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SHORT COMMUNICATION / *COMUNICAÇÃO*

Diagrammatic scale for assessment of grapevine rust

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ABSTRACT

A diagrammatic scale with six levels of disease severity (1, 5, 12, 25, 50 and 75%) was developed to assess grapevine (*Vitis* spp.) rust severity, caused by the fungus *Phakopsora euvitis*. Two versions of the scale, in black-and-white and in color, were validated by seven raters without previous experience with grapevine rust, who estimated the severity of 30 grapevine leaves showing rust symptoms, with and without the use of the scales. Precision and accuracy were determined by linear regression, relating the assessments using the scales to actual severity. Actual severity was assessed with the software ASSESS®. Using the diagrammatic scales, some raters were able to improve precision and accuracy. The color scale provided slightly more precise and accurate estimates than the black-and-white scale.
Keywords: disease assessment, pathometry, *Phakopsora euvitis*, *Vitis* spp.

RESUMO

Escala diagramática para avaliação da ferrugem da videira

Uma escala diagramática com seis níveis de severidade (1, 5, 12, 25, 50 e 75%) foi desenvolvida para quantificação da severidade da ferrugem da videira (*Vitis* spp.), causada pelo fungo *Phakopsora euvitis*. Duas versões da escala, em preto-e-branco e em cores, foram validadas por sete avaliadores sem experiência prévia com essa doença, os quais estimaram a severidade em 30 folhas com sintomas de ferrugem, com e sem auxílio das escalas. A severidade real foi determinada com o programa ASSESS®. A acurácia e a precisão foram analisadas por meio de regressão linear, confrontando valores de severidade reais com estimados. Com a utilização da escala, os avaliadores apresentaram melhores níveis de precisão e acurácia. O emprego da escala em cores proporcionou estimativas um pouco mais acuradas e precisas do que a escala em preto-e-branco.
Palavras-chave: avaliação de doenças, patometria, *Phakopsora euvitis*, *Vitis* spp.

Grapevine rust, caused by the fungus *Phakopsora euvitis* Y. Ono, occurs on leaves of *Vitis* spp. forming small, yellowing pustules of uredia, either scattered or densely distributed, mostly on the lower leaf surface (Ono, 2000). The disease causes premature defoliation of grapevines, by which fruit quality and yield are reduced. Its damages have been recorded in some tropical, subtropical and temperate areas of Asia and America. In America, this disease has been known for long time in the Southeastern United States, Central America, Venezuela and Colombia (Leu, 1988; Ono, 2000), but in Brazil it was found more recently (Tessmann *et al*., 2004). This disease was found recently also in Australia (Weinert *et al*., 2003).

This disease was first detected in Brazil in 2001, affecting commercial grapevines in the State of Paraná. It has spread to other states and become an endemic disease in some tropical and subtropical regions of the country (Tessmann & Vida, 2005). Still there are few published data about losses caused by this disease in vineyards, but it has potential to be destructive under some favorable conditions (Tessmann & Vida, 2005).

Diagrammatic scales are valuable tools for plant disease epidemiology and control. They reduce the subjectivity of disease severity visual estimates, while their use is expected to be easy and quick for a wide range of conditions, with reproducible, accurate, and precise results (Berger, 1980). Indeed, since Horsfall & Barratt (1945) introduced the application of ´´Weber-Fechner´s stimulus-response law´´ for plant diseases rating scales, many diagrammatic scales have been proposed for assessing disease severity for several crops (James, 1971; Campbell & Madden, 1990; Amorim *et al*., 1993; Andrade *et al*., 2005, Belasque Jr. *et al*., 2005; Nascimento *et al*., 2005; Godoy *et al*., 2006). For grapevines, diagrammatic scales are available only for bacterial canker (Nascimento *et al*., 2005) and downy mildew (European and Mediterranean Plant Protection Organization, 1981). The objective of this work was to develop and validate a diagrammatic scale for assessing grapevine rust severity.

