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GRAPEVINE CANOPY REFLECTANCE AND YIELD

K.A. MINDEN, W.R. PHILIPSON

Cornell University
Ithaca, New York

ABSTRACT

Field spectroradiometric and airborne multispectral scanner data were applied in a study of Concord grapevines. Spectroradiometric measurements of 18 experimental vines were collected on three dates during one growing season. Spectral reflectance, determined at 30 intervals from 0.4 to 1.1 µm, was correlated with vine yield, pruning weight, clusters/vine, and nitrogen input. One date of airborne multispectral scanner data (11 channels) was collected over commercial vineyards, and the average radiance values for eight vineyard sections were correlated with the corresponding average yields. Although some correlations were significant, they were inadequate for developing a reliable yield prediction model.

I. INTRODUCTION

Remote sensing has become a major tool for assessing crop condition and yield. Ten years ago, remote sensing research was primarily devoted to evaluating losses in crop vigor due to stress (Colwell, 1970). More recent studies have also explored the relationship of the spectral characteristics of vegetation to agronomic variables (Idso et al., 1977). These variables include biomass, leaf area index, disease, percent green, percent ground cover, nutritional status and yield.

Remote sensing of vineyards has been applied to several management problems, including drainage; soil depth, compaction and texture; and crop health and vigor (Wildman, 1979; Philipson et al., 1980). Ultimately, these factors all affect crop yield, the focus of vineyard management decisions. In large vineyards, detailed observations of crop status are time consuming and, consequently, limited to a small number of plants. A cost-effective method of predicting yield, at the earliest possible stage of crop growth, would be very valuable to viticulturalists.

The intent of this research was to examine relationships between agronomic variables and spectral properties of the vine canopy. The main objective was to define the optimum wavelength(s) for yield prediction modeling.

II. PREVIOUS STUDIES

Factors which affect leaf and canopy reflectance have been defined in several studies (Myers and Allen, 1968; Wiegand et al., 1972; Bauer, 1975). Radiometers have been the main tool for in situ crop canopy spectral reflectance measurements (Kanemasu, 1974; Casey and Burgess, 1979), while the Landsat Multispectral Scanner has provided most of the aerial data for spectral studies of crops (Heilman et al., 1977; Colwell, 1979). For both, statistically significant relationships have been found between reflectance and some agronomic variables for grass, wheat, sorghum, soybean and other crops. Generally, researchers found that crop parameters correlate best with reflectance in the red and near-infrared wavelengths, and with ratios of reflectance in these wavelengths. Linear combinations of two wavelengths are often used to compensate for sun angle and atmospheric effects (Tucker et al., 1979).

Studies of vineyard reflectance and crop condition using color-infrared aerial photography and airborne multispectral scanner data were performed by Philipson et al. (1980). They concluded that differences in vine vigor could be assessed visually with the color-infrared photographs, and that yield-reflectance relationships appear to exist for at least two grape varieties, Delaware and Concord.

III. METHODS AND MATERIALS

Field spectroradiometric measurements of 18 Concord vines were collected on three dates, at the Vineyard Laboratory of the New York State Agricultural Station, in Fredonia, N.Y. The experimental vineyards are part of the Chataugua County grapebelt, located eight kilometers southeast of Lake Erie. Replicated vines had been subjected to nine agronomic treatments involving levels of nitrogen, weed control, pruning and training.

One major problem in past crop reflectance studies is developing relationships which are applicable to more than just the training data (Stuff and Barnett, 1979; Duggin, 1980). This is caused, at least in part, by not accounting for the effects of solar zenith angle, azimuth angle and look angle. In order to provide accurate reflectance data and account for these effects, three portable spectroradiometers (ISCO model SR) were calibrated using a procedure developed by Duggin (1980) and modified by Duggin and Philipson (1981).

The fiber optic probe of each instrument was equipped with a 30° cone receptor to limit the field-of-view. The instruments were mounted on a grape harvesting tractor, with the probes of two spectroradiometers viewing the vineyard canopy and the probe of the third spectroradiometer viewing a white, Lambertian standard reflector. Radiance from the vines and standard was measured simultaneously, taking readings at intervals of 0.25 μm from 0.40 to 1.1 μm. The data were transformed into percent hemispherical-conical reflectance (Duggin and Philipson, 1981). This procedure was repeated on three dates during the 1980 growing season, July 9 or 10, August 21 or 22, and September 12.

