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Radiation, Productivity Potential and Actual Biological Yield at Delhi

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Quantitative estimation of total solar radiation and photosynthetically active radiation helps in predicting the productivity potential of different crops and their water requirement.

Total radiation, photosynthetically active radiation values, maximum and minimum temperatures for the year 1976-77 were recorded at Delhi. Total radiation and photosynthetically active radiation values were low in *kharif* season as compared to *rabi* season. The maximum value for the ratio of photosynthetically active radiation and total radiation was observed to be in the months of July and August which suggests that cloudiness and overcast sky do not interfere with photosynthetically active radiation transmission. The total radiation received during *rabi* season was more than *kharif* by about 8% due to longer duration of crop season in *rabi*. During the same period, photosynthetically active radiation was 59.9% and 48.2% respectively of the total radiation. The conversion efficiency of total radiation in maize is better than wheat but if one takes photosynthetically active radiation into consideration there was hardly any difference.

Key Words: Photosynthetic active radiation (PAR), Total radiation, Biological yield, Radiation conversion efficiency

Introduction

The influx of radiations at any given place is a major factor determining evapotranspiration and dry matter production potential. An assessment of total radiation and photosynthetically active radiation (PAR) can help in predicting the water requirements and productivity potential of different crops. A comparison of yields actually obtained can then be utilized in analysing factors which need to be given more attention.

In India mostly data on bright sunshine are available for the different parts of the country. These data, however, do not reflect the available radiations. More recently, Ganesan (1978) has published data of total radiations in different parts of the country, but there is almost no information on the availability of photosynthetically active radiation (PAR).

Delhi is situated at 28° 35'N and in this state two or more crops are cultivated when irrigation is available. Only one crop is usually taken in unirrigated land. Therefore, an effort was made to determine the total radiation and photosynthetically active radiation and to work out the radiation conversion efficiency of different crops in two seasons, the *rabi* and the *kharif*.

Materials and Methods

A photometer with three different sensors was used (Lamda Co., Lincoln, Nebraska, USA) for determining total radiation, photosynthetically active radiation and light intensity in lux. Observations were recorded at 8.00, 10.00, 12.00, 14.00 and 16.00 hr throughout the year. The total day length was used for computing radiations for the whole day.

The yield of two crops in *kharif* and two in *rabi* was taken as the maximum biological yield observed or reported. With appropriate conversion factors this can be converted into energy units and then the energy conversion efficiency can be worked out (Sinha & Aggarwal 1980).

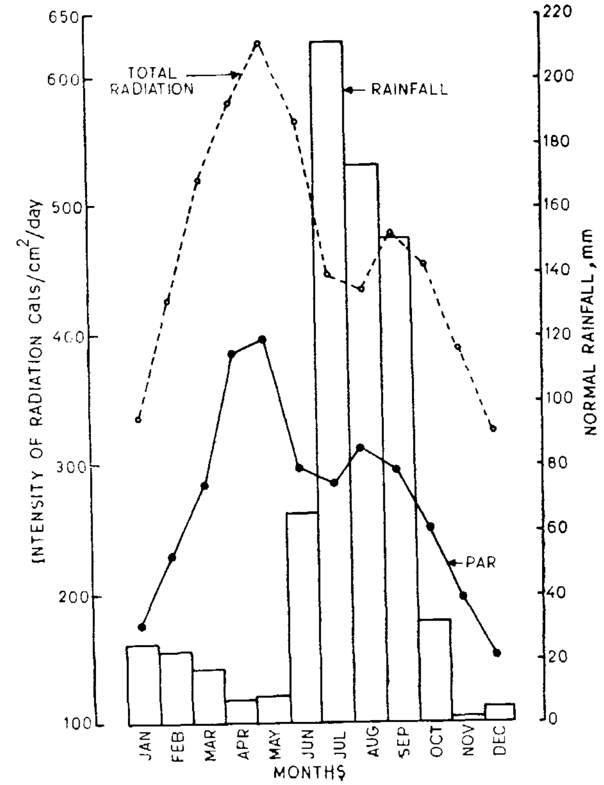

Figure 1 Normal rainfall, total radiation and PAR in different months

Result and Discussion

The total radiation varied from a lowest value of 323 cal. cm^{-2} day^{-1} to a maximum of 627 cal. cm^{-2} day^{-1} in the months of December and May respectively (figure 1). During the *kharif* or monsoon season the total radiation varied between 432 to 474 cal. cm^{-2} day^{-1}. However, in the *rabi* or winter season the range was from 323 to 518 cal. cm^{-2} day^{-1}. It was clear that the period when *kharif* or monsoon crop has the grain development period there is decline in total radiations as compared to the time of sowing and vegetative growth. As against this, when grain development occurred in winter the total radiation was at least 50% more than obtained at the time of seedling and vegetative growth.

