DISEASE EFFECTS ON RADIATION INTERCEPTION IN BARLEY CROPS

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SUMMARY

The effects of foliar disease on interception of solar radiation by green leaves was measured in four barley crops with different yield targets. Disease reduced green leaf area and crop radiation interception. The total amount of photosynthetically active radiation intercepted by green leaves (PARGL) in these crops, was correlated significantly with grain yield. Grain yield was described using the physiological variable as $Y = -0.179 + 0.024 (\text{PARGL})$. Use of this relationship to estimate losses caused by disease at different sites and in different seasons is discussed. Prediction of yield loss in disease surveys could be improved with a radiation-based correction factor for target yield of the crop.

INTRODUCTION

Relationships between crop yield and disease severity are often based on non-physiological variables (e.g. number of pustules) and are empirical. The total effect of the pathogen on potential host growth is not identified. The non-causal nature of these models does not address the variation in the relationships which occur between individual fields or in different environments (Gaunt 1987). Disease measurements based on a suitable physiological variable may overcome some of the problems of climatic variability. Since growth and yield of a cereal crop are dependent on the interception of solar radiation by green leaves (Waggoner and Berger 1987), measurement of intercepted radiation may be useful for investigations in different sites and seasons.

The objectives of this study were to determine the effects of disease on radiation interception by green leaves, and the relationship of radiation interception to grain yield. This relationship was investigated in four crops representative of different sites and seasons.

METHODS

Spring barley crops (cv. Triumph) were sown on 17 September (early crop) and 3 December (late crop) 1987 at Lincoln, Canterbury. Each crop was managed with different inputs of nitrogen and water, producing crops with high and low yield targets. Ten disease severity levels were produced in randomised plots (21 x 10 m) in each crop with appropriate fungicide applications for leaf rust (*Puccinia hordei* Otth), net blotch (*Drechslera teres* (Sacc) Shoemaker) and scald (*Rhynchosporium secalis* (Oud.) J.J. Davis). Measurements of green leaf area and yield have been described previously (Whelan and Gaunt 1988).

Solar radiation interception by the crop was measured with a tube solarimeter up to 9 times during crop growth at 1 to 2 week intervals. The photosynthetically active radiation (PAR) intercepted by green leaf tissue was calculated as:

$$\text{PARGLA} = [(\text{Solar Radiation} \times 0.5) \times I] \times \text{GLA}$$

where PARGL = photosynthetically active radiation intercepted by green leaves (MJ/m²).

0.5 = fraction of incoming radiation which is used photosynthetically by plants (400 to 700 nm, Gallagher and Biscoe 1978).

I = fraction of incoming radiation intercepted by the total plant area.

GLA = fraction of plant leaf area which is green.

Proc. 42nd N.Z. Weed and Pest Control Conf.

Logistic curves were fitted to radiation interception by the crops and to green area of leaves, using the Maximum Likelihood Programme (Ross *et al* 1979).

RESULTS

Results from the healthy and most fully diseased plots of the high yield target crops only are presented in Figures 1 and 2. Maximum green leaf area (GLA) of the late crop was reduced by 43%, compared to the early crop (Fig. 1). Green tissue was present on leaves in the healthy crops for 107 days in the early crop and 74 days in the late crop. Leaf rust was the dominant disease. First symptoms were observed 41 days (GS 31) and 8 days (GS 12) after crop emergence in the early and late crops respectively. Maximum GLA was decreased by disease by 23% and 47% in the early and late crops respectively (Fig. 1) and senescence of the last leaves occurred 10 days and 2 days earlier on diseased plants from these crops.

Fig. 1: Green leaf area (cm²) of high yield target early and late sown barley crops, with different levels of disease. Vertical bars represent SEM's for green leaf area. Decimal growth stages (Zadoks *et al* 1974) are indicated below the x axis.

Radiation intercepted by all crops increased to a maximum during the season (Fig. 2). Maximum crop radiation interception in the healthy plots was reduced from 82% in the early crop to 58% in the late crop. Disease reduced the amount of intercepted light by 11% and 8% in the early and late sown crops respectively (Fig. 2). Similar results for green leaf development and radiation interception occurred in the low yield target crops.

Disease reduced yield by 57% and 50% in the high and low yield target crops in the early crop (Fig. 3). In the late crop, yield was reduced by 67% and 61% in the high and low yield target crops respectively. The total amount of PARGL accumulated during the season for all plots in the experiment are presented in Fig. 3. There were higher values of accumulated PARGL in the early sowing, compared to the late sowing. In each yield target crop, the healthiest plots had the highest accumulated PARGL and the most diseased crops had the lowest accumulated PARGL. Grain yield was correlated significantly ($P \leq 0.001$) with accumulated PARGL ($R^2 = 0.86$).

Fig. 2: Crop radiation interception (%) in high yield target early and late sown barley crops with different levels of disease.

Fig. 3: Relationship between accumulated photosynthetically active radiation intercepted by green leaves (PARGL) and grain yield (t DM/ha).

DISCUSSION

Grain yield was proportional to the amount of accumulated radiation intercepted by green leaves. Disease reduced accumulated radiation interception by decreasing green leaf area production, inducing premature senescence and reducing the fraction of light intercepted by the crop. These effects have been reported in other infected crops; for example, field beans (Madeira *et al* 1988) and potatoes (Haverkort and Bicomumpaka 1986).

The relationship between grain yield and accumulated PARGL, as affected by disease, was similar in crops with different sowing dates. This suggests that a relationship based on PAR intercepted by green leaf is useful in crops with a range of yield targets associated with different management practices. Investigations in 1988 indicated that the relationship was similar at a different site.

The integration of the physiological variable, green leaf area, and the environmental factor, crop radiation interception, into a single variable, overcomes some of the problems which occur when these factors are studied independently. Inclusion in the variable of a measure of the amount of photosynthetically active radiation intercepted by the crop is needed when crops with similar green leaf development are grown in seasons when radiation is different. A crop receiving a larger amount of incoming radiation will have a greater yield. Measurement of green leaf area is required when two crops have similar radiation interception but one crop has a high disease severity and therefore, reduced green leaf area. A diseased crop with low green leaf area will yield less than a healthy crop in the same season.

Measurement of accumulated PARGL is time consuming because frequent percent GLA and crop radiation interception measurements are required. Accumulated PARGL is suited to detailed physiological studies, where an understanding of the effects of disease on plant growth is needed. Disease yield loss models used in surveys could be improved by inclusion of a factor for radiation received during the season. In a season with low radiation inputs, yield would be less than in a crop with similar amounts of disease but higher radiation receipts.

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