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THE RADIATION ENVIRONMENT AND ITS RELATIONSHIP TO PHOTOSYNTHESIS AND CROP PRODUCTION IN SUNFLOWER

The interception of radiation and its relationship to both the total amount and the display of leaf area is crucial to our understanding of yield in crop plants because in dry climates the correct balance between photosynthesis and water use is often an important factor in obtaining economic yields.

We used Monteith's model (1965) which took account of the leaf angle and azimuthal direction using an interception parameters S which is the proportion of radiation which is not intercepted by a leaf layer of unit LAI. The value of S approaches zero for crops with predominantly horizontal leaves and 1.0 for crops with predominantly vertical leaves.

The aim of this study was to measure both the value of S and the reflection coefficient of a sunflower crop in an attempt to specify the radiation environment of the crop. Photosynthetic rates were also measured throughout the growth of the crop so that the radiation environment could be related to the potential productivity of the sunflower crop.

Sunflower crops were sown at Armidale, N.S.W. (30^{o}S, 152^{o}E) in January 1974 and November 1974. The row width was 60 cm and the populations 74 000 plants/ha for trial one and 40 000 plants/ha for trial two.

Linear solarimeters used were of similar design to those of Szeicz et al. (5), but were 120 cm long to cover two rows. Two types were used, one to measure total short-wave radiation (0.4-3.0 mμ) and the other with a Wratten 88A gelatin filter to measure the infrared (0.7-3.0 mμ). The amount of photosynthetically active radiation (0.4-0.7 mµ) was obtained by difference. They were placed in the crops soon after establishment with one pair of solarimeters at ground level and another pair 30 cm above the ground. Additional pairs of solarimeters were added at 30 cm intervals as the crops grew so that the upper pair of solarimeters was always above the top of the crop. The outputs of these solarimeters were measured manually on one or more occasions each day during trial one but at 20 minute intervals throughout the growth of the crop during trial two.

Photosynthetically active radiation was used to calculate S by regression as described by Biscoe et al. In the early stages of growth meaningful values could not be obtained but thereafter all values for which the correlation coefficient was significant were used.

Measurement of incoming and reflected shortwave radiation (0.4-3.0 mµ) were made using two dome solarimeters, of a design similar to that of Szeicz. One of these solarimeters was placed in an inverted position two metres above the crop. This measured the reflected radiation as a percentage of the incoming radiation and hence gave the reflection coefficient. These solarimeters were read at the same intervals as the linear solarimeters but for trial two the mean of the values of the reflection coefficient at 1100, 1120 and 1140 hours was used.

Measurements of photosynthesis were made by passing a 20 s pulse of $^{14}CO_2$ labelled air of known specific activity and CO_2 content over a fixed area of the leaf as described by McWilliam et al. (1973). Comparison of this technique with an infra-red gas analyser indicated that it measured total photosynthesis and overestimated net photosynthesis by 23%

Growth analyses, using the stratified clip technique, were carried out during both trials at weekly intervals. The crop was analysed in 30 cm layers in order that the LAI could be obtained for the calculation of S in the light interception equation.

The pattern of light interception parameter, S, measured over the duration of the crops was similar for both trials. In both trials the value of S, 45 days after sowing, was approximately 0.15. This corresponds to, or was slightly prior to, the buds visible stage of the phenological development. The value of S then increased slowly to maxima of 0.32 in trial one and 0.30 in trial two which were attained shortly after anthesis. During the later stages of seed filling there was a decline in S. This occurred sooner in trial two because it was sown earlier in the summer and phenological development was more rapid. These results indicate that the inclination of leaves of a sunflower crop change with the development of the crop. The S value of 0.15 indicates that only 15% of the radiation is passing through a layer of leaves of unit LAI. The leaves changed to a more vertical position as the crop developed. The value of S obtained in these studies was slightly lower than the value of 0.38 calculated indirectly by Monteith (1969) from the data of Hiroi and Monsi (1966). However both are considerably lower than the values obtained for most other crops with the exception of cotton and clover. This indicates that leaves at the top of the canopy are light saturated for photosynthesis whereas those at the bottom may be approaching the light compensation point. As the value of S increases, radiation is distributed more evenly over the leaf area of the plant.

The reflection coefficient of the bare soil surface was between 5 and 10% in both trials. This increased as the crop developed to a maximum of 26% in trial one and 20% in trial two. For both trials the regression of reflection coefficient on LAI was very highly significant ($p < 0.001$). This is in agreement with the findings of Blad and Baker (1972) who found they could use the reflection coefficient to predict the percentage canopy cover knowing the initial value and the rate of increase. In this case the rate of increase of the reflection coefficient with LAI was different for the two crops. The higher maximum reflection coefficient of trial one was due to the LAI which attained a maximum in trial one almost double that in trial two. The maximum values for the reflection coefficients obtained for sunflower are similar to those obtained for a range of crops.

It has been suggested that if the reflection coefficient of a crop was increased from 25% to 40%, a saving of 30% in water use would be possible. Because a full crop cover reflects more radiation than a bare soil surface, it may be advantageous for the leaves of a crop in a water-limiting situation to be arranged so that they cover the maximum ground area as quickly as possible.

