Phytopathologia Mediterranea
The international journal of the Mediterranean Phytopathological Union

Firenze University Press
www.fupress.com/pm

OPEN ACCESS

Citation: G.C.B.M. da Silva, R. Pio, R.C.M. Pereira, P.M. Peche, E.A. Pozza (2019) Development and validation of a severity scale for assessment of fig rust. *Phytopathologia Mediterranea* 58(3): 597-605. doi: 10.14601/Phyto-10967

Accepted: November 6, 2019

Published: December 30, 2019

Data Availability Statement: All relevant data are within the paper and its Supporting Information files.

Competing Interests: The Author(s) declare(s) no conflict of interest.

Editor: Tito Caffi, DI.PRO.VE.S., Università Cattolica del Sacro Cuore, Piacenza, Italy.

Research Paper

Development and validation of a severity scale for assessment of fig rust

Gabriella Cristina Botelho Mageste da SILVA[1], Rafael PIO[1], Renata Cristina Martins PEREIRA[2], Pedro Maranha PECHE[1], Edson Ampélio POZZA[2,*]

[1] *Departament of Agriculture, Federal University of Lavras (UFLA) - Lavras – MG - 37200-000, Brazil*
[2] *Departament of Phytopathology, Federal University of Lavras (UFLA) - Lavras – MG - 37200-000, Brazil*
*Corresponding author: edsonpozza@gmail.com

Summary. Standardized methods for quantifying rust severity (*Cerotelium fici*) on fig leaves (*Ficus carica* L.) are required, so this study aimed to develop and validate a diagrammatic scale to assessment the severity of this disease. Fig leaves that exhibited varying severities of rust symptoms were collected in the field. The actual severity, maximum and minimum limits, and intermediate levels of the scale were determined based on the frequency distribution of the severity values found in the field. In validation of the scale, eight evaluators estimated the severity in 50 leaves with different levels of symptoms with and without the use of the diagrammatic scale. Accuracy and precision of the data were evaluated, and linear regression was used to assess the repeatability and reproducibility of the estimates. The use of the diagrammatic scale provided adequate results for the parameters analysed when compared assessments made without use of the scale, confirming reliability of the estimates to evaluate rust severity on fig leaves.

Keywords. *Ficus carica*, *Cerotelium fici*, Lin's method.

INTRODUCTION

Fig (*Ficus carica* L.) is among the most important cultivated world fruit species. The use of fig fruit as food, and of fig plants for ornamental purposes, have been recorded for thousands of years including in the Bible (Eisen, 1901). Turkey is the largest producer of figs in the world, producing 305,450 tonnes per year, followed by Egypt, Morocco, Algeria and Iran (FAO, 2018). European countries, including Portugal, Spain and Italy, are also major producers and exporters of figs (Khemira and Mars, 2017). In subtropical regions, fig crops are grown to produce ripe figs to supply fresh fruit markets, or unripe fruit for the production of sweets, compotes and crystallized figs (Dalastra *et al.*, 2009).

Although fig originated in temperate regions (Pio *et al.*, 2019), it can adapt to different climates and soil conditions, which has boosted expansion of fig production to Brazilian tropical and subtropical regions (Chalfun *et al*., 2012). In the last 10 years, Brazil's cultivated fig area has remained steady at approx. 2,591 ha (IBGE. 2019). The primary fig-producing states in Brazil include Rio Grande do Sul (11,918 tonnes), São Paulo (10,903 tonnes) and Minas Gerais (1,698 tonnes). Recent decades have seen increased exploitation of fig crops in Brazil and Chile, the produce from which is destined for export to North African and European countries during the production off-season in those regions (Pio *et al*., 2017). However, when grown in subtropical regions, some diseases affect fig crops.

Fig rust (*Cerotelium fici* (Cast.) Arth.) is the principal disease that affects fig crops (Galleti and Rezende, 2005). Symptoms of the disease on adaxial surfaces of fig leaves appear as angular yellow-green spots that progress to brown. On abaxial leaf surfaces orange-red pustules develop that contain powdery masses of spores. In severe infections, the leaves fall, and growth and ripening of the figs are halted. With the premature fall of leaves, there is a reduction in the accumulation of carbohydrates, which compromises the next fruit production cycle (Galleti and Rezende, 2005; Solano-Báez *et al*., 2017).

Due to the losses associated with fig rust, appropriate disease management methods are required. These include development of resistant cultivars, fungicide applications, development of biological control agents, resistance inducers, appropriate pruning techniques or crop management. However, to measure the effectiveness of these techniques and to identify which can be integrated into crop management, it is necessary to quantify the disease (Gomes *et al*., 2004).

Quantifying disease enables control measures to be evaluated for whether they will be effective and therefore recommended for application in the field. For producers, the benefits of disease quantification include the assistance for efficient crop management decisions and prioritization of resources to enable low environmental impacts in sustainable disease management (Bergamin Filho and Amorim, 1996).

