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Recent Development on Crop Variety Identification by U V, Visible and Infrared Remote Spectroscopy

E. J. Brach

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Recent Developments on Crop Variety Identification
by UV, Visible and Infrared Remote Spectroscopy¹

Eugene J. Brach,
Engineering Research Service,
Research Branch, Agriculture Canada,
Ottawa, Ontario, K1A 0C6.

When radiant energy falls on an object, a part of this energy will be absorbed (A), transmitted (T) or reflected (R). It may also induce the object to fluoresce. Reaction to the radiant energy depends on the objects' characteristics which include the physical and chemical structure, optical density and refractive index. Objects may be inert like minerals or rocks where the optical characteristics do not change, but agricultural or forest crops are dynamic and the optical characteristics change throughout their growth cycle. Therefore, the interaction between radiant energy and agricultural crops is also dynamic and changes during its growth.

Radiant energy is defined as the total energy reaching the earth surface from the sun and covers the range from about 0 to 300 μ . This is broken down to segments such as X-ray (below 0.01 μ), ultraviolet (UV) (0.01 - .38 μ), visible (.38 - .72 μ), near infrared (.72 - 3 μ) and far infrared (to 300 μ). The experiment discussed here covers the UV, visible and near infrared segments, considered as light energy. The energy in a light beam is concentrated in quantas or photons which can be thought of as an oscillating electric and magnetic field, i.e. two vectors. The interaction of the oscillating electric field of the quanta, with charges (i.e. the electrons) in the molecules of an object, is the basis of spectroscopic analysis.

When a light beam falls on a leaf some of the energy will be absorbed, but most will reflect in a dispersive mode. The dispersed energy contains the information or the optical characteristics (spectral signature)

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of that leaf. The dispersed energy may contain information on maturity, variety identity within a crop, the identity of the crop and information about stresses such as plant disease. Therefore, any efficient way to collect the dispersed energy for spectroscopic analysis is our ongoing concern. A mobile remote sensing laboratory (Fig. 1) was designed and developed to do this, and equipped to take remote spectral measurement in the UV, visible and infrared (IR) regions of the spectrum. It also has a laser induced fluorescence measuring capability (Fig. 2).

