ASSESSMENT OF SPRAY COVERAGE ON LEAVES BY LIGHT REFLECTANCE METHODS

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A number of methods have been employed for measuring quantitatively and qualitatively the deposition of spray materials on crops. Most methods involve the placement of targets prior to spraying. Techniques described by MacCarthy (4), Blodgett and Mader (1), were used to obtain precipitates of copper and zinc salts along with potato leaflet impressions on sensitized filter paper. Large numbers of these impressions used to assess sprayer performance (6) made an objective method of colour distribution assessment desirable.

Initial trials with a Photovolt Reflectometer showed promise of distinguishable differences between areas of precipitates. The most applicable method described herein utilized the Hunter Colour and Colour Difference Meter (2). This study was concerned with establishing a suitable calibration curve for converting meter readings into percent coverage of spray material on potato leaflets.

METHOD

Visual assessment of impressions of field sprayed leaflets were made by placing a transparent plastic grid over the leaflet impression and counting the number of squares containing precipitate. These samples were then placed on the sample viewer of the Colour Difference Meter to obtain measures of luminous reflectance (Rd), redness or greeness (a), and yellowness or blueness (b).

Samples were also prepared by masking portions of leaflets prior to spraying and using a planimeter to obtain more accurate measurement of percent coverage to be used as standards in developing calibration graphs.

COLOUR STANDARDS

The Hunter Colour and Colour Difference meter is best suited to measuring small differences in colour between two samples or of differences betwen samples and a standard. Most accurate results are obtained when the instrument is initially balanced on a colour similar to the one to be measured.

Colour standards were obtained from the Munsell Colour Company. Two colour standards were tried for copper sprayed samples. One standard, Munsell 2.5YB 5/4, approximated the reddish brown appearance of cupric ferrocyanide. The other standard, Munsell 5BG 8/2, approximated the bluish green background of the sensitized filter paper. The first number plus letters gives the Hue name and location in the colour solid. The Value notation gives the degree of whiteness 10/ or blackness 0/. The last number gives the Chroma or strength of saturation of the individual colour neutral gray /0 to Chroma as strong as /12 or more depending on the colour. These descriptions were converted to Hunter Rd, a and b coordinates for use with the meter.

Leaves sprayed with zinc compounds are pressed between filter papers sensitized with dithizone (diphenylthiocarbazone). The resulting precipitate is a light reddish pink which was approximated by a common ceramic plaque. This plaque was calibrated by the National Research Council in terms of Hunter coordinates which were Rd = 47.3, a = 19.1, b = 7.6. These coordinates were related to the standard ICI (International Commission on Illumination) specifications of colour by the following equations.

$$Rd = 100Y \qquad 1$$

$$a = 175fy\ (1.02X\text{-}Y) \qquad 2$$

$$b = 70fy\ (Y\text{-}0.847Z) \qquad 3$$

$$fy = 0.51\ \frac{(21 + 20Y)}{(1 + 20Y)} \qquad 4$$

The X, Y, Z terms are measured by a recording spectrophotometer.

SOURCES OF ERROR

Leaves are pressed between sensitized filter papers at pressures around 5000 psi. If leaves are fresh, chlorophyll stains are produced on the filter paper giving erroneous readings. The most suitable method found to overcome this problem was to dry the leaves at 155°F for two hours and then press between damp freshly sensitized filter paper.

Variation of area between leaves and changes in leaf area due to wilting are not considered important since the method of assessment is comparative. If a leaf shrinks on wilting so will the area covered by precipitate; conversely, any small increase in area due to applied pressure will affect areas of spray material in a similar manner.

The sensitizing solutions also impart colour to the filter paper. For copper detection, potassium ferrocyanide crystals which are bright yellow are dissolved in glacial acetic acid and distilled water. This solution tints the paper a light yellowish green and the colour increases in chroma with the age of the solution. Another undesirable effect of aged solution (over 2 days) is the formation of a bluish halo around the leaf imprint after application of pressure. Errors due to background colours can be minimized by using dry leaves and fresh sensitizing solution which should be kept in cool dark storage.