Among the methods for assessment of plant diseases, the most commonly implemented are those that are visual. These are simple because they do not require the use of sophisticated equipment, and they are accurate and precise (Campbell and Madden. 1990). Key tools for employing these techniques are diagrammatic disease severity scales. This method helps to define disease severity using photographs or diagrams of symptomatic plants or their organs. However, although this approach is simple, development must meet criteria to ensure the correct quantification of disease severity (Bergamin Filho and Amorim, 1996).

The primary aspects to be evaluated in the development of a diagrammatic disease severity scale are the minimum and maximum limits of the scale corresponding to the disease levels found in the field, and use of images that display a pattern compatible with the symptoms representing the levels of disease. A further important consideration is the limits of visual acuity of the human eye, according to Weber-Fechner's Law, assigning scores with respective severity intervals, as the human eye has difficulty seeing points or precise percentage values (Horsfall and Barratt, 1945; Nutter and Schultz. 1995).

The present study aimed to develop and validate a diagrammatic scale for accurate and precise assessment of fig rust, because no standardized methods were available for quantifying severity of the disease, which is the most important disease affecting fig orchards in subtropical conditions.

MATERIALS AND METHODS

Diagrammatic scale development

To develop the diagrammatic scale, 190 fig leaves from the field were randomly collected, that displayed different levels of disease severity. The leaves, naturally infected, were from several fig trees in an experimental orchard at the Federal University of Lavras, Brazil. The municipality is located at 21° 13' 40" south latitude and 44° 57' 42" west longitude, at an average altitude of 970 m above sea level. According to the Köppen climate classification, Lavras has a tropical climate of the Cwa type, characterized by dry winters and hot, humid summers (Alvares *et al*., 2014). To confirm the causal agent of the disease on the leaves, anatomical sections were prepared from a diseased leaf and analysed for the pathogen morphology.

All plant material was photographed on a white background, using a Nikon d3100 digital camera, in automatic mode, with 18–55 mm lens focal length. Subsequently, the diseased and total leaf area were determined for each leaf using the Assess® software (American Phytopathological Society). Pustules and the areas with necrotic and chlorotic tissue caused by the disease were considered as diseased areas.

According to the minimum and maximum levels found, a frequency plot was constructed, plotting the percentage of damaged leaf area (x-axis), in severity intervals of 5% (y-axis). These values were then fitted to a simple linear model and to non-linear exponential and logarithmic models (Campbell and Madden. 1990). The model that best fitted the frequency plot was chosen as indicated from the largest R^2 and the significance of the parameters of the equations in the t-test. The disease severity scale was created according to the intervals with the greatest concentration of leaves having the same percentage of damaged area. The severity intervals for each score were established according to Weber-Fechner's visual acuity law (Horsfall and Barrat, 1945; Nutter and Schultz, 1995) and according to the shape and distribution of the lesions. Photographs of leaves with disease lesions were then used to develop the scale.

Diagrammatic scale validation

To validate the diagrammatic scale, 50 leaves of fig showing symptoms of rust were used, representing all variation levels of dis-ease severity. In three evaluations, 8 evaluators without experience in quantification of plant disease observed images of diseased leaves using Microsoft PowerPoint 2010. The first evaluation was performed without using the scale. After an interval of 7 days, a second evaluation was performed aided by the diagrammatic scale. To assess the repeatability of the observed values, a third evaluation was performed after 7 days, also using the proposed scale.

Based on the data obtained from each evaluator the accuracy and precision the developed scale were determined using Lin's method. Lin's concordance correlation coefficient (Pc) (Lin. 1989), to assess agreement between pairs of observations, was used to measure adjustment between the actual values and estimated disease severities. The method also includes other variables to aid in validation. The scale shift factor, where 1 = perfect agreement between x and y, measures the difference between actual and estimated values, and is calculated as the difference between the slope of the fitted regression lines and the concordant line. The location shift factor, where 0 = perfect agreement between x and y, estimates the change of the fitted regression line relative to the concordant line, by measuring the difference in height between the two lines. The BIAS correction factor, which measures how far the fitted line deviates from the concordant line, was calculated from the location shift factor and the scale shift factor, derived from the means and standard deviations of x and y. In addition to these factors, Pearson's correlation was used to evaluate the precision of the assessments. The confidence interval (CI) ($P < 0.05$) between the groups of evaluators, with and without the use of the scale, was calculated to determine if there were significant differences between the evaluations.

The repeatability of the estimates from each evaluator was determined by R^2 values of the linear regression between two assessments using the scale (Nutter *et al.*, 1993). The reproducibility of the estimates was evaluated by R^2 values obtained from linear regressions between the estimated severities of the same sample unit using different evaluators in pairs (Kranz. 1988; Campbell and Madden. 1990; Nutter and Schultz. 1995).