For developing the scale, 50 leaves of ´Niagara´ grapevine showing different levels of rust severity, ranging from minimum to maximum severity, were collected in a commercial orchard. Leaves showing mixed symptoms with other grape diseases were not included in the analysis. The leaves were photographed with a digital camera and the images were used for assessing the percentage of leaf area affected by the disease with the software ASSESS® (American Phytopathological Society, Saint Paul, USA). The images were used to determine the minimum, maximum and intermediate levels of disease severity occurring in field. The determination of severity levels of the scale was according to Weber-Fechner´s stimulus-response law (Campbell & Madden, 1990).

The proposed scale was validated based on analysis of precision, accuracy and reproducibility of assessments. For this, seven people without previous experience with grapevine rust carried out a severity assessment of 30 grapevine leaves with different levels of rust symptoms. Severity values estimated by the raters without aid of the scale and using color and black-and-white scales were compared with actual severity values. The accuracy and precision of the assessments of each rater were determined by linear regression, where actual severity was the independent variable and estimated severity the dependent variable. The accuracy of the estimates of each rater was determined by t-test applied to the slope coefficient (*b*), to verify whether they were significantly different from 1.0, and to the intercept (*a*) to verify whether they were significantly different from zero. The precision of assessments was estimated by the coefficient of determination (R^2) of the regression line and by the variance of the absolute errors (estimated severity minus actual severity) for each assessment (Nutter & Schultz, 1995).

A diagrammatic scale was proposed, having severity levels of 1, 5, 12, 25, 50 and 75%, in black-and-white and in color version (Figure 1). It represents rust pustules produced on the lower side of the grape leaves, including chlorotic halos, necrotic tissue surrounding pustules and coalesced lesions. Even though the minimum level of grapevine rust severity in the scale was 1%, this level may actually be lower in field. Severity levels below 1% did not seem practical, since the early symptoms are a few scattered pustules which are difficult to see. The maximum severity on leaves was around 75%, with leaf drop occurring after this level.

The analysis of accuracy was applied to verify how close the estimate severity levels were to actual severity levels (Nutter Jr. & Schultz, 1995). Figure 2 shows the linear regressions obtained between actual and estimated severity for all raters, without and with the scales. Without aid of the diagrammatic scale, the values of the slope coefficients (*b*) were significantly different from 1.0 for raters 1, 2 and 6, meaning that the assessments done by these raters were not accurate (Table 1). With the black-and-white scale raters 2 and 6 were not accurate, and with the color scale only rater 2 was not accurate. Thus, this parameter indicated that the diagrammatic scale improved accuracy of assessments for some raters, but the color scale only slightly improved accuracy in relation to the black-and-white scale. The intercept parameter (*a*) was significant only for rater 2, without using the scale (Table 1). Actually, this parameter was not very informative for this study.

The analysis of precision was applied to verify the repeatability or variation associated with an estimate, regardless of the mean value. Precision is estimated by the coefficient of determination (R^2) and by the variance of the absolute errors (estimated severity minus actual severity) (Nutter & Schultz, 1995). The R^2 for assessments without aid of the scale, with color scale, and with black-and-white scale ranged from 0.76 to 0.91 (average 0.82), 0.84 to 0.96 (average 0.89), and 0.75 to 0.91 (average 0.82), respectively, showing that precision was not improved with aid of the black-and-white scale but it was improved with aid of the

