Proceedings V World Avocado Congress (Actas V Congreso Mundial del Aguacate) 2003. pp. 585-589.

LOGARITHMIC SISTEMS FOR MEASURING SEVERITY OF ANTHRACNOSE AND SCAB IN AVOCADO FRUITS

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ABSTRACT

Scab (*Elsinoe perseae*) and anthracnose (*Glomerella cingulata*) are the major diseases of avocado fruit (*Persea americana*) in Michoacan, Mexico, reducing the fruit acceptability for national and export markets. This research presents two logarithmic diagrammatic scales based on the Horsfall-Barratt principle for the study of the *E. perseae* and *G. cingulata* pathosystems in avocado fruit. These scales provide a precise, accurate, and reproducible evaluation of each disease. The scales were generated calculating the ratio of diseased tissue on fruits with different severity levels using digital-image analysis and a software used to generate disease severity values for an evaluation system based on classes. Linear regression analyses of estimated and actual data from 30 evaluators were used to estimate precision (r^2), accuracy (b_1) and reproducibility (t-test of r^2 and b_1 of two trials). The precision and accuracy achieved during the validation of these measurement systems showed the scales to be reliable for field use ($r^2 > 0.8$ and $b_1 > 0.8$, respectively).

Key Words: Epidemiology, diagrammatic scale.

INTRODUCTION

Mexico is the World's first avocado (*Persea americana* Mill.) producer, turning out 782,000 metric tons – approximately 34% of the world total – from 96,000 ha (Teliz *et al*., 2000). The most serious diseases on avocado fruit in Mexico are scab and anthracnose.

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Non-arbitrary systems have been proposed for the selection of numerical values for severity measurement, specifically those that follow the Weber-Fechner principle, are not decisively the most epidemiologically adequate due to their reproducibility, precision, and accuracy (Hebert, 1982; Shokes *et al.*, 1987). Evaluation systems designed with a logarithmic or linear principle can be equally adequate since with proper training accuracy and precision can obtained (L. Campbell, 1998, personal communication; Nutter *et al.*, 1993). Scales and diagrams have been proposed to represent values or classes associated to an evaluation system regardless of the method used to select these values or classes (Campbell & Madden, 1990; Fetch & Steffenson, 1999).

MATERIALS AND METHODS

1. Collection of diseased fruits. Fruits of avocado 'Hass' with symptoms of scab and anthracnose were collected in the avocado-producing region of Michoacan, Mexico during the 1999 Winter. Five orchards were assessed for this purpose. The fruits were photographed and digitalized for subsequent area analysis.

2. Measurement of healthy and diseased areas of the fruits. Starting from the digital images of 50 avocado fruits with different degrees of severity and using Micrografx Designer 4.0®, healthy and diseased portions of the fruits were coloured (Figure 1). The ratio of the two areas was determined using Image Tool 1.28 for Windows, (Uni. of Texas, 1997). The proportions for healthy and diseased tissue allowed the calculation of disease severity.

3. Construction of the scale. Scales were generated with DOSLOG version 1.0 for Windows®, (Osada & Mora, 1997) which employs an adjustment of the method proposed by Horsfall & Barratt (1945), based on the Weber-Fechner law. The severity intervals were defined using midpoints of each class. An image with a severity value descriptive for each class midpoint was used to create the scales.

4. Validation. The reproducibility, precision, and accuracy of each measurement system were determined with the participation of students in two successive evaluations. They received 15-minute training in the use of the scale. Fifty photographs of fruits previously analyzed were shown with a digital image projector. Each evaluator used a colour diagrammatic logarithmic scale printed on a letter-size page to evaluate each fruit by comparison. Each measurements were correlated with actual data to estimate precision (r^2) and accuracy (b_1) through a simple linear regression model by SAS·. r^2 values for the first and second evaluations were compared by t-test, for an equal number of b_1 for both evaluations were analyzed, to determine the reproducibility of the independent evaluations of the same images.

RESULTS

Anthracnose scale. The logarithmic scale was generated for a maximum severity of 88% (Figure 2). Each class was represented by a midpoint (in percent). The evaluators improved their precision, with values of r^2 averaging 0.85 in the first evaluation and 0.91 in the second. In general, precision (r^2) and accuracy (b_1) improved in the second evaluation. These results show that previous evaluator training is advisable to improve precision and accuracy of measurements. Reproducibility is inferred from the fact that r^2_1 (r^2 from the first evaluation) vs. r^2_2 and the first b_1 vs. the second b_1 did not show significant differences between the two evaluation sessions measured by a t-test. **Scab scale**. The measurement system considered a 100% maximum severity, distributed in eight classes (Figure 3). Determination coefficients were obtained in two repetitions. Forty-five percent of the evaluators improved their precision (from 0.85 to 0.94) and accuracy (from