The data were tabulated and the statistical analyses performed using the RStudio software (R Core Team, 2018), and the epi.ccc function of the epiR package (Stevenson *et al.*, 2018) to determine the Lin's concordance correlation coefficient.

RESULTS

Scale development

The minimum and maximum severity of fig rust was 0% and the maximum severity was 89.3%. A high proportion (43%) of leaves were in the frequency intervals up to 5% severity (Table 1). Based on the disease severity found in natural infections, the scale had a maximum level of 89.3%, with clorotic and necrotic areas.

The best model adjusted for the frequency values in the severity intervals was logarithmic, in this case in according of Weber-Fechner's law, with the greatest R^2 (87%) and significance of the parameters of the equations in the t-test (Table 2).

The severity scale was developed using six scores or percentage intervals (Figure 1), three of which were distributed into intervals ranging up to 15.0% of diseased leaf area. The interval up to 1% included 11.6% of the total leaves, constituting the greatest frequency unit interval. The six percentage severity intervals of the scale were 0, 0.1–5.0%, 5.1–15.0%, 15.1–25%, 25.1–50.0% and >50%.

Scale validation

According to Lin's method, estimates of disease severity assessments improved with the use of the proposed scale (Table 3). According to the concordance coefficient and correlations between the actual and estimated values, greater estimation efficiency was obtained with use of the scale (a = 0.80) compared to evaluations without use of the scale (a = 0.71). The evaluators overestimated disease severity when not using the scale (c = 0.33), and underestimated severity when they used the scale (c = -0.28). The confidence interval between the two evaluations did not differ significantly, however, proving that there was no significant improvement in the variable under analysis. The Pearson's correlation

Table 1. Frequency distribution, in unit intervals, of disease severity values (%) of rust on fig leaves.

Interval (Severity %)	Frequency	Percentage (%)	Cumulative frequency	Cumulative Percentage (%)
0-1	22	11.6	22	11.6
1-2	2	1.1	24	12.6
2-3	7	3.7	31	16.3
3-4	5	2.6	36	19.0
4-5	7	3.7	43	22.7
5-6	2	1.1	45	23.7
6-7	4	2.1	49	25.8
7-8	4	2.1	53	27.9
8-9	4	2.1	57	30.0
9-10	3	1.6	60	31.6
10-11	1	0.5	61	32.1
11-12	1	0.5	62	32.6
12-13	2	1.1	64	33.7
13-14	3	1.56	67	35.3
14-15	4	2.1	71	37.4
15-16	6	3.2	77	40.5
16-17	2	1.1	79	41.6
17-18	5	2.6	84	44.2
18-19	3	1.6	87	45.8
19-20	1	0.5	88	46.3
20-21	4	2.1	92	48.4
21-22	5	2.6	97	51.0
22-23	3	1.6	100	52.6
23-24	1	0.5	101	53.3
24-25	5	2.6	106	55.8
25-26	2	1.1	108	56.8
26-27	0	0.0	108	56.8
27-28	3	1.6	111	58.4
28-29	2	1.1	113	59.5
29-30	1	0.5	114	60.0
30-31	1	0.5	115	60.5
31-32	4	2.1	119	62.6
32-33	1	0.5	120	63.1
33-34	1	0.5	121	63.7
34-35	4	2.1	125	65.8
35-36	1	0.5	126	66.3
36-37	2	1.1	128	67.4
37-38	1	0.5	129	67.9
38-39	1	0.5	130	68.4
39-40	0	0.0	130	68.4
40-41	3	1.6	133	70.0
41-42	2	1.1	135	71.0
42-43	3	1.6	138	72.6
43-44	3	1.6	141	74.2
44-45	0	0.0	141	74.2
45-46	0	0.0	141	74.2
46-47	2	1.1	143	75.3
47-48	1	0.5	144	75.8
48-49	0	0.0	144	75.8
49-50	1	0.5	145	76.3
>50	45	23.7	190	100.00

Table 2. Parameters of the linear and non-linear models for the frequency of severity of fig rust, in severity intervals.

Model	R^2 [a]	r [b]	y_0 [c]
Exponential	0.75	0.04***	39.42***
Logarithmic	0.87	-0.0004***	0.02***
Linear	0.57	-0.28***	22.95***

[a] Coefficient of determination (R^2).
[b] Progress rate (r).
[c] Initial inoculum (y_0).
*** Significant according to the t-tests (*P* = 0.001).

coefficient indicated increased precision of the evaluators when using the scale (e = 0.86), compared to the evaluations without the scale (e = 0.76). However, the value of the BIAS correction factor without the use of the scale (d = 0.94) was greater than that of the estimates obtained using the scale (d = 0.93). This indicated that there was no increase in the accuracy of the evaluators. Considering the confidence intervals, the assessments for fig rust with and without the use of the diagrammatic scale differed significantly at the 95% confidence interval, except for the location shift factor.

