DISEASE MEASUREMENT IN BARLEY CROPS

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SUMMARY

Disease severity, assessed as green leaf area, and near infrared reflectance were measured in two spring barley crops with different yield targets. Reflectance and green leaf area values were similar in all crops at most growth stages, and reflectance correlated with green leaf area in three of the four crops. Yield correlated equally well with area under the reflectance curve and area under the green leaf area index curve. Reflectance measurements could therefore replace time consuming and labour intensive green leaf area measurements, providing a rapid assessment of disease in yield loss studies, fungicide efficacy and cultivar resistance trials.

INTRODUCTION

Investigations of the effect of disease on plant growth and yield have traditionally been pathogen based, with disease measured as incidence or severity. A measure of the total effect of pathogens on potential host growth is required for a better understanding of disease-induced yield losses. Lim and Gaunt (1986) reported that the green leaf area (GLA) of barley was reduced by leaf rust *(Puccinia hordei)* and powdery mildew *(Erysiphe graminis* f. sp. *hordei)*. Yield loss correlated better with GLA than with disease severity. They suggested that GLA was more useful than pathogen based measurement in studies of the physiological basis of yield loss.

There are several problems with GLA measurements. They are very time consuming and require a large labour input. GLA is measured often only for leaves on the mainstems, or mainstems and first tillers, of cereal plants and therefore is not expressed on a unit area basis. Remote sensing (e.g. infrared reflectance) offers a possible solution to these problems in field experiments. Healthy crops characteristically have high reflectance of near infrared (wavelength 0.7-1.3 μm) solar radiation (Jackson 1986). Diseased leaves reflect less radiation than healthy leaves and this relation can be used as an estimate of the effect of disease on plant production.

The objectives of this study were to compare GLA and infrared reflectance as measures of the effect of pathogens on barley, and to determine if infrared reflectance measurements are suitable for intensive field experimentation.

METHODS

Two spring barley crops (cv. Triumph) with different yield targets were sown on 17 September 1987 at Lincoln, Canterbury. There were two nitrogen rates (70 and 170 kg N/ha) and each crop was irrigated on estimated demand, with the high nitrogen rate crop receiving more water overall. The crops were planted in adjacent blocks with a 15 m border of barley around the experimental area sown 3 weeks prior to the establishment of the experimental plots to provide an inoculum source. Disease epidemics of different severity were produced in each crop with appropriate fungicide applications for leaf rust, net blotch *(Drechslera teres)* and scald *(Rhynchosporium secalis)*.

Reflectance, leaf area and disease development were measured at frequent intervals during crop growth. Reflectance was measured by a handheld multispectral radiometer (Cropscan Inc., North Dakota, USA) with eight narrow wavebands (wavelength 0.5-0.85 μm). The sensors were positioned 2 m above the canopy with a field view of 1 m^2. Reflectance was measured only on clear days, within 2 hours of solar noon. The 0.794-0.806 μm waveband measurements are presented in this paper because these correlated best with GLA and yield.

Disease was assessed on 8-10 plants sampled randomly from the area for which reflectance was measured. Percentage non green leaf area was estimated on all green leaves for all tillers using standard area diagrams (James 1974). Leaf area was measured with a leaf area meter (Licor 3100) and total green leaf area per plant was calculated as:

$$TGLA = \sum_{i}^{n} Ai \frac{(100 - NGLAi)}{100}$$

Where TGLA = total green leaf area per plant (cm^2)
Ai = area of individual leaf
NGLAi = per cent non green area for an individual leaf
n = youngest green leaf on the plant
i = oldest green leaf on the plant.

Green leaf area per plant was multiplied by the plant population (365 plants/m^2) to give the green leaf area index (m^2/m^2).

Ten 0.1 m^2 quadrat samples were collected at harvest (21 January 1988) from each plot, bulked, threshed and weighed as an estimate of plot yield.

Results from healthy and natural epidemic plots only are presented in this paper.

RESULTS

Leaf rust was the dominant disease in the experiment. First disease symptoms were observed 48 days after crop emergence. In the low nitrogen treatments, GLA increased to a maximum at GS 32 (Zadoks *et al* 1974), 8 days before the high nitrogen treatments (Fig. 1). GLA subsequently declined as plants matured. Total senescence of leaves occurred 10 days earlier on diseased plants than on healthy plants. Disease reduced GLA from GS 12 in the low nitrogen plots and GS 33 in the high nitrogen plots. The reflectance curves were similar to GLA up to GS 70 (Fig. 1). After GS 70 the reflectance was higher than the corresponding GLA. Reflectance was correlated significantly ($P \leqslant 0.05$ in the healthy, high nitrogen treatment and $P \leqslant 0.01$ in the disease treatments) with GLA throughout crop growth for three of the four treatments (Table 1).

TABLE 1: Correlation coefficients, yield, area under the green leaf area index curve (AUGLAIC) and area under the reflectance curve (AURC) for barley crops with different yield targets and disease levels.