For general analysis and screening, the reflectance data were plotted versus wavelength for each plant, for each date. Correlations were computed between yield and spectral reflectance of each vine on each date. Relationships between vine reflectance and pruning weight, clusters, nitrogen input, and weed control were also evaluated.

As an extension of the field program, airborne multispectral scanner data (M2S, 11 channels) were flown by NASA on September 3, 1980, over the vineyards of the Taylor Wine Company, Inc., in Hammondsport, N.Y. The mission was flown in mid-afternoon with high haze and approximately 50% cloud cover. Sufficient aerial data were collected to analyze eight Concord vineyard sections. The spectral radiance values for each section were correlated with average section yield. Several ratios of average reflectance were also correlated with average yield.

IV. RESULTS

Correlations between yield and reflectance of 18 plants sampled during the 1980 growing season were generally poor, with most values being below the 5% probability level. Yields from 1980 (and 1979) were not significantly correlated with July reflectance data. For August data, reflectance in the visible range was positively and significantly related to yield, while for September data, yield and reflectance were negatively correlated, with the most significant correlations occurring in the near-infrared range.

The level of nitrogen and method of weed control, which together determine the available nitrogen, were found to significantly affect yield, clusters and pruning weight. Because available nitrogen affects chlorophyll levels, 12 of the sampled vines were stratified into two groups of six vines: Group 1 used between-row cultivation for weed control, while Group 2 used mowed sod with herbicides. An analysis of variance showed that the effect of nitrogen on the 12 plants sampled was not as significant as the effect on all plants which received the same treatments at the experimental site. However, correlations between yield and reflectance improved for each group relative to correlations based on all 18 plants.

Pruning weight and the number of clusters per vine were also related to reflectance. Pruning weight was significantly correlated with reflectance when all 18 plants were used, but there was no significant correlation with the plant groups stratified by method of weed control. In contrast, when the number of clusters per vine was correlated with reflectance, the opposite occurred. There were no significant correlations when all 18 plants were used, but when yields from the smaller groups were correlated with reflectance, the resulting coefficients were highly significant. As expected, the number of clusters was highly correlated with yield.

Plants were also stratified into groups based on the time of day in which reflectance measurements were made. Correlations between yield and reflectance for these groups was better than for all 18 vines sampled.

Correlations between the airborne multispectral scanner data and averaged yield were not significant.

V. DISCUSSION AND CONCLUSIONS

Most correlations between spectral reflectance and yield were generally not significant at the 5% probability level. August reflectance data showed better correlation with yield than did July or September reflectance data.

Clusters per vine were highly correlated with yield, and more highly correlated with reflectance than yield. A yield prediction model based on spectral reflectance might attempt to incorporate some measure of clusters. It is also apparent that a successful model might have to stratify the vines by available nitrogen.

The effect of time of day on reflectance correlations with yield might relate to leaf-layer shadowing, leaf orientation or a systematic instrument error.

Future sampling should be performed on a larger sample. In addition, data collection could be limited to certain wavelengths depending on growth stage. In July, the highest correlations occurred in different visible and near-infrared wavelengths. August data collection, however, could be limited to certain wavelengths depending on the weed control method: the visible range for cultivated rows, and the infrared for those with sod and herbicide application. In September, the data collection could generally be limited to the infrared range. At any time, the main visible wavelengths to be considered are 0.400-0.475 µm and 0.625-0.675 µm.

The lack of correlation between the airborne multispectral scanner data and yield was likely due to a combination of factors, which are still under investigation.

VI. SUMMARY

Some correlations between vine spectral reflectance and both yield and clusters per vine are statistically significant, however they are inadequate for developing a reliable yield prediction model. Canopy reflectance was strongly influenced by available nitrogen and stage of crop growth. Future sampling can emphasize specific wavelength regions, but these depend on several factors, including stage of growth and agronomic treatment.

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Katherine A. Minden received her B.S. in Natural Resource Development from Michigan State University, in 1978, and she is presently completing her M.S. in Aerial Photographic Studies and Remote Sensing, at the Cornell University School of Civil and Environmental Engineering. Before entering graduate school, she worked at the U.S.G.S. EROS Program Office in Reston, Virginia, as a physical scientist, specializing in Landsat studies of Antarctica. She has attended graduate school since January 1980, participating in both teaching and research activities in remote sensing.

Warren R. Philipson received his B.C.E., M.S. in Civil Engineering, and Ph.D. in Soil Science (Agronomy) from Cornell. Since 1965, he has taught, conducted research and participated in remote sensing projects in various parts of the world. An associate professor, he has co-directed Cornell's Remote Sensing Program since 1972.