0.94 to 1.01) in the two successive evaluations. **Precision.** Acceptable coefficients of determination (> 0.8) were achieved for both diseases, demonstrating precision can be obtained with the use of these measurement systems. On the contrary, an adequate precision may not reached without the use of a diagrammatic scale for disease evaluation since the eye tends to misjudge values, as noted by Sherwood *et al*. (1983) and Cassanello *et al*. (1989). **Accuracy**. Values close to 1.0 in the validations reflected the accuracy of the logarithmic diagrammatic scales. **Reproducibility**. There was no significant difference ($p = 0.05$) between r^2 or b_1 values between evaluations. It is necessary that the evaluator adopts for each region a different disease measurement system according to the type of symptoms or different severity levels, allowing a correct evaluation of the disease within the severity range found in the region. **Training and interpolation.** The precision and accuracy improved in the second evaluation, due to the training of evaluators. For this reason, previous evaluator instruction is necessary to improve the measurements. This coincides with the opinions of Campbell, C.L., 1998 (Personal communication) and Nutter *et al*. (1993). For this reason, it is recommended that the evaluators be trained for a period of at least 30 minutes prior to the evaluation.

The measurement systems were appropriate for evaluating diseases from their initial disease severity Y_o, to their maximum disease severity, Y_{max}, which are important in epidemiological studies; nevertheless, it is recommended that interpolations be made between midpoints of classes for more precise measurements.

CONCLUSIONS

Logarithmic diagrammatic scales to assess anthracnose and scab diseases of 'Hass' avocado fruit were characterized by their ease and quickness during evaluations, which makes them very practical for disease assessment in the field. A similar magnitude in two independent measurement events reflected the reproducibility of the measurement systems. It is also concluded that the scales are precise, because the two repeated measurements had a small range of variation. It is evident that the precision and accuracy improved with practice, as the evaluator acquired skill, so previous evaluator training is essential to assure quality measurements. The logarithmic systems are available from the authors.

Acknowledgements

The authors express our gratitude to the avocado producers Alejandro Ayala-Morfin, Alejandro Guerrero-Vázquez, and Juan Carlos Robles-Monroy who made possible the application of the rating scales.

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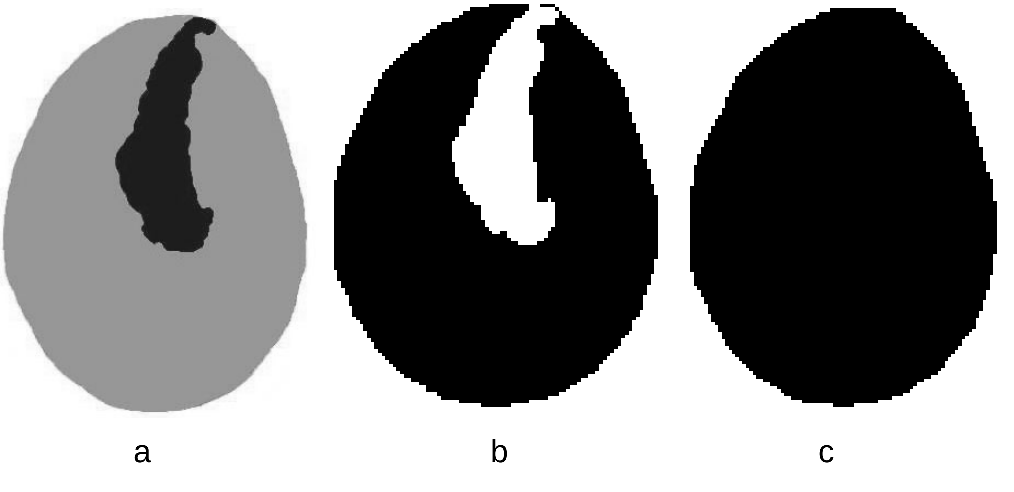

Figure 1. (a) Image of an avocado fruit coloured for conversion to binary image. (b) Binary image of the fruit, to determine the proportion of diseased tissue. White count (with symptoms) contrast with black count (healthy tissue). (c) Total fruit surface.

