपी फसलों के पत्तों से उपलब्ध प्रसारित/प्रतिक्षेपित विकिरण ऊर्जा की प्रतिशतता का भी विश्लेषण किया गया है तथा उसकी रिपोर्ट दी गई है।

ABSTRACT. During the periods of high moisture availability in the monsoonal wet tropical area of Kerala at Kottamparamba (11° 15′ N; 75°52′E and 80 m above m s l) the insolation (0.15-3.0 μm) gets reduced from 500 Wm^{-2} to 60 Wm^{-2} for period of 120-150 days due to cloudy conditions during monsoon season. Correspondingly, the near infrared radiation (0.71-4.0 μm) gets reduced from 220 to 35 Wm^{-2}, the photosynthetic irradiance (0.38-0.41 μm) from 35 to 5 Wm^{-2} and illumination (0.36-0.75 μm) from 45 to 8 klux. The study on the distribution of radiant energy and moisture availability at Kottamparamba reveals that the availability of any one of these is a constraint for prolonged periods for photosynthesis and biomass production of vegetation in the region.

The percentage of available radiant energy that can be reflected and transmitted from the leaves of nine plantation crops have also been analysed and reported.

1. Introduction

The southwest and northeast monsoons cause intensive cloud development in the humid tropical Kerala (8°18′ to 12° 48′ N and 74° 52′ to 77° 22′E) during June to November. The reduction in the radiation due to cloudy weather will have profound influence on photosynthesis and biomass production of crops of the region.

The radiant energy incident on leaf surfaces will be disposed through transmission, reflection and absorption. Reflection, transmission and absorption coefficients of leaves will vary due to differences in leaf structure and age, adaptation, diseases etc (Brandt and Tageyeva 1967; Gates *et al.* 1965; Birkebak & Birkebak 1964). The pigments in the leaf absorbs the blue (0.40-0.51 μm) and red (0.61-0.70 μm) bands of the visible spectrum with a relative peak of reflection and transmission between 5.0 and 5.5 μm (Montieth 1965). Such optical properties of tree leaves find their use in remote sensing for identification of vegetation and its disorders, estimating the amount of biomass yields in agricultural and forestry etc (Ross 1975).

The solar radiation and moisture availability in a wet monsoonal tropical area from the analysis of short wave, photosynthetic, near infrared and illumination components of radiation, rainfall and estimated soil moisture at Kottamparamba (11°15′ N; 75°52′ E and 80 m above msl) are reported in this paper. In addition, the reflection and transmission coefficients for the leaves of banana (*Musa paradisiaca*), cashew (*Anacardium occidentale*), cassava (*Manihot esculenta*), cinnamon (*cinnamomum zeylanicum*), coconut (*cocos nucifera Linn.*), jack (*Artocarous integrifolia*), pepper (*piper nigrum*), pineapple (*Ananas comosus*) and mango (*Mangifera indica*) have also been presented.

2. Methodology

The insolation at short-wave (SW 0.15 - 3.0 μ m), near infrared (NIR 0.71-4.0 μm), photosynthetic (PAR 0.38-0.71 μm) and illumination (IL 0.36-0.75 μm) bands of radiation were monitored from March 1982 to February 1983 in the monsoonal wet tropical Kerala at Kottamparamba (11° 15′ N; 75° 52′ E and 80 m a. m.s.l.) using LI-200 SB, LI-220 SB, LI-190 SEB and LI 210 SB quantum sensors.