Treatment	Correlation coefficient[1]	Grain Yield (g DM/m^2)	AUGLAIC (m^2/m^2)	AURC
Healthy, High N	0.77*	756	244	4262
Diseased, High N	0.91**	329	133	3086
Healthy, Low N	0.53NS	640	207	3622
Diseased, Low N	0.87**	324	103	2840

[1] Correlation coefficient between GLAI (m^2/m^2) and % reflectance (0.794-0.806 μm waveband) for all measurements of a treatment at all growth stages.
NS = non significant
* $P \leqslant 0.05$
** $P \leqslant 0.01$

Disease reduced yield by 56% in the high nitrogen treatment and 49% in the low nitrogen treatment. The area under the green leaf area index curve (AUGLAIC) and the area under the reflectance curve (AURC) are presented in Table 1. Grain yield was correlated significantly ($P \leqslant 0.05$) with AUGLAIC (r = 0.98) and AURC (r = 0.97).

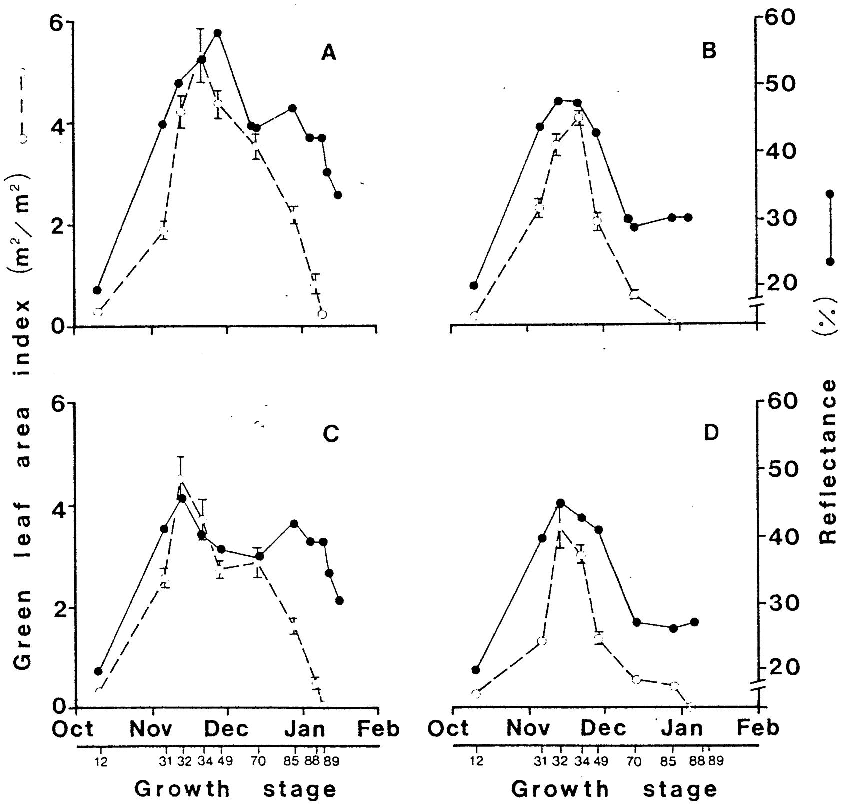

Fig. 1: **Green leaf area index (m^2/m^2) and per cent infrared reflectance (0.794-0.806 μm) for barley crops:**

(A) high nitrogen, healthy
(B) high nitrogen, diseased
(C) low nitrogen, healthy
(D) low nitrogen, diseased.

Vertical bars represent SEM's for green leaf area index.
Decimal growth stage (Zadoks *et al* 1974).

DISCUSSION

A multispectral radiometer detected differences in the reflectance of near infrared radiation from healthy and diseased plants. Reflectance correlated significantly with GLAI; the correlation being higher in the diseased than healthy treatments. The higher values for reflectance relative to GLAI after GS 70 (Fig. 1) may be associated with reflectance from green tissue on the ears; the green area of stems and ears were not measured as part of GLAI. If the contribution to green area index from ears was included in GLAI, the resultant curve would probably be more similar to the reflectance curve at the later growth stages. Thus infrared reflectance could be used as an estimate of GLA during growth. The collection of reflectance data is considerably less time consuming and labour intensive than leaf area measurements.

Green leaf area accumulation during the season represents the ability of the plant to supply assimilate to the grain (Gallagher and Biscoe 1978). Reduced GLA by disease will result in less radiation interception, dry matter production and yield (Haverkort and Bicamumpaka 1986). GLA will provide a measure of the effect of disease on plant growth. Grain yield correlated significantly with area under the green leaf area index curve and area under the reflectance curve.

It is important to note that infrared reflectance may be affected by other factors which affect plant growth such as water and nutrients. If this is the case, reflectance could not be used to separate the effects of these factors from the effects of disease. It is likely that reflectance would be most useful in comparative experiments in which one factor is considered.

We are using reflectance measurements in further investigations of the effect of disease on barley crops with different yield targets. A multispectral radiometer could determine whether GLA is sufficient to support the yield potential of the crop. With sufficient development of the technology, reflectance measurements could be used to assess yield-limiting damage in crop management. Reflectance may be useful for routine assessment of host resistance to pathogens in cultivar evaluations and in fungicide efficacy trials.

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