For reproducibility, without using the diagrammatic scale the value of the determination coefficient (R^2) ranged from 64 to 88%, with a mean of 81.1% (Table 4). With use of the scale, R^2 values ranged from 71 to 91% (mean = 80.7%) for the first evaluation, and from 61 to 81% (mean = 72.2%) in the second evaluation, with $R^2 \geq 70\%$ in approximately 82% of the combinations of evaluators.

There was good repeatability between the estimates of the same evaluator (Table 5). Between the two evaluations with the use of the scale, only one evaluator (A) exhibited a slope significantly different from 1, with good precision of the estimates of 87.5% of the evaluators. The evaluators all presented good repeatability in the estimates of leaf rust severity, as the mean variation between the first evaluation and the second evaluation was approx. 70%.

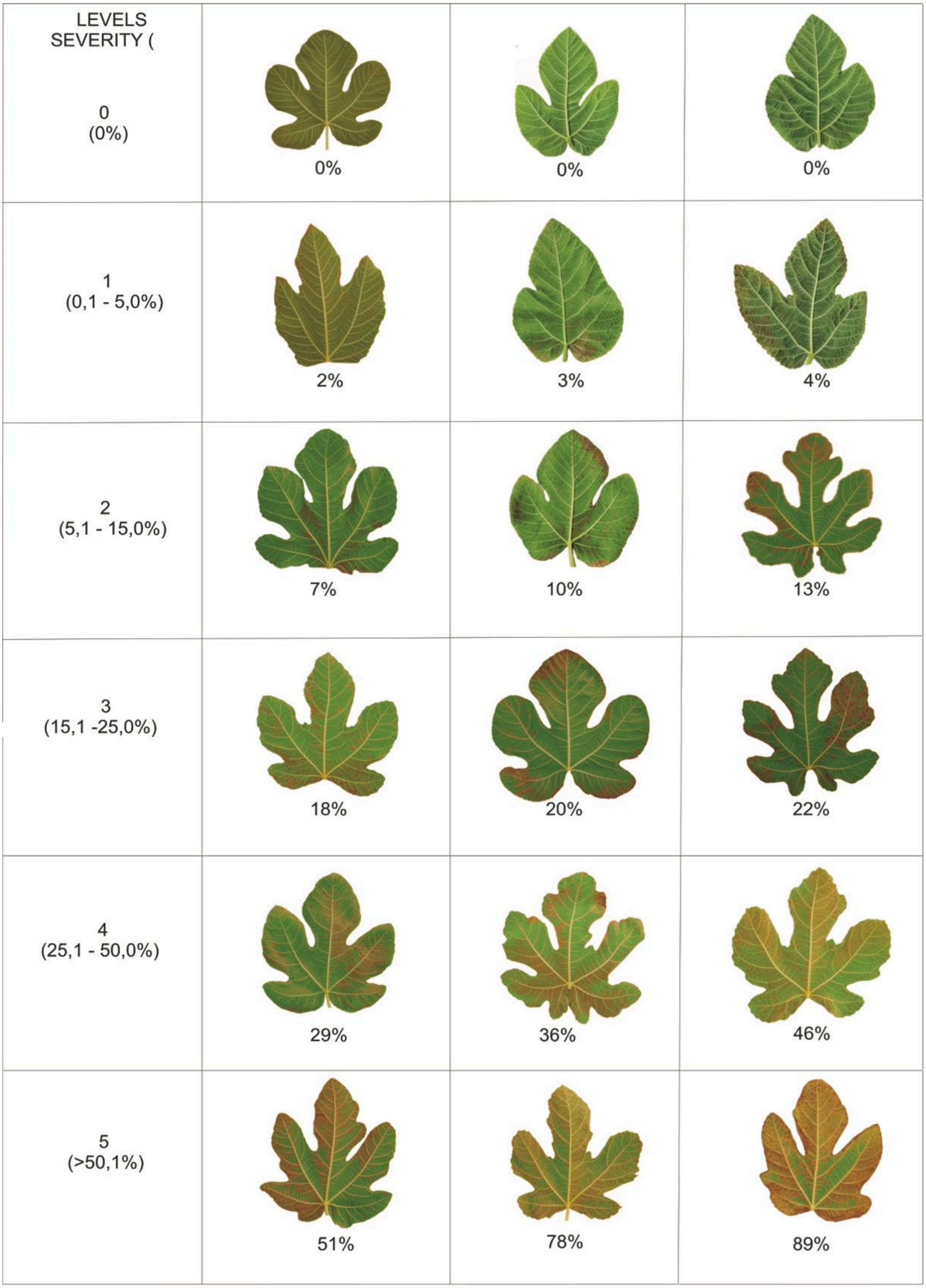

Figure 1. Diagrammatic scale for assessment of rust severity on fig leaves. The numbers represent percentages of leaf area diseased. leaf area.