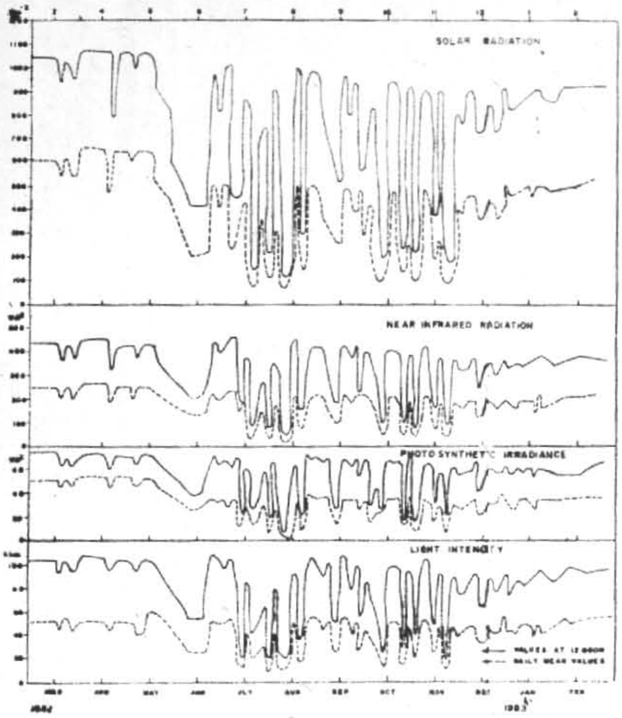

Fig. 1. Insolation in monsoonal wet tropics at Kottamparamba

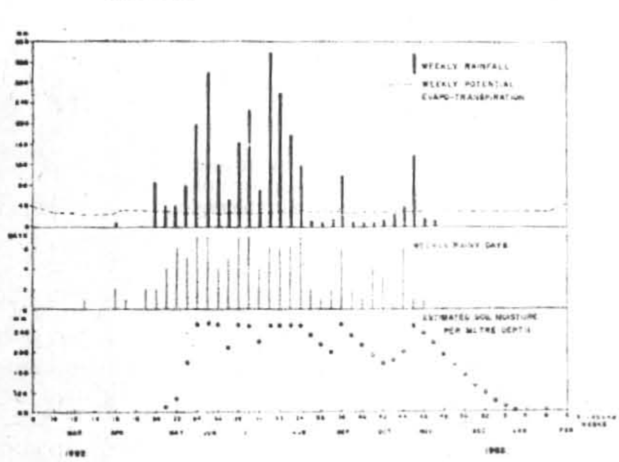

Fig. 2. Water balance in monsoonal wet tropics at Kottamparamba

Solar radiation received during the periods of high soil moisture availability is effective for vegetation development. Hence, the estimates for soil moisture values during the period were obtained according to the procedure given by Thornthwaite and Mather (1957). The potential evapotranspiration values were computed with a modified Penman's formula (Rao *et al.* 1971). The daily soil moisture observations taken in the area for laterite soil during the dry periods of summer 1981 show that the soil moisture never depletes below 80-100 mm per metre depth whereas the estimated soil moisture storage from Thronthwaite and Mather (1957) is less than 5 mm per metre depth of the corresponding period. The lower estimates of soil moisture were corrected assuming that the soil moisture will not deplete below 80 mm per metre depth.

The transmitted and reflected radiation from horizontally exposed leaves of banana, cashew, cassava, cinnamon, coconut, jack, pepper, pineapple and mango were monitored during the period. The observations were taken from 10 a.m. to 4 p.m. to study the effect of solar elevation on transmission and reflection from the leaves. Since, the spectral properties of leaves changes during the growing season (Brandt and Tageyeva 1967), the tree leaves were taken for observation from established plants and which were grown under proper environmental conditions. The study was confined to a dry period and for rainfed crops excepting banana and pepper which were irrigated with a frequency of once in two days. The soil moisture content and the leaf moisture content (gm/cm^2) during the period of observation were monitored and reported.

3. Results and discussion

3.1. *Insolation in different periods*

The SW, NIR, PAR, and IL components of solar radiation at noon (IST) and the daily mean values recorded at Kottamparamba are shown in Fig. 1. The observations could be summarized as follows :

3.2. *Total solar radiation (SW)*

The daily solar radiation (SW) was varying from 60 Wm^{-2} in July on a cloudy day to 650 Wm^{-2} in March on a cloud-free day. The values for the corresponding periods at noon were 120 Wm^{-2} and 1030 Wm^{-2}. The lower values under observation were confined to the rainy days. There were only 121 rainy days during the period of observation, but normally the area will have rainfal for about 150 days during May to November. Such prolonged reduction in the radiation due to monsoon clouds especially in the wet periods and high variations in the insolation may cause deleterious effects on physiology of crop plants of the region and also influence their rate of photosynthesis and biomass production of vegetation.