The photosynthetically active radiations also varied from 163.4 cal. cm^{-2} day^{-1} in December to a maximum of 395·6 cal. cm^{-2} day^{-1} in May. Again like total radiation, PAR was high during seedling and vegetative stage but reduced during grain filling stage in *kharif*. The reverse was the case for the *rabi* crop.

An interesting feature of the total radiation and PAR was that their ratio changed from month to month (figure 2). The maximum PAR to total radiation ratio was observed in months of July and August, the period when the sky is overcast with clouds. Thus it would appear that clouds do not interfere with the transmission of photosynthetically active radiations as compared to the remaining part of the spectrum.

Both the total and photosynthetically active radiations were determined at different times of the day. It was observed that total radiation was always more in *rabi* than *kharif* (figure 3). However, it was because of the longer day length in *kharif* that the total radiations per day became more during this period. The photosynthetically active radiations did not differ except in the early hours during the *kharif* and *rabi* seasons. Again, it was because of longer day length that PAR per day was more in *kharif*. However, when data were computed for the entire cropping season, it was found that total radiation received during the *rabi* was more than *kharif* by about 8% due to longer duration of the crop season being about 150 days as against 120 days in *kharif*. The total radiation received during the *rabi* and *kharif* were 60.3×10^{11} cal. ha^{-1} and 55.4×10^{11} cal. ha^{-1} respectively. As against this, PAR was 31.6×10^{11} cal. ha^{-1} and 35.1×10^{11} cal. ha^{-1} during *rabi* and *kharif* respectively. This was due to the fact that during the *kharif* and *rabi* PAR was 59.9% and 48.2% respectively of the total radiation (table 1).

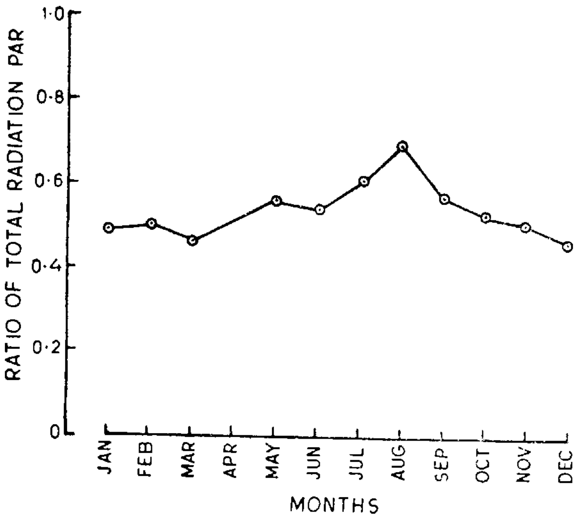

Figure 2 Total Radiation to PAR ratio in different months

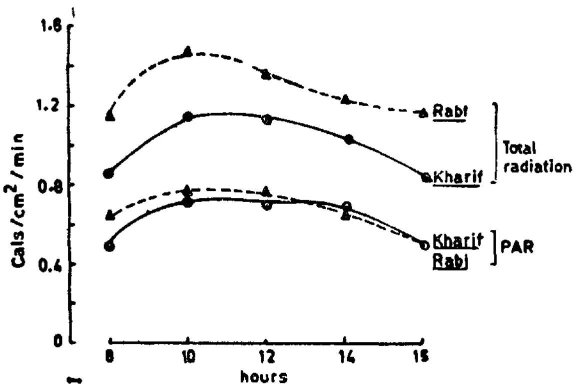

Figure 3 Radiation at different times of the day during *kharif* and *rabi*

Table 1 *Total and photosynthetically active radiations during* Kharif *and* Rabi *1977-78*

	Kharif	Rabi
Total radiation		
cal. cm^{-2} day^{-1}	450.7	399.6
cal. cm^{-2} day^{-1}	285.7	209.4
Total Radiation		
cal. cm^{-2} (season) 10^{11}	55.4	60 3
PAR		
cal. cm^{-2} (season) 10^{11}	35.1	31.6
% PAR	59.9	48.2

Biological Yield of Crops

The maximum biological yield of 2 crops each in two crop seasons are given in table 2. It was interesting to observe that both the cereals like maize and wheat have yielded about 20 tonnes ha^{-1} dry matter as against a maximum of 12 tonnes in two grain legumes grown in two seasons. Thus under identical and adaptable conditions, cereals produce more phytomass than legumes. Therefore, limitation in biomass production or photosynthesis could be one of the major factors limiting the yield of grain legumes as emphasized earlier (Sinha 1974, 1977). Considering the conversion efficiency of total radiations, maize was better than wheat, but in respect of PAR there was no difference between wheat and maize (table 2). If at all, the former was slightly superior than the latter. This was rather surprising because maize is a C_4 plant and is known to be photosynthetically more efficient than wheat.