Table 3. Lin's concordance correlation coefficients for eight evaluators without or with the diagrammatic disease severity scale, used to estimate rust severity on fig leaves.

Lin´s statistic	Without scale	With scale	95% CI[f]
Lin's concordance correlation coefficient [a]	0.71	0.80	**0.6872*; 0.8123***
Scale shift factor [b]	1.16	0.76	**0.8738*; 1.4020***
Location shift factor [c]	0.33	-0.28	-0.1705; 0.3112
Bias correction factor [d]	0.94	0.93	**0.7948*; 0.9328***
Pearson's correlation [e]	0.76	0.86	**0.8603*; 0.8837***

[a] Lin's concordance correlation coefficient.
[b] Scale shift factor relative to perfect agreement.
[c] Location shift factor relative to perfect agreement.
[d] Bias correction factor.
[e] Pearson's correlation.
[f] Upper and lower limits of the 95% confidence intervals.
Bold* represents a significant difference ($P \leq 0.05$) between the two evaluations, according to the t-tests.

Most evaluators presented good precision, regardless of whether the scale was used. Sixty-three percent of the participants presented R^2 values in the second evaluation that were greater or equal to those for the first evaluation, suggesting equal or greater precision with the second evaluation. Absolute errors were reduced when the scale was used, decreasing the range of values between the first and second evaluations (Figure 2). However, in the second evaluation, using the scale, the minimum and maximum values observed for the residuals of all the evaluators were, respectively, -49.67 and 70.90, increasing the range of the determined values.

Table 4. Coefficients of determination (R^2) of the linear regression equation between pairs of different evaluators, with or without the use of the disease severity assessment scale in two evaluations, estimating rust severity on fig leaves.

Evaluator	Without scale						
	B	C	D	E	F	G	H
A	0.73	0.76	0.75	0.68	0.64	0.77	0.73
B		0.83	0.78	0.88	0.75	0.85	0.71
C			0.82	0.80	0.81	0.86	0.77
D				0.80	0.74	0.81	0.74
E					0.82	0.83	0.66
F						0.87	0.84
G							0.84
	With scale – 1st assesment						
	B	C	D	E	F	G	H
A	0.74	0.79	0.71	0.86	0.87	0.78	0.81
B		0.78	0.79	0.82	0.79	0.75	0.76
C			0.91	0.78	0.85	0.80	0.82
D				0.79	0.79	0.77	0.78
E					0.83	0.81	0.85
F						0.86	0.89
G							0.83
	With scale – 2nd assesment						
	B	C	D	E	F	G	H
A	0.70	0.72	0.65	0.79	0.74	0.65	0.78
B		0.61	0.63	0.80	0.81	0.77	0.72
C			0.69	0.64	0.74	0.65	0.72
D				0.78	0.73	0.75	0.69
E					0.75	0.79	0.68
F						0.78	0.77
G							0.69

Table 5. Intercept (β_0), slope (β_1) and coefficient of determination (R^2) of the linear regression equations relating the first to second estimates of rust severity on fig leaves, for estimates performed by eight evaluators using the disease severity scale.

Evaluator	Coefficients		
	β_0	β_1	R^2
A	10.55*	0.80 ns	0.62
B	8.67 ns	0.69 ns	0.64
C	2.63 ns	0.71 ns	0.51
D	0.56 ns	1.04 ns	0.73
E	2.82 ns	0.90 ns	0.80
F	1.47 ns	0.85 ns	0.79
G	2.61 ns	0.80 ns	0.74
H	6.22 ns	0.83 ns	0.75

* ns represent situations where the null hypothesis ($\beta_0 = 0$ or $\beta_1 = 1$) was, respectively, rejected and not rejected according to t-tests ($P = 0.05$).

DISCUSSION

The diagrammatic scale developed in here allowed the evaluators to obtain accurate and precise estimates of fig rust severity, according to the validation analyses.

Linear and non-linear models were fitted to the data to determine if the scale levels should increase logarithmically or linearly. The particulars of each pathosystem are considered for determination of scale intervals, and this fitting is required to assess the accuracy of the assessments. The model with the best fit was the logarithmic model, and with this the intermediate levels of the scale were determined based on the highest frequency intervals of disease levels on the leaves, combined with the logarithmic increase in severity, in accordance with Weber Fechner law (Campbell and Madden, 1990).