3.3. *Near infrared radiation (NIR)*

The daily NIR received in a year was between 15 and 265 Wm^{-2} whereas the values at noon were between 35 and 460 Wm^{-2}. The NIR values were quantitatively varying according to the solar radiation. When the rain occurred for a number of consecutive days NIR values were very low. Such low values of NIR which normally prevail for 120-150 days in the area during June to November can retard the metaphorgenic activity of vegetation.

3.4. *Photosynthetic irradiance (PAR)*

The PAR will influence thermal, photosynthetic and photomorphogenetic activity of plant life (Ross 1975). The mean daily PAR component of solar radiation was between 5 and 40 Wm^{-2} and at noon (IST), the values were between 5 and 75 Wm^{-2}. The PAR was also varying according to the variation in the insolation. Hence, high PAR values were confined to 5-6 months in the dry period while PAR values were low during wet period.

TABLE 1

Mean transmission and reflection coefficients of some leaves of plantation crops

Crop	Leaf moisture content (gm/cm^2)	Short wave		Near infrared		Photosynthetic-irradiance		Illumination	
		Trans-mission	Reflec-tion	Trans-mission	Reflec-tion	Trans-mission	Reflec-tion	Trans-mission	Reflection
Banana	0.0198	0.33 (0.29–0.37)	0.33 (0.25–0.44)	0.50 (0.45–0.53)	0.53 (0.43–0.68)	0.05 (0.02–0.07)	0.08 (0.05–0.14)	0.08 (0.06–0.11)	0.11 (0.09–0.14)
Cashew	0.0116	0.35 (0.31–0.41)	0.33 (0.27–0.39)	0.48 (0.41–0.58)	0.50 (0.41–0.58)	0.04 (0.02–0.05)	0.08 (0.05–0.11)	0.07 (0.05–0.08)	0.11 (0.08–0.14)
Cassava	0.0067	0.39 (0.37–0.42)	0.26 (0.22–0.34)	0.57 (0.48–0.64)	0.33 (0.29–0.43)	0.07 (0.06–0.09)	0.06 (0.04–0.08)	0.12 (0.11–0.13)	0.06 (0.06–0.09)
Cinnamon	0.0132	0.30 (0.27–0.34)	0.30 (0.25–0.36)	0.48 (0.44–0.52)	0.41 (0.34–0.50)	0.04 (0.02–0.05)	0.05 (0.04–0.06)	0.06 (0.03–0.07)	0.07 (0.05–0.08)
Coconut	0.0215	0.28 (0.25–0.30)	0.22 (0.18–0.27)	0.43 (0.37–0.48)	0.32 (0.26–0.40)	0.02 (0.01–0.02)	0.07 (0.05–0.10)	0.03 (0.02–0.03)	0.08 (0.05–0.10)
Jack	0.0141	0.27 (0.24–0.33)	0.35 (0.28–0.42)	0.43 (0.33–0.47)	0.46 (0.33–0.69)	0.02 (0.01–0.03)	0.08 (0.04–0.10)	0.03 (0.02–0.05)	0.80 (0.03–0.12)
Mango	0.0104	0.33 (0.30–0.38)	0.31 (0.29–0.39)	0.52 (0.43–0.54)	0.46 (0.36–0.57)	0.05 (0.04–0.06)	0.08 (0.06–0.14)	0.08 (0.07–0.09)	0.10 (0.09–0.17)
Pepper	0.0214	0.36 (0.33–0.39)	0.29 (0.20–0.35)	0.51 (0.45–0.57)	0.38 (0.29–0.46)	0.05 (0.04–0.06)	0.07 (0.06–0.10)	0.08 0.05–0.10)	0.08 (0.06–0.10)
Pineapple	0.0867	0.23 (0.21–0.25)	0.29 (0.23–0.40)	0.37 (0.32–0.40)	0.44 (0.42–0.53)	0.02 (0.01–0.02)	0.07 (0.04–0.09)	0.03 (0.02–0.03)	0.07 (0.06–0.10)

Figures in parenthesis refer to possible range of coefficients

3.5. *Illumination*

The daily mean illumination at the observational area was between 8 and 52 klux and at noon (IST) the values were between 16 and 107 klux.