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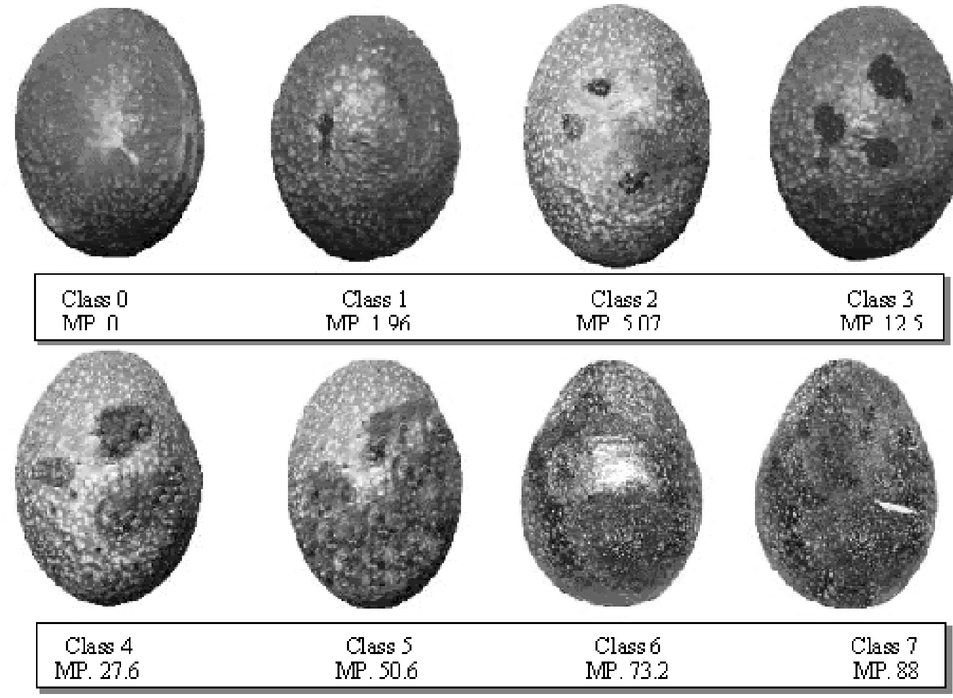

Figure 2. Logarithmic diagrammatic scale for evaluating anthracnose (*Glomerella cingulata*) symptoms on 'Hass' avocado fruit. Michoacan, Mexico. 2000. MP= midpoint severity in percentage.

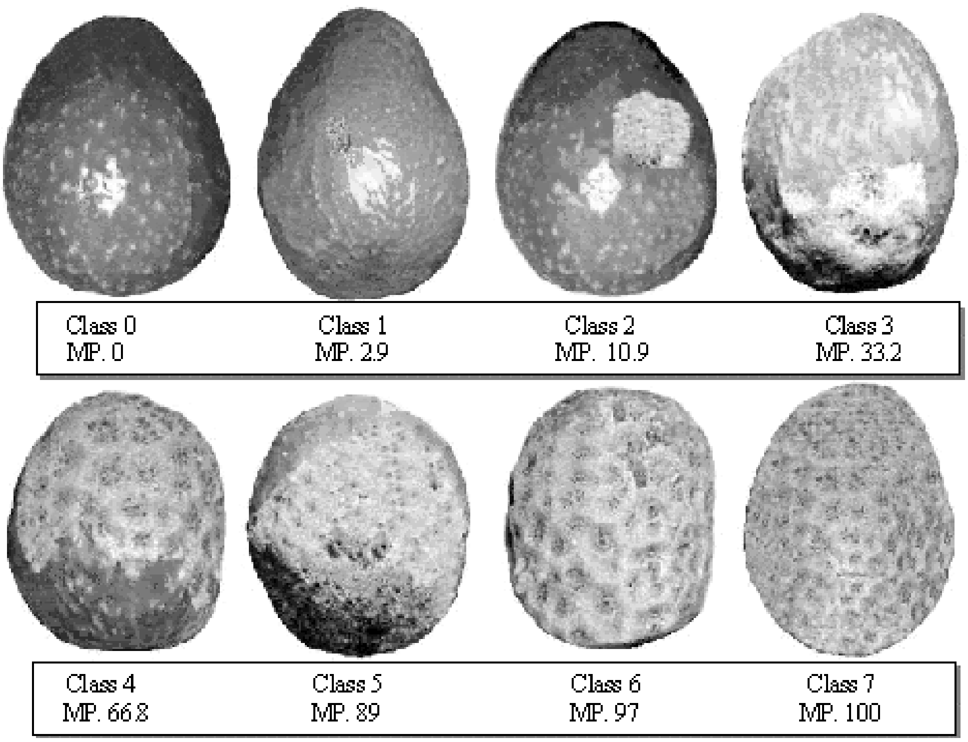

Figure 3. Logarithmic diagrammatic scale for evaluating scab (*Elsinoe perseae*) symptoms on 'Hass' avocado fruit. Michoacan, Mexico. 2000. MP= midpoint severity in percentage.