Each level of the scale was defined according to the frequency distribution of the number of leaves with a

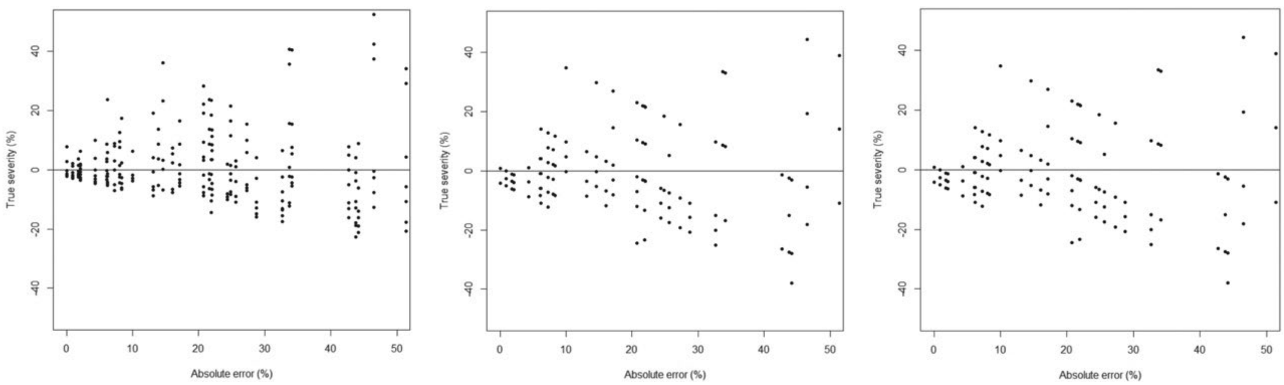

Figure 2. Distributions of residuals (estimated severity – actual severity) of estimates of rust severity on fig leaves, with or without the use of the disease severity scale, in two assessments by eight evaluators.

specific disease leaf area found in the field. Although the greatest unit interval of diseased leaves was between 0 and 1%, this interval was not used in the scale due to the difficulty in visually locating a lesion of that size on a fig leaf. Lorenzetti (2008) proposed a diagrammatic scale to quantify the severity of the same rust disease. However, their scale was expressed in percentages, with no values less than 4% of disease severity, and with large intervals between the percentages, factors that increase the subjectivity of the estimates of actual disease severity.

Based on the severity of fig rust found in natural infections, the scale had a maximum level of 89.3%, with chlorotic and necrotic areas. The absence of leaves with severities greater than 89% in the current study could be characteristic of the pathogen–host interaction of this disease. At greater disease intensities, leaf tissue necrosis was present that led to early leaf abscission.

Severity values greater than 50% were combined in the proposed scale because the human eye has difficulty distinguishing disease severity greater than this percentage (Campbell and Madden. 1990), and few leaves have been found in the unit intervals above this value due to defoliation caused by the disease (Pastore *et al.* 2016). The scale developed by Angeloti *et al.* (2011) for assessment of grapevine rust found a maximum level of severity in leaves of 75% for a similar reason. Dolinski *et al.* (2017), when developing a scale to quantify severity of peach rust severity, defined a maximum level of 30%. Although these authors found leaves with greater severity levels, as the variation in the disease severity can be due to cultivar susceptibility differences, cultivation practices and climate variations.

For the construction of the fig rust scale, photographs were used instead of graphical representations, which is a common practice. Belan *et al.* (2014) noted that this method increases the precision and accuracy of disease assessments. Using the real images or photographs, rather than black and white or colour diagrams, draws evaluators to the reality, facilitating the disease assessments.

In most studies involving validation of diagrammatic scales to determine disease severity in plant leaves, evaluators have exhibited tendency to overestimate the severity of particular diseases (Capucho *et al.*, 2011; Belan *et al.*, 2014; Freitas *et al.*, 2015). In some cases, such as early blight in potato, leaf disease severity was underestimated (Michereff *et al.*, 2000; Gomes *et al.*, 2004). In the present study, it is not possible to make such an inference because there was no significant difference between the evaluations.

In the validation of other rust severity evaluation scales, increased accuracy and precision by evaluators has been observed with their use. Capucho *et al.* (2011), using a diagrammatic scale for coffee leaf rust, validated the results using Lin's method, and the mean Pearson's correlation coefficient increased from 0.77 to 0.87 when using the proposed scale. In a study of diagrammatic scale validation for sugarcane orange rust, Klosowski *et al.* (2013) determined the indices by simple linear regression and obtained satisfactory results, with 100% of the evaluators obtaining intercepts statistically equivalent to zero and slope values equal to 1, indicating the absence of systematic deviations.

Although it is the most commonly used method for validating scales, linear regression does not detect the values of intercept 0 (β0) and slope (β1), when the data are scattered (Bock *et al.*, 2010), and this may lead to erroneous conclusions. Lin's method provides a single index ("Lin's concordance correlation coefficient"), and the accuracy and precision of severity estimates. This method has been used to analyse how disease severity data behave, and how they relate to actual estimates and with evaluations of the repeatability of estimates (Nita *et al.*, 2003; Bock *et al.*, 2008).