Since the coloured precipitate is not evenly distributed over a leaf imprint a small variable speed rotator was used to spin the leaf imprint over the sample viewer of the meter. Lukens (3) reported good results with similar techniques on heterogenous samples of foods. In our case spinning the samples had little effect on results. It did not alter the Rd values and caused less than one unit difference in the sum of "a" and "b" scales.

CALIBRATION GRAPHS

Data from the meter were compared with percent coverage figures to determine which colour property or combination of properties would yield some relationship to percent coverage. The Rd value or reflectance properties varied only slightly between samples so that it was not seriously considered. Theoretically, since the instrument measures the difference of the sample colour from a standardizing colour in terms of three dimensional coordinates, the vectoral distance should be related to the percent of coloured precipitate present. In terms of meter readings this vectoral distance would be

$$E = \sqrt{\triangle Rd^2 + \triangle a^2 + \triangle b^2} \qquad 5$$

which is slightly greater than the largest difference of any component but is less than the arithmetic sum of these components.

Fortunately a very simple relationship, the algebraic sum of (a + b), was found to bear a relationship to spray deposits. In the case of zinc a calibration graph shown in figure 1 provided results such that 80 percent of the unknowns were judged by the meter to have spray coverage within 8½ percent of that measured with the transparent grid. The remaining 20 percent of the samples were judged to have spray coverage within 15 percent of the true value. The equation of best fit is

$$S = 2.58C^{0.41} - 2 \quad 6$$

where S is the algebraic sum of "a" and "b"

C is the spray coverage in percent

Twenty-two samples were used in this test and each sample was viewed twice by the meter. Good results can be expected provided precautions are taken to have freshly sensitized filter papers and to use wilted leaves to avoid chlorophyll stains. Since green and red are both measured on the "a" scale the green which is negative can easily exceed the weak red which is positive. The algebraic sum is then too small and erroneous values are obtained.

Results with copper sprayed leaves have not been as rewarding as with zinc. There appears to be greater colour variability within the precipitate of cupric ferrocyanide as evidenced by several tests of pure precipitate sprayed onto filter paper to give complete coverage. The Munsell standard found most suitable was 2.5YR 5/4 having Hunter colour values of Rd = 19.65, a = 13.50, b = 14.70. The Rd values of the precipitate had a range of eleven units and the "a" and "b" values had a range of 2.4 units each. The mean values were Rd = 21.7, a = 9.5, b = 9.1. This variation alone would not account for measurement errors.

Calibration graphs were prepared using two different colour references. In the first instance the Colour Difference Meter was standardized to the background colour of the sensitized paper using Munsell standard 5BG 8/2 or Hunter colour coordinates Rd = 60.33, a = −11.0, b = −0.5

The calibration graph using this standard is shown in figure 2. The equation of best fit is

$$S = 5.4C^{0.21} \quad 7$$

where S and C have been previously defined.

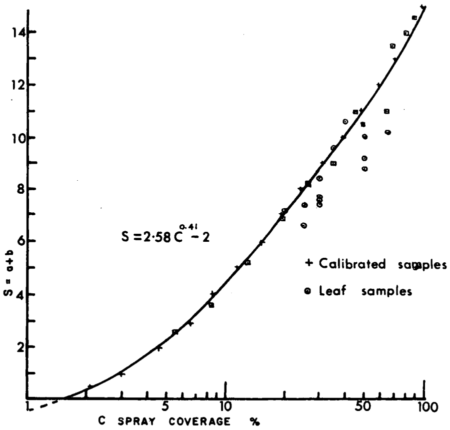

Figure 1. Calibration curve for zinc sprayed leaves standardized to Rd = 47.3 a = 19.1, b = 7.6 on Hunter Colour and Colour Difference Meter.

This graph gives best results at low coverages (less than 50 percent). Out of 66 samples represented in figure 2 with less than 50 percent spray coverage, 70 percent fell within five percentage points of the true coverage and the remaining 30 percent are within 15 percentage points of true coverage. Spray coverage of potato leaflets in excess of 50 percent was rarely encountered in the latter part of the growing season when foliage was dense. This accuracy is considered to be as good as that of an experienced observer. Warner (5) reports that the difference in estimated coverage by a group of assessors may be as much as 20 percent. An individual assessor also tends to estimate coverage consistently high or consistently low.