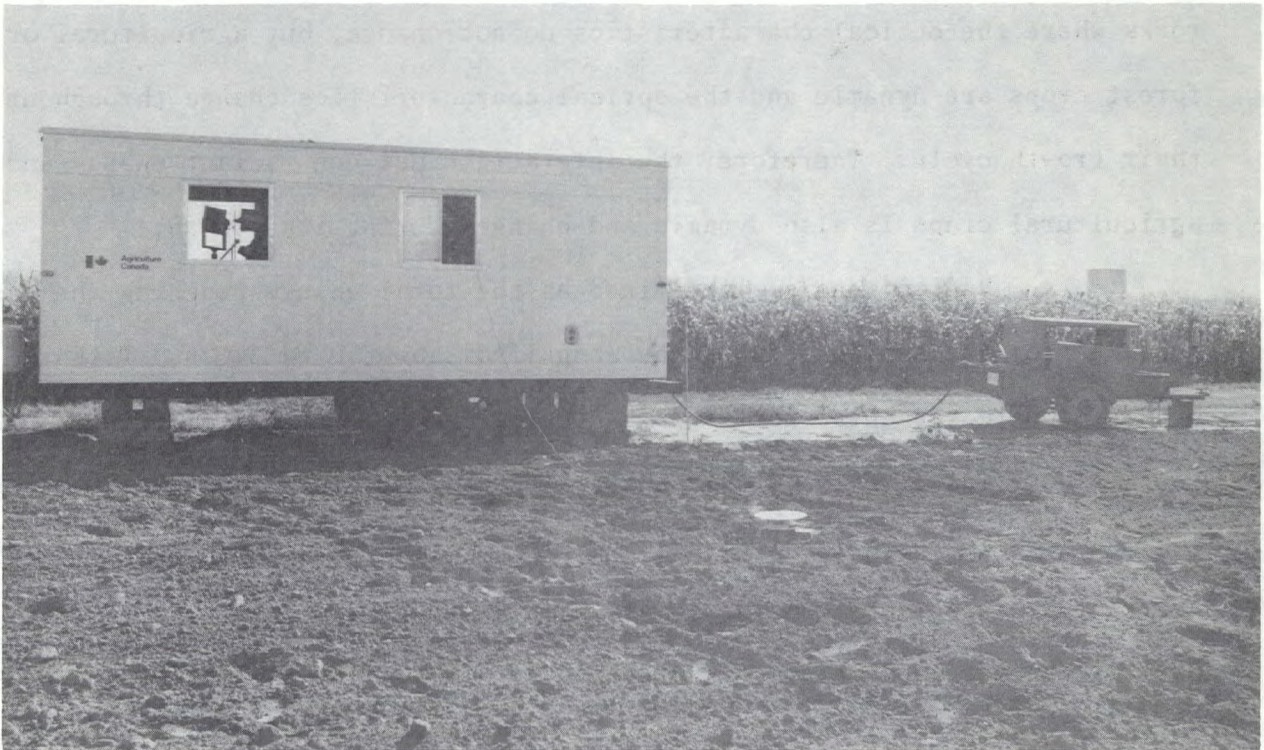