The reproducibility of the disease severity estimates among the evaluators was analysed using paired linear regression (Nutter and Schultz, 1995), and greater standardization was observed in the estimations with the use of the described here. However, in some pairs the coefficient of determination reached values between 61 and 69% in the second assessment using the scale. It is possible that these results were due to inexperience among some evaluators with disease quantification.

More than 75% of the evaluator pairs presented R^2 values greater than 70% using the diagrammatic scale, similar to that found in the validation of scales for other pathosystems, such as rust (Capucho *et al.*, 2011) and bacterial blight (Belan *et al.*, 2014) of coffee leaves, with mean values, respectively, of 87% and 99%.

The range of the residuals in the assessments using the scale described here were -57.50 to 72.03 for the first evaluation, and -49.67 to 70.90 for the second. The high values are explained by the difficulty in evaluating the disease. Due to the characteristics of the lesions, which are individual and small, and scattered on fig leaf surfaces, this causes evaluators to underestimate or overestimate the diseased leaf areas. This can influence the quality of disease estimation through psychological stimuli and responses, including the complexity of the sample units, size and shape of the lesions, colour and number of lesions, evaluator fatigue or difficulty to concentrate on the task (Sherwood *et al.*, 1983; Kranz, 1988).

Disease severity evaluation results are considered satisfactory when the means of the absolute errors are between 10 and 15%. This was described by De Paula *et al.* (2016), proposing and validating diagrammatic scales to assess brown eye spot in red and yellow coffee cherries, and also by Godoy *et al.* (2006) validating a scale for quantification of soybean rust. Belan *et al.* (2014) reported mean absolute errors between -20.95 and 20.01 in two evaluations, with a scale for assessment of bacterial blight in coffee leaves, especially at high severity levels, which is contrary to the observations in the present study.

In conclusion, we have developed and validated a diagrammatic scale for assessment of rust severity on fig leaves. The disease severity scale outlined here provides good accuracy, precision, repeatability and reproducibility, for evaluation of this disease.

ACKNOWLEDGEMENTS

Financial support for this study was provided by the Brazilian Federal Agency for the Support and Evaluation of Graduate Education (CAPES) – Financing Code 001, for a scholarship awarded to the first author. The Fruticulture sector of the Department of Agriculture and the post-graduate students of the Department of Phytopathology of the Federal University of Lavras/MG provided assistance to develop and validate the diagrammatic scale described here, and with interpreting the results obtained.

LITERATURE CITED

Alvares C.A., Stape J.L., Sentelhas P.C., Gonçalves J.L.M., Sparovek, G., 2014. Koppen's climate classification map for Brazil. *Meteorologische Zeitschrift*, 22: 711–728.

Angelotti F., Scapin C.R.; Tessman D.J., Vida, J.B. Oliveira R.R., Canteri, M.G. (2008). Diagrammatic scale for assessment of grapevine rust. *Tropical Plant Pathology*, 33, 439–443.

Belan L.L., Pozza E.A., Freitas M.L.O., Souza R.M., Jesus Junior W.C., Oliveira J.M., 2014. Diagrammatic scale for assessment of bacterial blight in coffee leaves. *Journal of Phytopathology*, 162: 801–810.

Bergamin Filho A., Amorim, L., 1996. Doenças de Plantas Tropicais: Epidemiologia e Controle Econômico. *Agronômica Ceres*, São Paulo, São Paulo, Brazil, XXX pp.

Bock C.H., Parker P.E., Cook A.Z., Gottwald T.T., 2008. Visual rating and the use of image analysis for assessing different symptoms of citrus canker and the grapefruit leaves. *Plant Disease*, 92: 530–541.

Bock, C.H., Poole, G.H., Parker, P.E., & Gottwald, T.T., 2010. Plant disease severity estimated visually, by digital photography and image analysis, and by hyperpectral imaging. *Critical Reviews in Plant Science*, 29: 59–107.

Campbell C.L., Madden L.V., 1990. *Introduction to plant disease epidemiology*. John Wiley, New York, USA, XXX pp.

Capucho, A. S., Zambolim, L., Duarte, H. S. S., & Vaz, G. R. O., 2011. Development and validation of a standard area diagram set to estimate severity o f leaf rust in *Coffea arabica* and *C. canephora*. *Plant Pathology*, 60: 1144–1150.

De Paula P.V.A.A., Pozza E.A., Santos L.A., Chaves E., Maciel M.P., Paula J.C.A. (2016). Diagrammatic scales for assessing Brown Eye Spot (*Cercospora coffeicola*) in red and yellow coffee cherries. *Journal of Phytopathology*, 164: 791–800.

Dolinski M.A., Duarte H.S.S., Silva J.B., De Mio L.M.M., 2017. Development and validation of a standard area diagram set for assessment of peach rust. *European Journal of Plant Pathology*, 148: 817–824.