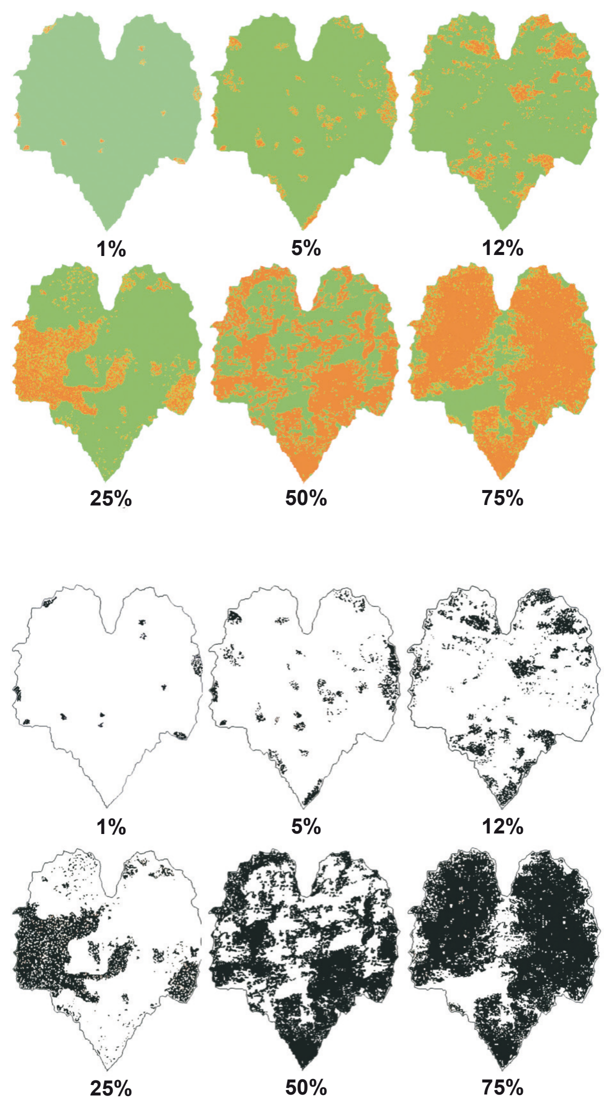

FIG. 1 – Diagrammatic scale of grapevine (*Vitis* spp.) rust severity, caused by *Phakopsora euvitis*, in color **A.** and black-and-white **B.** Numbers are the percentage of diseased leaf area.