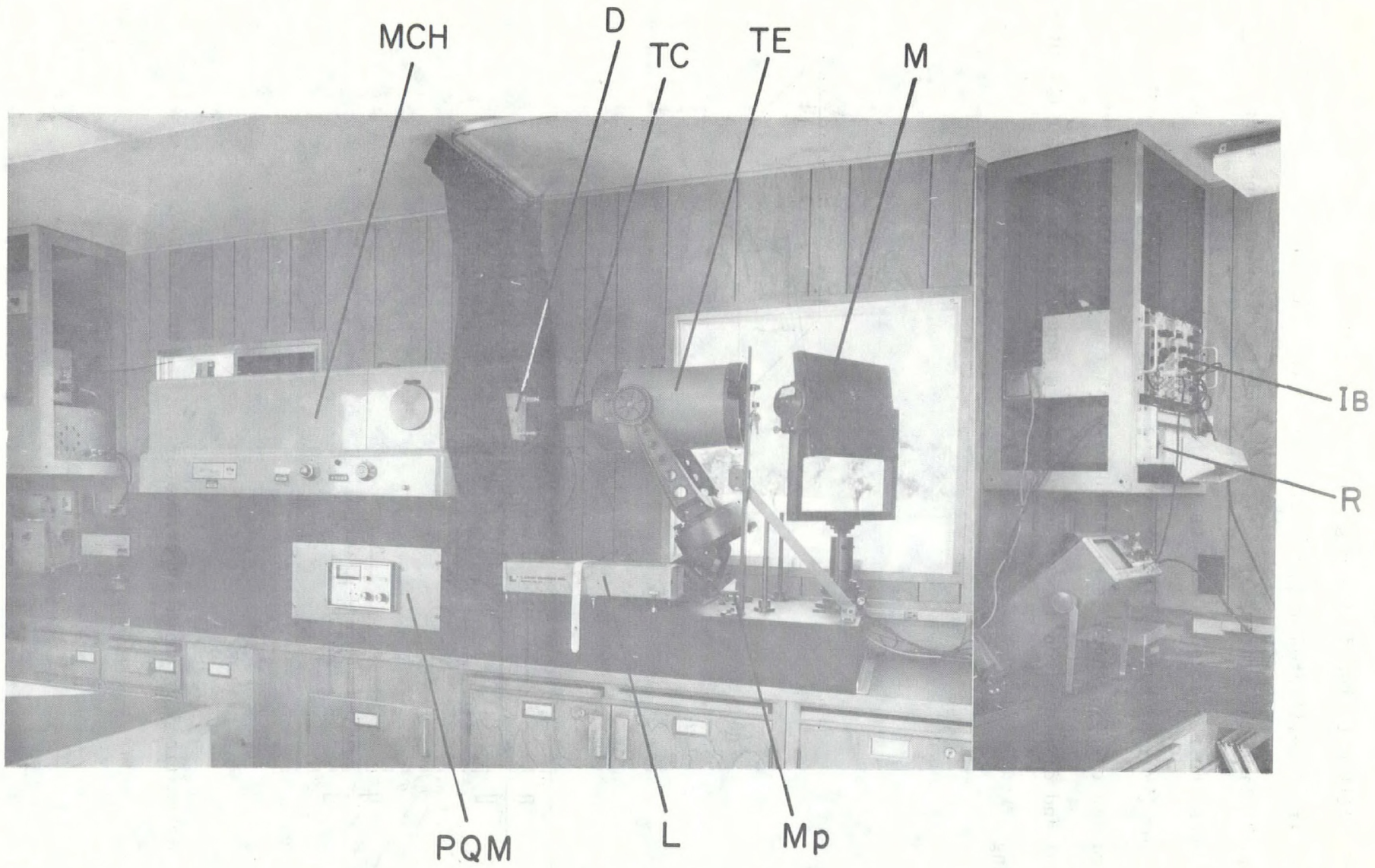