Profiles of photosynthesis are shown in Figure 1 for three separate days of each trial. On the first two occasions in each trial, leaves at the bottom and top of the plant had lower rates of photosynthesis than those in between, but on the final day the leaves at the top of the plant had the highest rate of photosynthesis. On the first two occasions, the leaves at the bottom had already passed maturity and their rate had declined, whereas those at the top of the plant were immature. On the third measurement occasion for each trial the leaves at the top were exhibiting their maximum rate. However the maximum rates of leaf 20 and above are slightly lower than those for leaves 15 to 20. It is this latter group of leaves which are also the largest leaves and are responsible for providing most of the photosynthate during the seed-filling period.

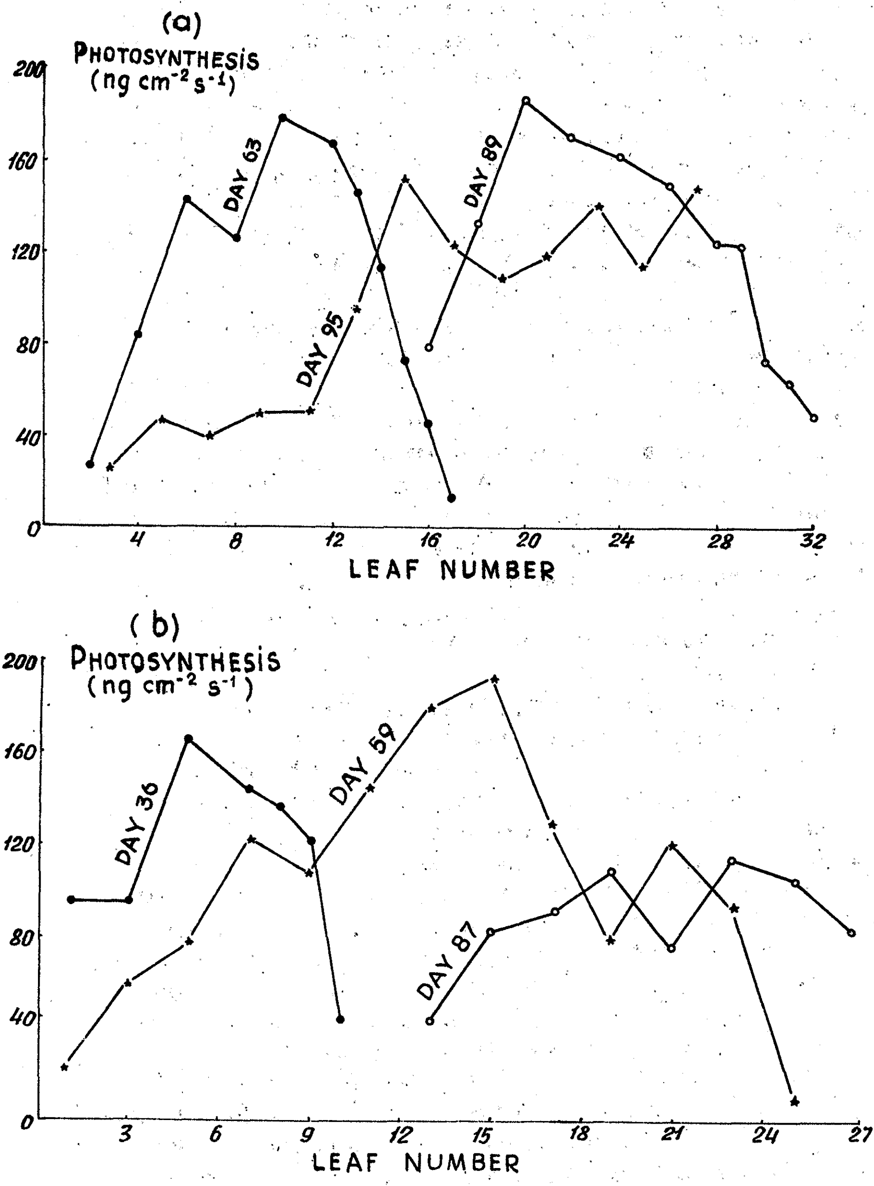

Fig. 1. Profile of photosynthetic rate for three days during (a) trial one and (b) trial two

Thus do save water reserves in the soil it is desirable to increase the reflection coefficient from the initial stages of vegetation on, but the only way this could be achieved without having more leaves would be to make the leaves more horizontal. This would lead to a reduction in the light interception parameter S and hence make the plant less efficient photosynthetically. The ideal would appear to be a canopy with predominantly horizontal leaves in the early stages of growth so that the ground surface is covered quickly with a change to more vertical leaves as the canopy develops. After flowering, the requirement is a larger leaf area displayed with the leaves in a more vertical position so that the available radiation is more evenly distributed over the canopy leading to maximum photosynthesis.

Many of the lower leaves are unimportant during the seed-filling stage and it is the leaves in the upper third of the canopy which contribute most of the photosynthate. Not only do they have a high rate of photosynthesis but they are also much larger than the lower leaves.

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