The information on light and CO_2 assimilation rates for all plantation crops is not available. Brun (1961) has reported that the photosynthetic activity of banana leaves increases rapidly at illuminations between 2 and 10 klux and more slowly between 10 and 30 klux. The stomatal opening and net assimilation in coffee increases with light intensity upto 20 klux and sharply decreases at 60 and 90 klux (Alvini 1968). Crews *et al.* (1975) showed that both light and dark CO_2 assimilation by pineapple increases with light intensity to 80.7 klux. De Wit (1965) has reported that there could be 50 per cent of reduction in potential photosynthesis when the light intensity gets reduced to only 20 per cent of the intensities on clear days in the tropical areas at 10° N.

If the above limits of illumination for maximum photosynthesis are examined with the distribution of light energy, it can be concluded that the availability of light energy is a major constraint for maximum photosynthesis in some plantation crops during monsoon period of the region.

4. Rainfall and moisture availability

During the period of observation, Kottamparamba received 2690 mm of rainfall in 121 days compared to normal rainfall of nearly 3,800 mm distributed in about 150 days. The observations were taken during the year with lowest rainfall from 1950 to 1982. Otherwise, low insolation for larger number of days might prevail in this area. The rainfall, number of rainly days and the estimated soil moisture *per metre depth* are also given in Fig. 2. The soils are laterites with available water capacity (AWC) between 25 and 10 per cent. The analysis shows that the soil moisture was low during the periods of high insolation and *vice versa.*

5. Transmission and reflection coefficients

The mean and possible range of transmission and reflection coefficients at SW, NIR, PAR and illumination bands of radiation for leaves of nine crops considered are presented in Table 1.

The reflection was maximum from jack and banana leaves whereas the transmission was maximum from cassava leaves.

The reflection from the leaves was lower than the transmission at SW and NIR bands of radiation, whereas it was higher than the transmission at PAR and illuminated bands of radiation.

The mean transmission coefficients at SW and NIR for the leaves were between 0.23 and 0.57 whereas at PAR and photometric wavelengths the values were between 0.02 and 0.12. The reflection coefficients for the leaves at SW and NIR bands of radiation were between 0.22 and 0.53 whereas the values at PAR and photometric wavelengths were between 0.05 and 0.11. This shows that the maximum absorption of radiation upto 93-97 per cent was in the light and **PAR** bands of radiation for these leaves.

The transmission was minimum from the pineapple leaves due to its thick structure and high moisture content. The large peltate scutiform trichomes covered on both upper and lower leaf surfaces of pineapple increases the reflectance from the leaf and thus reduces the heat load in an intensive radiation environment (Krauss 1949).

The reflection coefficients of the leaves at shortwave and NIR were increasing with the decrease in insolation and solar elevation.

The optical properties of the leaves obtained above can be utilized to prepare radiation models for crop canopies and thereby to plan the main and inter crops for maximum utilization of insolation in the region

6. Summary and conclusions

The climate of the humid tropical Kerala is characterized with low insolation for prolonged periods due to the prevailing clouds in the season (June-November). The insolation and the soil moisture availability in different periods at Kottamparamba in the region are studied. The solar radiation gets reduced upto 90 per cent of its mean daily values of about 500 Wm^{-2} on cloudy days which prevail for 120-150 days. Such variations are also observed in photosynthetic, infrared and illumination components of radiation. The available light intensity in the monsoon periods of the area is below the requirement for maximum photosynthesis of certain plantation crops. In addition to that, the limited soil moisture available in the remaining dry periods put together will considerably retard the potential photosynthesis and biomass production of crops of the region.

The transmittance and reflectance coefficients for leaves of selected plantation crops are with an order of 1 to 10 per cent at photosynthetic and illumination bands of radiation and the values are between 20 and 60 per cent at shortwave and infrared radiation.

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