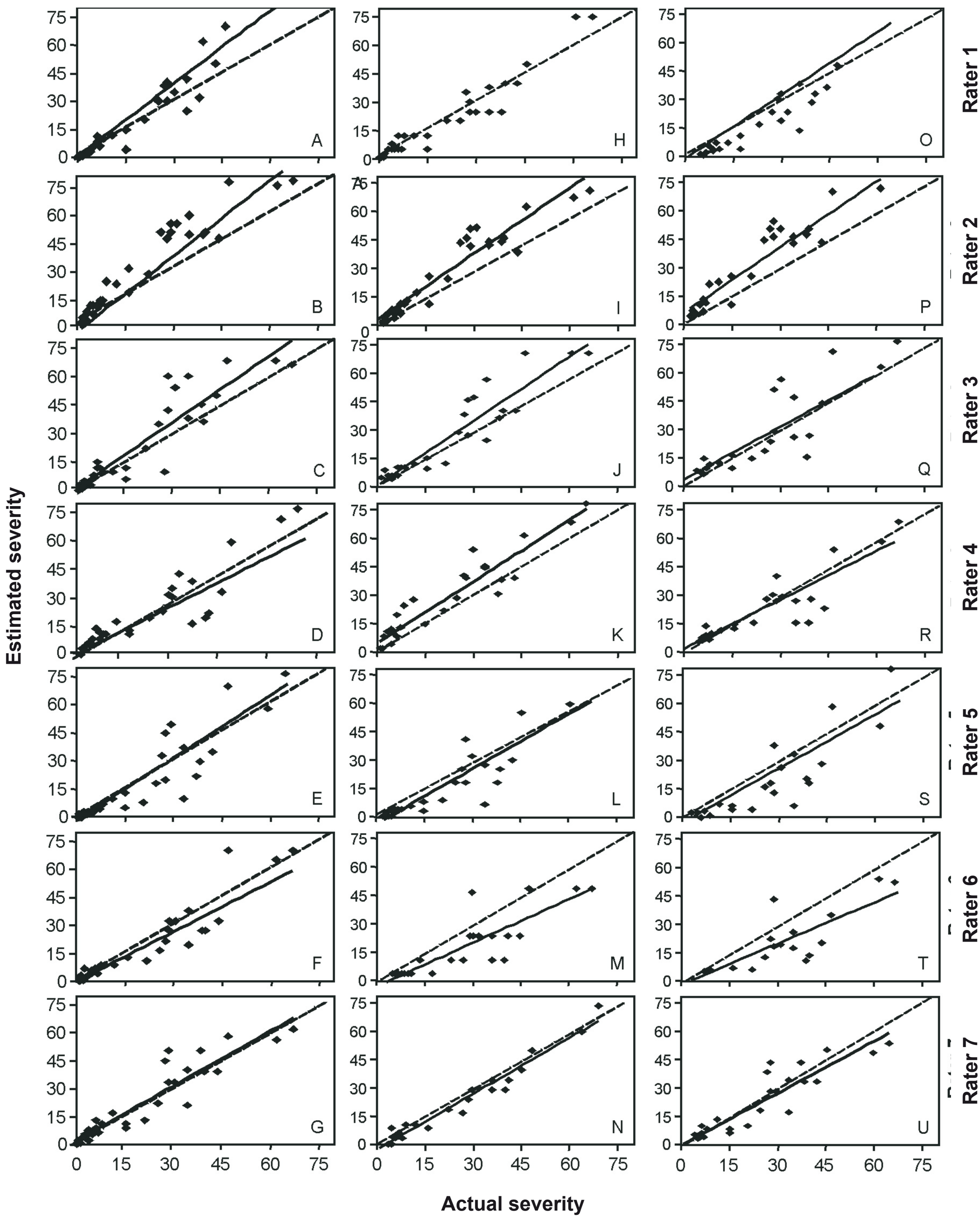

FIG 2. – Estimated severity (•) of grapevine (*Vitis* spp.) rust, caused by *Phakopsora euvitis,* and linear regressions obtained between actual and estimated severity (solid line). Dotted lines represent an ideal situation, with estimated severity equal do actual severity. **A-G**: without scale. **H-N:** with aid of the color scale. **O-U:** with aid of the black-and-white scale.

color scale (Table 1). The variance of absolute errors among raters, with and without aid of the scales, is shown in Figure 3.

The precision of assessments can also be evaluated by analyzing the reproducibility of measurements among raters when assessing the same sample (Nutter Jr. *et al*., 1993). In this study, the coefficients of linear regression analysis of assessments among raters were higher for color scale (0.80 to 0.96) than for black-and-white scale (0.77 to 0.92) or without aid of the scale (0.67 to 0.93), providing additional evidence that diagrammatic scales improved precision.