Eisen G. A. 1901. *The Fig: its History, Culture, and Curing*. Washington: Governament printing Office.

FAO: Food And Agriculture Organization, 2018. *Figs*. http://www.fao.org.

Freitas M.L., Pozza E.A., Belan L.L., Silva J.L., Abreu M.S., 2015. Diagrammatic scale for blister spot in leaves of coffee treee. *African Journal of Agricultural Research*, 2068–2070.

Galleti S.R., Rezende J.A.M., 2005. Doenças da figueira. In H. Kimathi *et al*. Eds., *Manual de Fitopatologia: doenças de plantas cultivadas*, Agronômica Ceres, São Paulo, Brazil, 351–354 pp.

Godoy C.V., Koga L.J., Canteri, M.G., 2006. Diagrammatic scale for assessment of soybean rust severity. *Fitopatologia Brasileira*, 31: 63–68.

Gomes A. M. A., Michereff S. J., Mariano R. L. R., 2004. Elaboração e validação de escala diagramática para cercosporiose da alface. *Summa Phytopathologica*, 30: 38–42.

Horsfall J.C., Barratt R.W., 1945. An improved grading system for measuring plant diseases. *American Phytopathology Society*, 35: 655–655.

IBGE: Instituto Brasileiro de Geografia e Estatística. SIDRA: Banco de dados agregados do IBGE. http://www.sidra.ibge.gov.br/.

Khemira H., Mars M., 2017. Fig production in subtropical south-western Saudi Arabia. *Acta Horticulturae*, Iran, 169–172 pp.

Klosowski A.C., Ruaro L., Bepalhock Filho J.C., De Mio, L.L.M., 2013. Proposta e validação de escala para a ferrugem alaranjada da cana-de-açúcar. *Tropical Plant Pathology*, 38:166–171.

Kranz J., 1988. Measuring plant disease. In: J. Kranz, & J. Rotem (Eds.), *Experimental Techniques in Plant Disease Epidemiology.* Springer-Verlag, Berlin, Heidelberg 35–50 pp.

Lin L., 1989. A concordance correlation coefficient to evaluate reproducibility. *Biometrics*, 45: 255–268.

Lorenzetti E.R., 2008. Escala diagramática para avaliação da severidade de ferrugem do figo causada por *Cerotelium fici* (Cast.). In XX Congresso Brasileiro De Fruticultura, 2008, Vitória, ES, Brazil.

Michereff S. J., Maffia L. A., Noronha M. A., 2000. Escala diagramática para avaliação da severidade da queima das folhas do inhame. *Fitopatologia Brasileira*, 25: 612–629.

Nita M., Ellis M.A. Madden,L.V.,2003. Reliability and accuracy of visual estimation of Phomopsis leaf blight of strawberry. *Phytopathology*, 93: 995–1005.

Nutter F.W., Gleason M.L., Jenco J.H., Christians N.C., 1993. Assessing the accuracy, intra-rater repeatability, and inter-rater reliability of disease assessment systems. *Phytopathology*, 83: 806–812.

Nutter F.W., Schultz P.M., 1995. Improving the accuracy and precision of disease assessments: selection of methods and use of computer-aided training programs. *Canadian Journal of Plant Pathology*, 17: 174–184.

Pastore R.L., Boff P., Golinski N.G., Boff M.I.C., 2016. Rust resistance of fg landraces in an organic cropping system in Santa Catarina. *Biological agriculture & Horticulture*, Brazil, 63–71 pp.

Pio R., Souza F. B. M., Kalcsits L., Bisi R. B., Farias D. H., 2019. Advances in the production of temperate fruits in the tropics. *Acta Scientiarum. Agronomy*, 41: 1-10.

Pio R., Oliveira A.C.L., Pasqual M., Pio L.A.S., Curi P.N., Bisi R.B., 2017. Protocol for flow cytometric estimation of nuclear DNA amount in fig (*Ficus carica* L.) cultivars. *Acta Horticulturae*, 1: 99–104.

R Core Team, 2018. R: a language and environment for statistical computing. https://www.R-project.org/.

Solano-Báez A.R., Jiménez-Jiménez B., Camacho-Tapia M., Leyva-Mir S.G., Nieto-López E.H, Tovar-Pedraza J.M., 2017. First confirmed report of *Cerotelium fici* causing leaf rust on *Ficus carica* in Mexico. *Plant Pathology & Quarantine*, 7: 160–163.

Stevenson M., Nunes T., Sanchez J., Thornton, R., Reiczigel J. … Sebastiani P., 2018. *An R package for the analysis of epidemiological data*. http://CRAN.R-project.org/package=epiR.

Sherwood R.T., Berg C.C., Hoover M.R., Zeiders K.E., 1983. Illusions in visual assessment of stagonospora leaf spot of orchardgrass. *Phytopathology*, 73: 173–177.