The second colour reference used to standardize the Colour Difference Meter was Munsell standard 2.5YR 5/4 or Hunter colour coordinates Rd = 19.65, a = 13.5, b = 14.7. The calibration graph using this standard is shown in figure 3. The best equation to fit the data is

$$S = 0.095C^{1.15} \quad 8$$

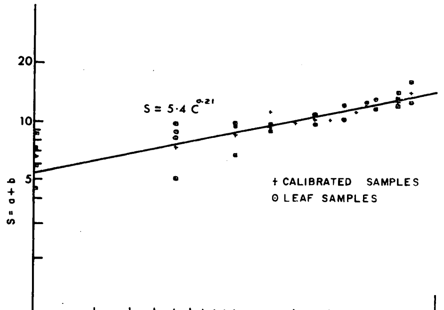

Figure 2. Calibration curve for copper sprayed leaves standardized to Munsell colour 5 BG 8/2 on Hunter Colour and Colour Difference Meter.

where S and C have been previously defined.

This graph gives best results at high coverages (over 50 percent). Of 32 samples represented in figure 3 with more than 50 percent spray coverage, 75 percent are within 10 percentage points of the true coverage and the remaining 25 percent are within 15 percentage points of true coverage. During the early part of the growing season spray coverage on leaflets was frequently greater than 50 percent.

It would appear that two separate colour standards are required in this case. As pointed out earlier in this paper best accuracy of distinguishing colour differences occurs when the Colour Difference Meter is calibrated to a similar colour. There is considerable contrast between the cupric ferrocyanide precipitate and the blue green background of the sensitized paper. In fact they are nearly diametrically opposed in the colour solid as evidenced by their Hunter colour coordinates. Therefore it seems improbable that a single calibration graph would serve the complete range of precipitate coverage involving these particular colours.

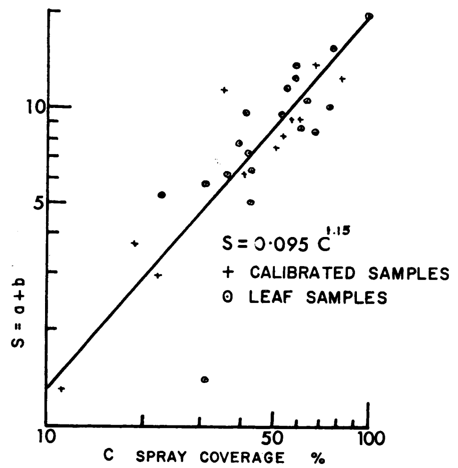

Figure 3. Calibration curve for copper sprayed leaves standardized to Munsell colour 2.5 YR 5/4 on Hunter Colour and Colour Difference Meter.

Although the method does not provide precise results it is at least as accurate as an observer can estimate visually. Where large numbers of samples are used for statistical purposes the errors involved should not be significant. There is also an advantage in time saved. The Hunter Colour and Colour Difference meter automatically balances. Once calibrated the sample is placed over the aperature which is 2.5 inches in diameter, the three scale readings noted and a new sample is presented to the meter. For small leaflet sizes a smaller diameter aperature is available.

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Following that 5 to 10 to 15 percent increases were separated by isoquants into their respective areas on the cross-sectional diagram. Figure 2 shows areas of different moisture increases within the soil profile.

A planimeter was used for measuring the surface areas between 2 to 5, 5 to 10, and 10 to 15 percent isoquants located outside the dyked area. On the diagram only areas extending to the right from number four hole were measured as these represented water losses from irrigated land. Readings on the diagram were converted into actual areas in square feet by multiplying with the appropriate scale ratio.

Actual areas and average moisture increases in percent between isoquants were used to calculate the number of pounds of water that had seeped outside of the dyke at each sampling location.

Calculations were made for a block of soil one foot wide, four feet deep, reaching out to the zero to two percent moisture line which was considered to be unchanged.

Sample calculations:

$$\frac{A \times B \times C \times D}{100} = \text{in pounds of water per lineal foot of dyke.}$$

A—average moisture increase in percent 2 to 5%; (3.5%)

B—the weight of one cubic foot of water in pounds (62.4)

C—the bulk density of the soil (1.16)

D—the actual measured area between isoquants outside of the center line of the dyke in square feet (0.475)

$$\frac{3.5 \times 62.4 \times 1.16 \times 0.475}{100} = 1.2 \text{ lbs}$$

The actual bulk densities as determined for each plot were used in calculations. Water losses in pounds were calculated for each moisture range and each soil profile. The data were tabulated according to the application rates and crops.

