Monitoring Cereal Rust Development With A Spectral Radiometer

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ABSTRACT

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Three wheat cultivars susceptible to either stem rust or stripe rust were evaluated to determine the association of stripe rust and radiometric leaf reflectance to rust development and yield. Four vegetative indices based on these measurements were used to detect differences between healthy and diseased plants. Vegetation index differences between inoculated and control plants became progressively greater as the rust infection developed. Thus, it would appear feasible to use remotely collected radiometric reflectance data to estimate disease incidence over large production areas. This information could also be used to estimate potential yield losses due to disease.

Additional key words: disease forecasting, Puccinia graminis, Puccinia striiformis, remote sensing.

Economic loss due to foliar pathogens has long been a worldwide threat to cereal producers. On a large land mass, the concern is with epidemics that develop over entire areas rather than with a single infection focus that develops on a few plants. The former situation may result from spore showers blanketing large areas. It often becomes difficult to describe and visually assess the amount of disease on a large scale and then to associate it with yield loss. Assessment of the severity of plant disease epidemics is essential for successful, timely, and cost-effective chemical control. Conventional methods of visual assessment are labor-intensive and results may vary with the experience of the individual. Remote-sensing techniques, including aerial photographs and high altitude satellite data, may provide an easily available permanent record of disease intensity for large crop areas without observer bias and error.

Aerial photography, ground-based sensor data, and Landsat multispectral scanner (MSS) data have been used to measure disease incidence in many agricultural systems. In 1933, Bawden (2) first used aerial photography for detecting plant virus diseases. Aerial photography was also used in 1956 by Colwell (5) to survey the cereal rusts and in 1962 by Brenchley and Dodd (4) and in 1967 by Manzer and Cooper (19) who investigated potato late blight. More recently, disease surveys have been done on a number of crop species (5,13,20,25,28). In addition, remote sensing has been used for crop recognition surveys (3,33), yield predictions (12,14,15,22), land-use mapping (32), soil erosion and water use surveys (6,9,12,15,21), smog damage assessment (8), and observation of crop canopy temperatures (9,11,15,17) and stand densities (1). There is, however, limited reference to use of hand-held radiometer or MSS data for the detection of disease and estimation of eventual crop loss . For the most effective control measure scheduling and accurate potential loss estimation, it is often imperative that disease be detected early in the infection process. Differences between the

visible and near-infrared reflectance from healthy plants and those under stress are measurable with instruments before changes are detectable by eye (3,7,24,32,33). This may be the greatest advantage of using MSS data in disease surveys. Diseases profoundly decrease the infrared reflectance but increase the visible reflectance from plants (8,10,33,34). Healthy vegetation is highly reflective in the near-infrared but this quickly declines due to cellular changes caused by disease. Some investigators have reported that high reflectivity in a healthy crop is due to the leaf chlorophyll (8,23,33). The basis for most of these studies has been the observation that changes in the normal reflectivity pattern (signature) of a crop result from the loss of vigor in the diseased plants. Numerous formulae, such as vegetation indices (VIs), have been developed to reduce multi-spectral data to a single number for assessing vegetation characteristics. This provides a method of showing changes in crop canopies (3,27) that can later be verified by field observation.

The objective of this study was to investigate the use of VIs derived from data obtained with a hand held multi-spectral radiometer for detecting rust infections in winter and spring wheat and to compare these results with yield components and total grain yield. Assuming that rust pathogen activity is manifested in VI changes, efficient, rapid, and accurate quantification of infection and the study of its effect on yield should be possible.

MATERIALS AND METHODS

Itana (CI 12933), a winter wheat cultivar, and two spring wheat cultivars (Lemhi [CI 11415] and Federation [CI 4734]) were planted in 1.8 × 3.3-meter field plots on the Montana State University Experiment Station at Bozeman. Plots were separated into two treatments: protected with the systemic fungicide triadimefon (Bayleton, Mobay Chemical Co.); and inoculated (Itana and Lemhi) with Puccinia striiformis West. (the stripe rust pathogen) or (Federation) with Puccinia graminis Pers. f. sp. tritici Eriks. & E. Henn. (the stem rust pathogen).