Fig. 1. The laboratory in operation.

The radiant energy from the sun ($H\lambda$, Fig. 3) falls on to the plant, the reflected energy (δ) from the plant is collected by a Schmidt-Cassegrain telescope (T_E , Fig. 2) via a flat mirror (M). The spectral reflectance ($N\lambda$, Fig. 3) from the telescope is focussed by a telecompressor lens (T_c) on to the monochromator (MCH, Fig. 2) entrance slit (S_1 , Fig. 3) completely filling the

Fig. 2. Interior of mobile remote sensing laboratory.



area of the slit with incident energy which passes to the collimating mirror (M_c) where it is collimated and reflected on to the grating (G). The diffracted light from the grating is reflected back to the focussing mirror (M_f) which focuses the reflected energy on to the monochromometer exit slit (S_o). The detector (PM), a photomultiplier for the visible and UV regions, detects the diffracted energy, which is measured by a photon quantum meter (PQM, Fig. 2, 3) and displayed on a recorder (R) and a paper tape punch for computer processing.

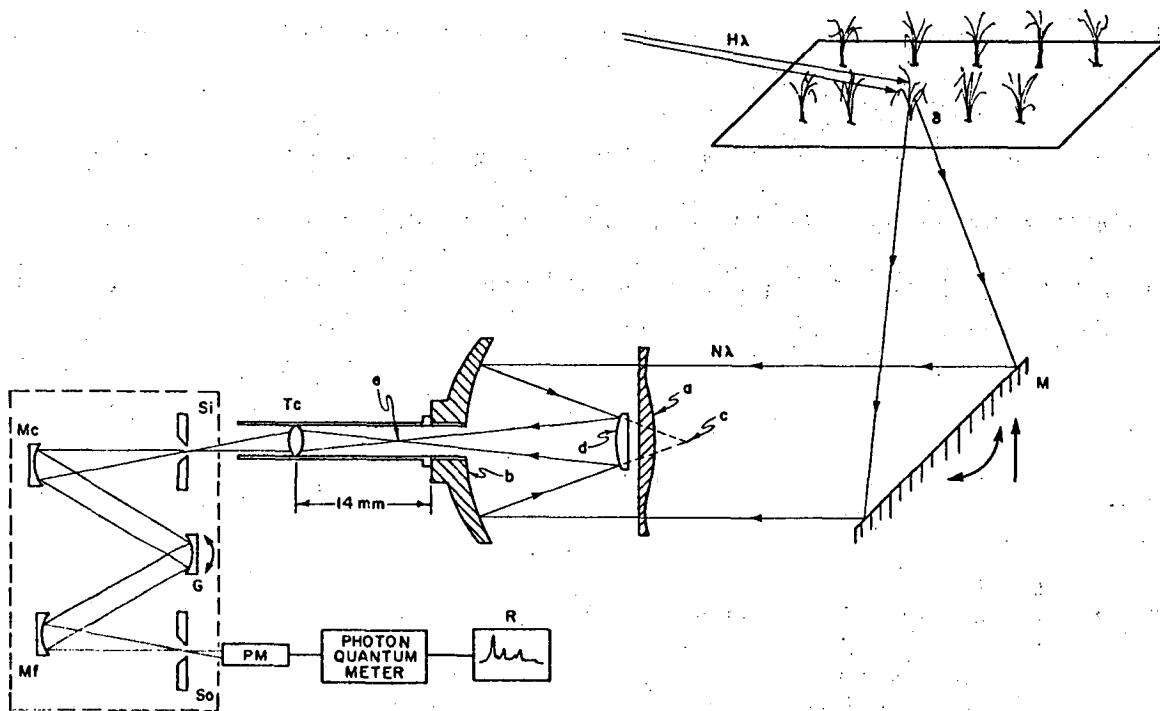


Fig. 3. Schematic diagram of spectrometer.

To test the system, experimental plots were set up in duplicate. The plot dimensions, row width, seeding date and crop variety are given in figure 4. Some of the plots could not be measured due to the shade from large corn plants. Spectral measurements of the soil and a reflectance plate for reference purposes (Figure 5 at right) and of a soybean field (Figure 5 left) were taken each time spectral measurements were made on the plots. The ambient temperature and the total incoming radiant energy were continuously recorded. Measurements were taken daily in the morning and in

SPECTRAL MEASUREMENT OF VARIOUS
AGRICULTURAL PLANTS

REPLICA 1		REPLICA 2	
1	SOD D ₁	19	WHEAT SELK D ₁
2	POTATOES D ₁	20	WHEAT OPEL D ₁
3	SOYBEANS D ₁	21	BARLEY D ₁
4	CORN D ₁	22	OATS D ₁
5	WHEAT SELK D ₁	23	SOD D ₁
6	WHEAT OPEL D ₁	24	POTATOES D ₁
7	BARLEY D ₁	25	SOYBEANS D ₁
8	OATS D ₁	26	CORN D ₁
9	BARLEY D ₂	27	WHEAT SELK D ₂
10	SOD D ₂	28	WHEAT OPEL D ₂
11	CORN D ₂	29	BARLEY D ₂
12	WHEAT SELK D ₂	30	OATS D ₂
13	WHEAT OPEL D ₂	31	CORN D ₂
14	OATS D ₂	32	SOD D ₂
15	OATS D ₃	33	WHEAT SELK D ₃
16	BARLEY D ₃	34	WHEAT OPEL D ₃
17	WHEAT SELK D ₃	35	BARLEY D ₃
18	WHEAT OPEL D ₃	36	OATS D ₃
18A	WINTER WHEAT D ₁	36A	WINTER WHEAT D ₂

5' 4'5" 5'

D₁ SEEDING DATE MAY 22, 1975
D₂ " " JUNE 4, 1975
D₃ " " JUNE 18, 1975
D₄ " " AUG 22, 1975
ROW WIDTH CEREALS 6', OTHERS 18"

Fig. 4. Plot layout.