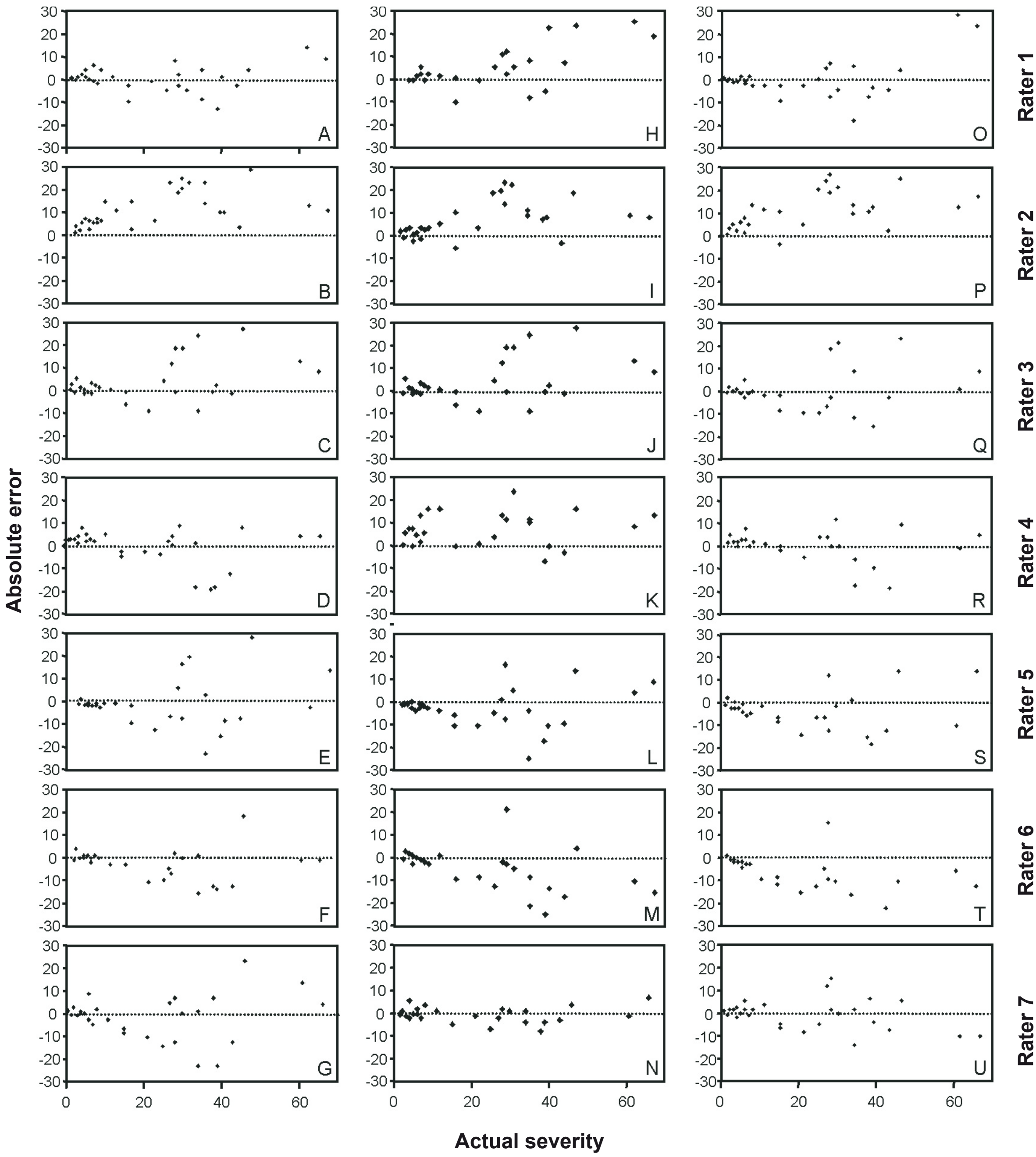

FIG 3. – Absolute errors (actual severity – estimated severity) for assessments of grapevine (*Vitis* spp.) rust severity, caused by *Phakopsora euvitis,* without the aid of the diagrammatic scale. and linear regressions obtained between actual and estimated severity (solid line). Dotted lines represent an ideal situation, with estimated severity equal to actual severity. **A-G**: without scale. **H-N:** with aid of the color scale. **O-U:** with aid of the black-and-white scale.

In this study most of the assessment errors occurred in the range of 20 to 40% of severity (Figure 3). These results did not differ from other studies. Godoy *et al*., (2006) observed most errors for assessment of soybean rust were in the range from 20 to 50% for inexperienced raters, and from 10 to 20% for experienced raters; and Andrade *et al*., (2005) observed that most errors for assessment of eucalyptus leaf spot ranged from 15 to 30% of severity, for either inexperienced or experienced raters.

In this study, it was verified that some raters needed help from the scale for good assessments. It is possible that these results are due to non-declared previous experience of some raters with quantification of other diseases, as well differences in their natural ability for plant disease quantification. The results showed that even though the advantages of the color scale compared to black-and-white

TABLE 1 - Intercepts (a), slope coefficients (b), and coefficients of determination (R^2) of the regression line for actual (independent variable) versus estimated severity (dependent variable) of grapevine rust (*Phakopsora euvitis*) for seven raters, without the diagrammatic scale and with the scale in color and black-and-white

Rater	Without scale			Color scale			Black-and-white scale		
	a[a]	*b*[b]	R^2	*a*	*b*	R^2	*a*	*b*	R^2
1	0,61	1,29*	0,85	0,99	1,14	0,90	-4,14	1,20	0,88
2	5,97*	1,24*	0,91	3,55	1,22*	0,92	4,21	1,27*	0,91
3	1,68	1,16	0,83	0,21	1,21	0,88	-1,34	1,04	0,78
4	1,89	0,88	0,83	2,49	1,09	0,89	1,69	0,88	0,82
5	-2,70	1,08	0,79	-3,43	1,03	0,84	-4,05	0,98	0,80
6	-0,27	0,85*	0,76	-0,82	0,92	0,87	-1,90	0,73*	0,75
7	-2,28	1,03	0,78	-0,39	0,99	0,96	1,99	0,88	0,86

* Situations when the null hypothesis (*a*=0 or *b*=1) was rejected by t-test, $P<0.05$.

seemed quite limited, the proposed diagrammatic scale can be used for adding accuracy and precision of grapevine rust severity assessments.

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