Spreader rows of susceptible wheat cultivars were planted around the inoculated plots to ensure adequate and uniform infection levels. Plants in the spreader rows were inoculated by dusting them with a mixture of talc and lyophilized spores of the

appropriate pathogen (30). either *P. striiformis* or *P. graminis*. Lemhi was inoculated with *P. striiformis* on 7 June and again on 18 June 1982. Itana was inoculated with *P. striiformis* once in early May. Federation was inoculated with *P. graminis* on 23 June. Plants were in the early-tiller to mid-tiller stage (stages 2 to 3) of growth (18). The spore concentration utilized for both pathogens was 1 g of spores per 30 m of spreader row. Inoculum of *P. graminis* consisted of race TNM (15B) as identified by the Cereal Rust Laboratory in St. Paul, MN. Inoculum of *P. striiformis* was a mixture of isolates endemic to the Bozeman area in 1981. Development of disease caused by the two pathogens was both severe and uniform in all inoculated plots. All control plots were sprayed with triadimefon at 90 g/ha (50WP) with a backpack sprayer on 25 June, when plants were in the late tiller to stem elongation stage (stages 4 to 5) of growth. Only a trace of rust developed in the control plots.

Growth stage estimates were made according to the Feekes scale (18). These assessments were made for 9 wk at 3- to 5-day intervals beginning on 16 June and ending on 19 August. Flecks that developed preceding pustule formation were considered to be the onset of initial infection. A modified Cobb scale and conventional visual procedures were used to assess several individual culms and the readings were averaged to give percent severity and infection type for each plot. In addition to the disease data, several other plant and meteorological parameters were recorded: time of day, cloud condition, amount of dew, precipitation, barometric pressure, solar radiation, wind speed, plant height, growth stage, and general crop condition. Color photographs of both the healthy and the diseased plots were taken at weekly intervals. All observations were assumed to be representative of the entire plot. Infection was uniform and the rust diseases developed well in environments favorable for spread (Table 1). An Exotech model 100A Spectrometer, which is a multispectral radiometer (MSR), was used to obtain spectral measurements which were recorded for each plot at 3- to 5-day intervals beginning on 15 June and ending on 20 August 1982. The Exotech MSR, a small hand-held instrument that can be carried and operated by one person, has the same band characteristics as the multispectral scanner (MSS) used on the land satellites (Landsat) (16). The spectral band widths covered by the Exotech radiometer correspond to MSS bands 4 through 7. Two of these bands are in the visible wavelength range: band 4 (0.5–0.6 μm) and band 5 (0.6–0.7 μm). The remaining two bands are in the near-infrared range: band 6 (0.7–0.8 μm) and band 7 (0.8–1.1 μm).

Various VIs have been used to interpret spectral data relative to crop condition and or estimates for biomass, leaf area, percent ground cover etc. (1,3,7,10,16,17). The vegetative indices used in this study were a band ratio (R75), a normalized difference index (ND7), and two perpendicular vegetative indices (PVI6 and PVI7). The general form of these indices is described by Perry and Lautenschlager (27), but the coefficients in the indices used were custom fitted for this analysis by using local soils data.

The data recorded in this study were analyzed to ascertain the relationships between the radiometric data and the conventional visual estimates of disease severity. The relationship between the radiometric data and test weight, number of heads per unit area, number of kernels per head, and kernel weight was assessed. This assessment was based on data collected after the harvest of all wheat heads within one square meter; these data were then converted to the number of heads per unit area.

RESULTS

All four VIs (R75, ND7, PVI6, and PVI7) were significantly lower in diseased plots than in the control plots. This observation is consistent with other reports that relate spectral data and plant vigor (8, 10, 33, 34). The VIs R75 and ND7, in that order, gave the best indication of disease incidence and subsequent yield loss regardless of the wheat cultivar or the rust pathogen. PVI6 and PVI7, in that order, were the next best indicators of disease (Figs. 1 to 3). The spectral differences observed between the stem rust-affected plots and their corresponding control plots were never as large as the corresponding differences observed for stripe rust.