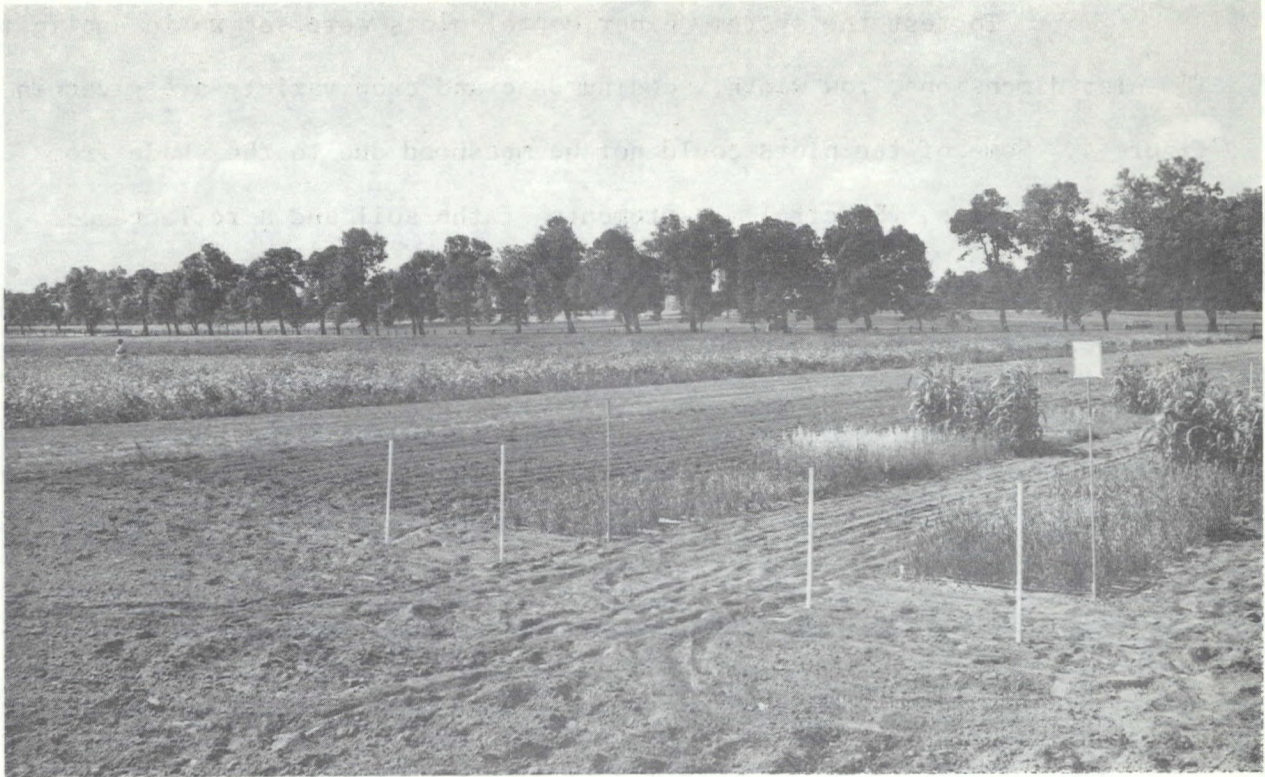


Fig. 5. Soybean field and test plots.

the afternoon except when it was raining. A typical spectral curve covering the range 3500 to 8000 Å of a corn plant taken August 14, 1975 is shown in figure 6. The amplitudes of the valleys and peaks at different wavelengths