RESULTS

The average water losses for each pair of duplicate plots varied from 9.83 to zero pounds of water per lineal foot of dyke (figure 2). Generally higher losses occurred from plots that contained higher soil moisture prior to irrigation. Also, higher application rates tended to contribute more heavily to border losses.

The average loss from plots in perennial crops was 4.20, from cereal plots, 3.81, and from the row crops 2.37 pounds of water per lineal foot of dyke. The average for all crop and application rates was 3.47 pounds per lineal foot of dyke. This loss presented about three percent of the water applied to a 30- x 30-foot dyked plot.

This sampling and calculating technique provided data on the magnitude of water losses from border dyked areas, on a fine sandy loam to fine sandy soil. The errors in consumptive use studies arising from water lost outside of a border dyked area are about equal to errors involved in determining soil moisture by the gravimetric sampling technique. Border dykes are efficient barriers to the lateral movement of water.

REFERENCES

1. Richards, L. A., Gardner, W. R. and Ogata, G. Physical Processes Determining Water Losses from Soil. Soil Sci. Soc. Amer. Proc. 20: 310-314. 1956.
2. Staple, W. J. and Lehane, J. J. Movement of Moisture in Unsaturated Soils. Can. Jour. of Agricultural Sci. 34: 329-341. 1954.
3. Wilcox, J. C. Rate of Soil Drainage Following Irrigation. Can. Jour. Soil Sci. 39: 107-119. 1959.
4. Wilcox, J. C. IV. Rate of Soil Drainage Following Irrigation. Can. Jour. Soil. Sci. 42: 129-136. 1962.

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SUMMARY

A Hunter Colour and Colour Difference meter can distinguish between variations in area of coloured precipitates of zinc and copper spray compounds. The accuracy obtainable is at least equal to visual methods of comparing unknown coverages to prepared samples whose coverage has been determined by using a transparent squared grid or by planimeter. Special precautions are necessary to minimize the effect of background colour. All sensitizing solutions should be freshly prepared in clean pyrex containers. Sensitized filter papers should be dried and stored in a cool dark place for not more than two days. Leaves that are to be pressed between sensitized paper should be wilted to avoid staining the paper by chlorophyll. While the method of obtaining coloured precipitates involves no special equipment the Hunter Colour Difference meter costs approximately $3800. Where large numbers of leaf samples are involved its speed of operation and repeatability probably justify the cost. The instrument is very versatile and can be utilized for many projects involving colour assessment.

For zinc a suitable colour standard was a ceramic wall tile with Hunter colour values of Rd = 47.3, a = 19.1 and b = 7.6. Good results were obtained provided there were no chlorophyll stains.

For copper two colour standards were used. For spray coverage below 50 percent Munsell colour 5BG8/2 gave best results and for spray coverage over 50 percent Munsell colour 2.5YR 5/4 gave best results although neither method worked as well as the zinc.

REFERENCES

1. Boldgett, F. M. and Mader, E. O., "A Method of Recording Distribution of Copper Dusts or Sprays on Leaves", Phyhto Pathology 24:418-422, 1934.
2. Hunter, R. S., "Instrumental Methods of Colour and Colour-Difference Measurement", Am. Ceramic Soc. Bulletin July 1957 Vol. 36: 249-255.
3. Lukens, H. C. and Creese, F. G., "A Sample Rotator for the Hunter Colour and Colour-Difference Meter", Food Technology Oct. 1958 Vol. 12, No. 10, 570-572.
4. MacCarthy, H. R., "A Technique for Assessing Leaf Coverage with Zinc Fungicides", Plant Disease Reporter Jan. 15, 1959 Vol. 43 No. 1.
5. Warner, L. M., "Colour Measurement Applied to the Determination of Spray Coverage on Leaf Surfaces", Unpublished student thesis April 1961 University of B.C. Vancouver.
6. Windt, T. A. and Staley, L. M., "Potato Sprayers", Can. J. Agr. Eng. Jan. 1962 Vol. 4, No. 1: 36-38.

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