Table 2 *Biological yield and radiation conversion efficiency of different crops in* Kharif *and* Rabi *at Delhi*

Season, crop and variety	Dry matter kg ha^{-1}	Estimated energy converted cal. x 10^9	% total radiation	% of PAR
KHARIF				
Maize				
Ganga 5	19119	63	1.13	1.79
Expt Hyb 2420	22473	74	1.33	2.10
Expt Hyb 2310	17640	58	1.04	1.65
Pigeon pea				
Pusa Agati	10220	42	0.75	1.19
P_1–31	12107	50	0.90	1.42
P_4–54	10773	44	0.79	1.25
RABI				
Wheat				
C 306	20070	61	1.01	1.93
MG–197–8	20250	67	1.11	2.12
MG 191–24–1	19100	63	1.04	1.99
Chick pea				
Pusa 53	9972	41	0.68	1.29
C 235	12166	50	0.83	1.58
Sel. 589-1	9224	38	0.63	1.20

(based on Jain et al. 1976)

Discussion

Some of the main points which emerge from this study are :

1. The maximal radiations received per day are in the months of April, May and June when the water availability is lowest. Therefore, the high insolation is of not much use for agricultural productivity.
2. The total radiations and PAR do not maintain the same proportion. The % PAR is more in months of July, August and September when the sky is overcast with clouds. Thus it appears that the cloudy weather reduces total radiations but does not reduce PAR to the same extent. Therefore, some of the effects during the *kharif* ascribed to low photosynthesis, as in rice, because of low light intensity need to be reevaluated.
3. Although the total radiation and PAR in *kharif* and *rabi* differed only by about 8% but there was no significant difference between the productivity of maize and wheat. There are possibly two reasons for this.

   (a) The total radiation and PAR are near maximum when the crop is sown in *kharif* and there is decrease in radiations when the reproductive phase starts. Therefore, the interception is low when radiations are high whereas at the later stage when crop canopy is fully developed and interception is almost 100%, the radiations are reduced. In the case of *rabi* crops it is a reverse process. The crop germinates and develops canopy when radiations are low whereas full interception and high radiations coincide in the months of February and March.

(b) The night temperatures are usually above 25°C during the *kharif* whereas during the *rabi* night temperature range between 5° to 15°C (figure 4 and figure 5). Therefore, the respiratory losses are likely to be relatively much higher in *kharif* than *rabi* and accordingly, the yields would be affected. Selection for low respiration rate may prove useful in *kharif* crops.

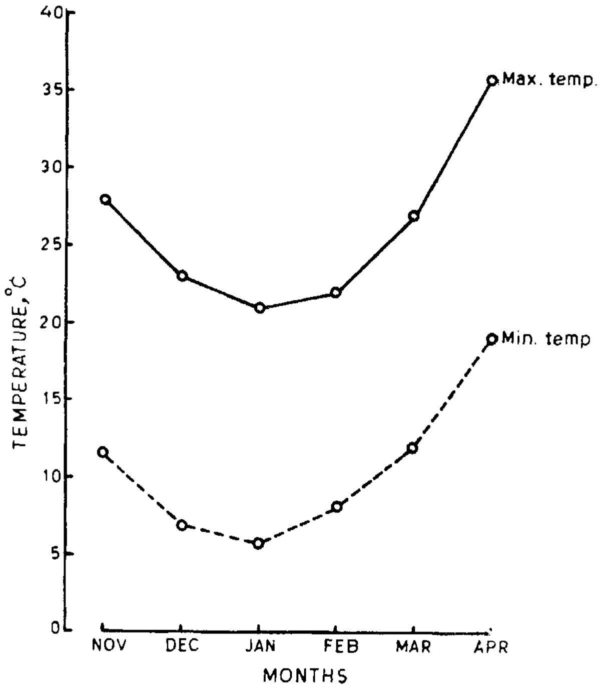

Figure 5 Temperature during *rabi*, 1976

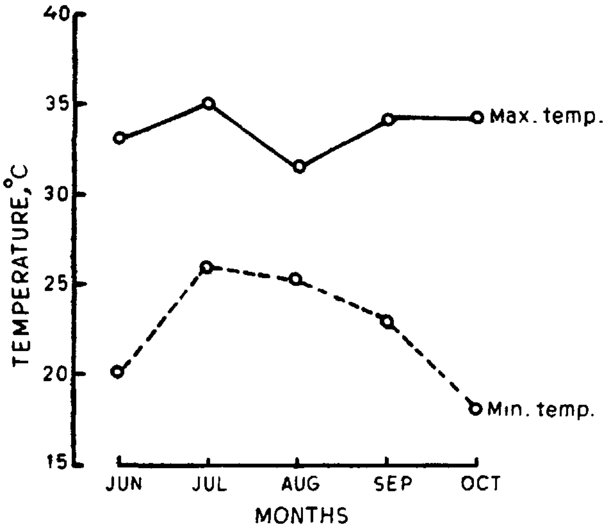

Figure 4 Temperature during *kharif*, 1976

From the above discussion it is clear that an analysis of various physical factors can be of considerable importance in recognising constraints in the productivity of crops.

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