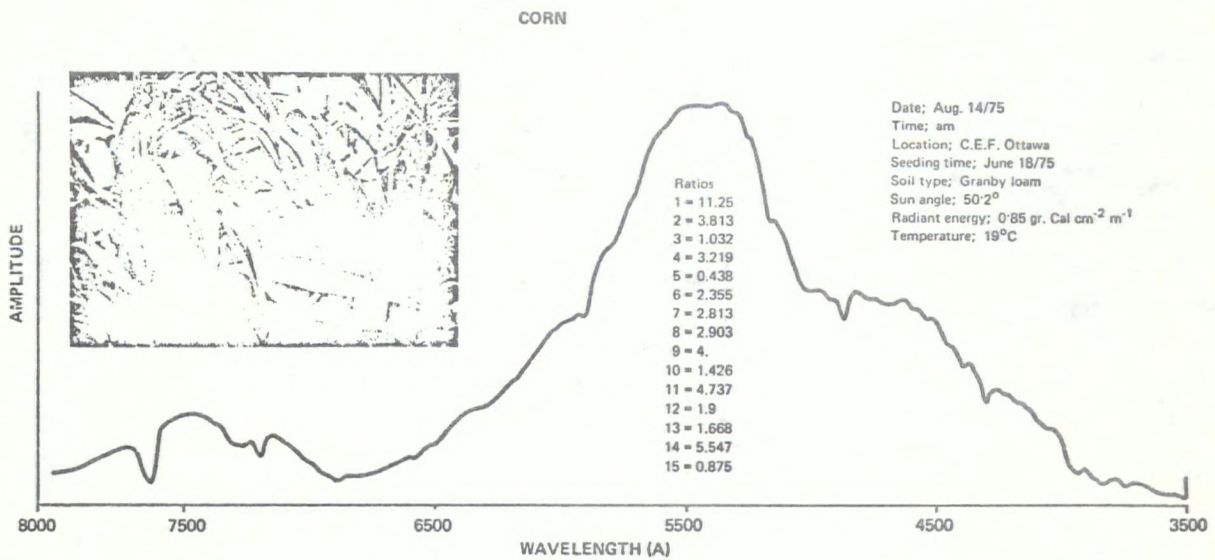


Fig. 6. Typical reflectance curve for corn leaf.

were used to calculate energy ratios as indicated in figure 7. The various

- No. 1=5500/6900; No. 2=7450/6900; No. 3=6900/7625; No. 4=7150/6900
No. 5=6900/7200; No. 6=7200/7625; No. 7=4300/6900; No. 8=4300/7625
No. 9=5500/4300; No. 10=5500/5000; No. 11=4300/3800; No. 12=3800/3600
No. 13=5200/4850; No. 14=4850/6900; No. 15=6700/6900

Fig. 7. Ratio calculated between energy levels at selected wavelengths. ratios indicate maturity of a crop, or differentiate between crops and possibly between varieties within a crop. Figures such as 6 and 7 may be used to form a spectral atlas for agricultural crops and used as an aid to evaluate and study crop characteristics from remote sensed data. Figure 8a gives the spectral curves for oats seeded on three different dates and taken July 31, 1975 which indicate qualitative (wavelength) and quantitative (amplitude) differences which can be attributed to maturity.