All four VIs gave clear indications of both diseases, particularly stripe rust. Itana winter wheat was first to show stripe rust symptoms, both visually and in the spectral data (Fig. 3). For winter wheat cultivar Itana, VI differences were apparent by the early tillering stage (15 June) Feekes 4.0–5.0 (18). The largest differences in VIs occurred during grain ripening (10–15 July) Feekes 10.8–11.3. These differences narrowed when the high infection levels in both the control and inoculated plots eventually
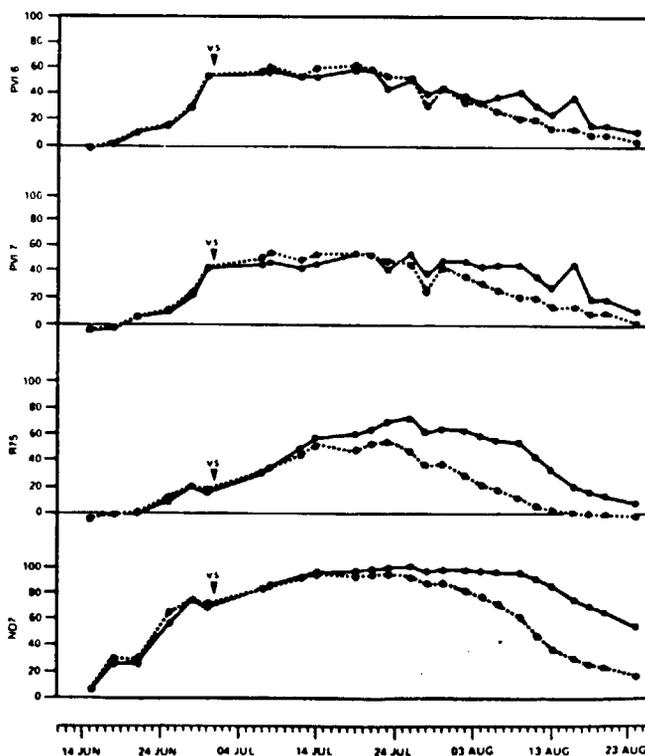
TABLE 1. Disease severities[a] following inoculation at different growth stages of three wheat cultivars with two cereal rust pathogens at Bozeman, MT, in 1982

Growth stage[b]	Cultivar					
	Federation		Lemhi		Itana	
	Prot[c]	Inoc[d]	Prot[c]	Inoc[e]	Prot[c]	Inoc[e]
One shoot	0	0	0	0	-	-
Tillers formed	0	0	0	5	-	-
Leaf sheaths lengthen	0	0	0	10	-	-
Leaf sheaths strongly erected	0	10	0	20	0	20
First stem node visible	0	20	0	20	0	70
Second stem node visible	0	20	0	20	0	70
Last leaf visible	0	20	0	40	0	80
Ligule of last leaf visible	0	30	5	50	0	80
In boot	1	40	5	50	0	80
Ripening	10	80	20	80	10	100

[a] Severity based on modified Cobb scale. Infection type was a uniform susceptible type "4" for all cultivars.
[b] According to the Feekes scale (18).
[c] Protected control treated with Bayleton at 90 g ha.
[d] Federation wheat inoculated with uredospores of *P. graminis*.
[e] Lemhi and Itana wheat inoculated with uredospores of *P. striiformis*.

Fig. 1. Inoculated (------) versus control (- - -) comparison of four vegetation indices for wheat cultivar Federation and the wheat rust pathogen, *Puccinia graminis*. Arrow (vs) indicates date that flecks were first observed.

desirable control measures more effectively. Future investigations are planned to further delineate spectral differences among various plant diseases and to determine the possibility of estimating disease losses at early growth stages.

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