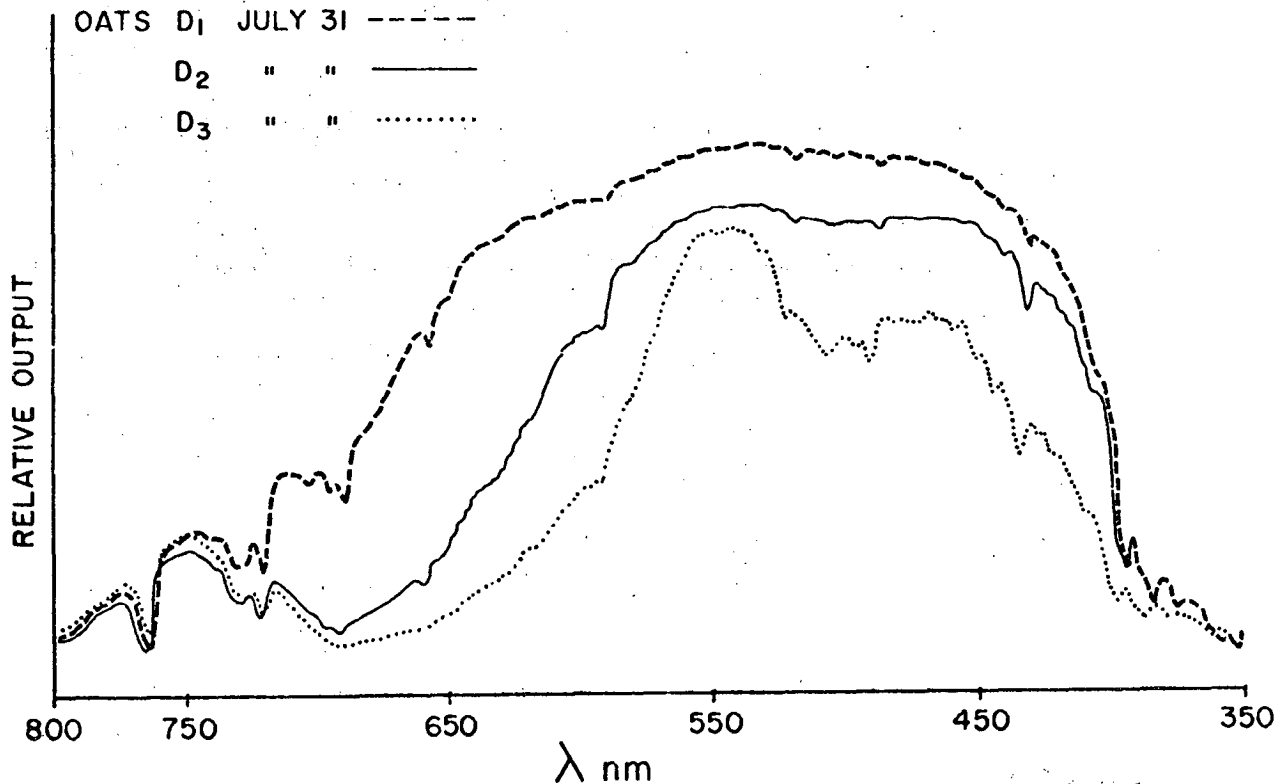


Fig. 8a. Simultaneous spectral curves for oats seeded at three dates.

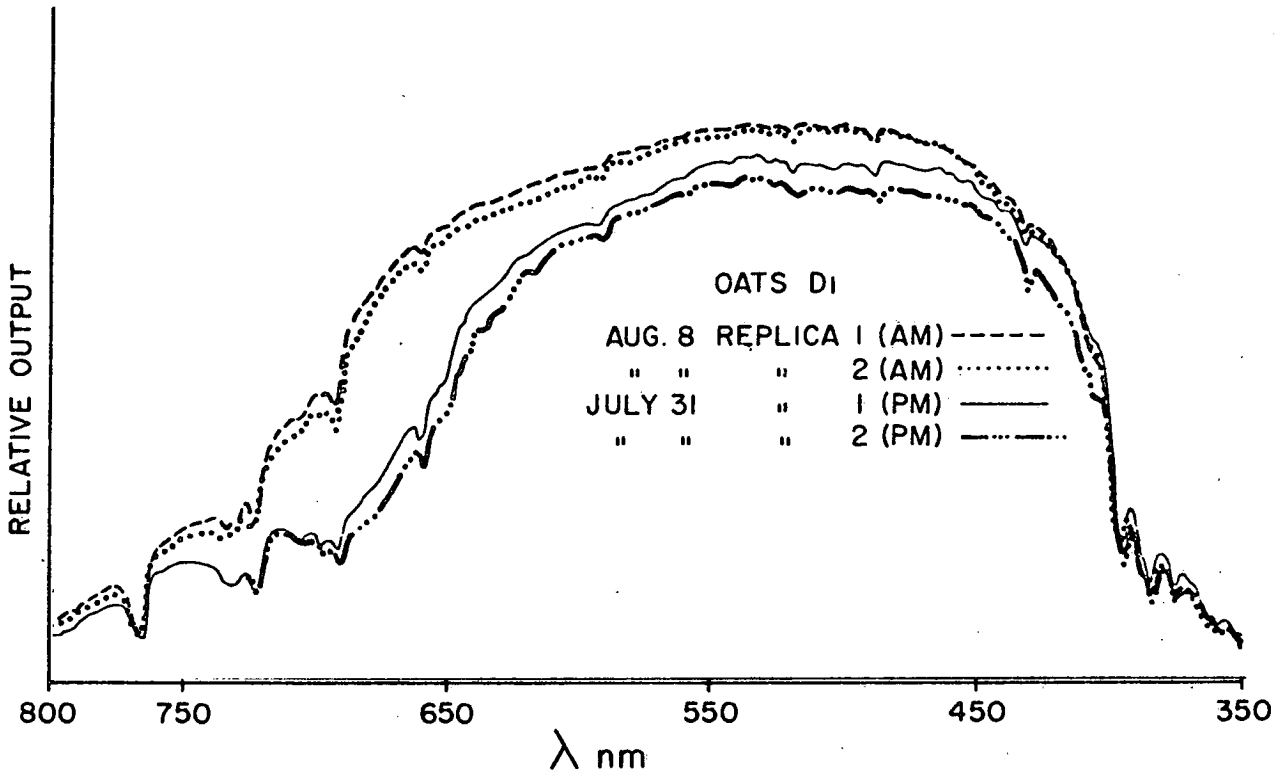


Fig. 8b. Spectral curves for two replicates of oats taken on two dates.

Fig. 8b shows the accuracy of the measuring system where the spectral curves of two replicas follow each other closely. Figure 8c shows spectral curves of two varieties of wheat taken at different dates and indicates that two varieties of the same crop can be differentiated.

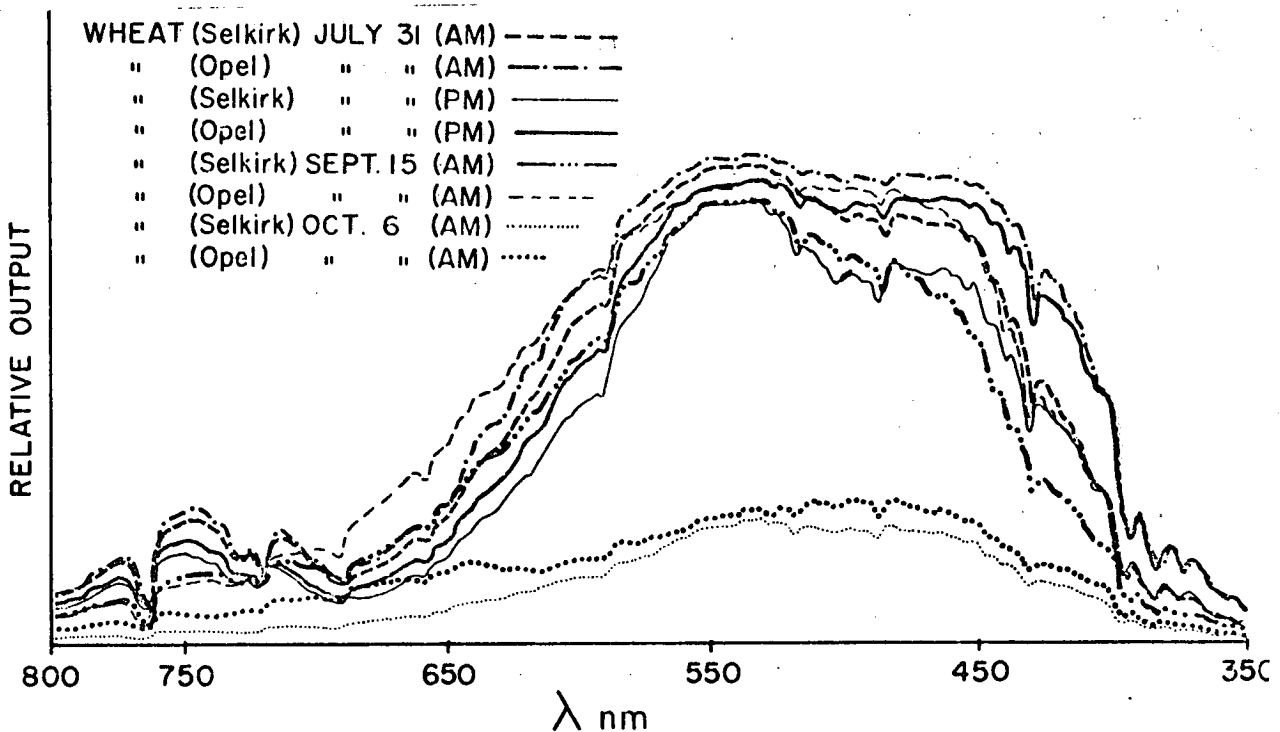


Fig. 8c. Comparison of two wheat varieties on different dates.

It is obvious that final conclusion in any biological experiment cannot be taken from the results of one year. Several year's data are needed to form a final conclusion. The first year's data encourages us to continue this work and expand it to the infrared range where protein content of growing crops might be detected and also to use laser fluorometry, which may sense chemical changes due to various stresses.

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