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Standard Area Diagram Set for Bacterial Spot Quantification in Entire-Margined Leaves of Sour Passion Fruit

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Abstract

This study developed and validated a standard area diagram set (SADs) to aid in the estimation of bacterial spot (*Xanthomonas axonopodis* pv. *passiflorae*) severity in entire-margined leaves of sour passion fruit (*Passiflora edulis* Sims). The SADs consisted of eight severity levels (3; 6; 12; 25; 50; 77, and 88%). For its validation, 20 raters, who initially estimated the disease severity without the aid of the SADs, were divided into groups (G1 and G3, inexperienced; G2 and G4, experienced). Subsequently, G1 and G2 performed the second evaluation without the SADs, and G3 and G4 completed the second evaluation using the proposed SADs. The accuracy and precision of the assessments were determined by simple linear regression and by the Lin's concordance correlation coefficient. The increase in accuracy was confirmed by the 80% constant error-free estimates (G3 and G4) and 100% (G3) and 80% (G4) systematic error-free estimates when the SADs was used. Precision increased with the increase in the coefficient of determination, the reduction in absolute errors, and the increase in the reproducibility of the estimates between pairs of raters. Inexperienced raters benefited the most from the use of the SADs. The increase in the accuracy and precision in the non-aided groups, when present, was less pronounced than those increments observed in the SADs-aided groups. The Lin's concordance correlation coefficient confirmed the increased accuracy and precision detected by the linear regression analysis and indicated increased agreement between the estimated and actual values of disease severity in the SADs-aided groups.

Keywords: *Passiflora edulis* Sims, phytopathometry, *Xanthomonas axonopodis* pv. *passiflorae*

1. Introduction

Brazil is the world's largest producer and consumer of passion fruit. It has a production of 554,598 tons in 41,090 hectares harvested (IBGE [Brazilian Institute of Geography and Statistics], 2017). Sour passion fruit (*Passiflora edulis* Sims) is the most cultivated and commercialized species in the country. Its fruits are used for fresh consumption and industrial purposes (Carvalho, Stenzel, & Auler, 2015). Despite the tremendous social and economic importance of passion fruit, the crop has experienced oscillations in its planted area and yield due to several phytosanitary problems. These problems compromise the crop's yield and may even prevent passion fruit cultivation in some areas (Santos Filho & Santos, 2003; Fischer, Lourenço, Martins, Kimati, & Amorim, 2005).

Among the limitations caused by diseases, bacterial spot (*Xanthomonas axonopodis* pv. *passiflorae*) should be highlighted since it has compromised the sour passion fruit growth mainly because of its difficult control (Ishida, Protazio, & Oliveira, 2017). The initial lesions on leaves have a greasy appearance and light brown coloration. Later, they become dark brown, irregular in shape, and can coalesce and reach the entire leaf limb. The infection can progress through the veins of the leaves, evolve into the petiole, and reach the finer vascular bundles, resulting in a systemic invasion in the plant (Dias, 2000; Fischer, Bueno, Almeida, & Garcia, 2007). Bacterial spot disease leads to intense defoliation and drought of the branches from the extremities, which drastically reduces fruiting. It can finally lead to the death of the whole plant and even the total loss of the orchard (Carvalho et al., 2015).

Accurate estimates of disease severity are critical for appropriate decisions to be taken in disease management, to monitor disease progression over time, and to minimize disease impact on crop yield. Moreover, accurate and precise estimates are essential for the identification of resistance sources and selection of resistant materials (Duarte et al., 2013; Braido et al., 2014). Descriptive keys have commonly been used for assessing disease severity in breeding programs of sour passion fruit. However, these keys are prone to high subjectivity and do not allow adjusting the visual acuity when evaluating the severity levels (Campbell & Madden, 1990). As a consequence, the precise quantification of the injured area is impaired (Santos, Mussi-Dias, Freire, Carvalho, & Silveira, 2017). Conversely, diagrammatic scales or standard area diagram sets (SADs), which are reference images representing several severity levels, provide more accurate, precise, and reliable assessments than other methods (Pethybridge & Melson, 2018).

The increase in accuracy and precision of visual estimates, particularly those performed by inexperienced raters, has already been reported for different SADs developed for the evaluation of bacterial spot in several crops (Braido et al., 2015; Duan, Zhao, Wang, & Yang, 2015; Nuñez et al., 2017). These diagrams have been used directly in breeding programs, aiding in disease resistance and genotype selection evaluations (Berrueta, Gimenez, Galvan, & Borges, 2016; Varago, Citadin, Sachet, Penso, & Raseira, 2017). It has also indirectly helped out these researches, subsidizing studies on the efficiency of control methods for diseases caused by *Xanthomonas* (Itako, Tolentino Jr., Silva Jr., Soman, & Maringoni, 2015; Rodrigues, Bueno, & Tebaldi, 2016).

Despite the great importance of diseases in sour passion fruit crop, the only SADs validated for disease quantification in this species was developed by Fischer et al. (2009) for the evaluation of anthracnose in fruits. Considering the economic, social, and food importance of the sour passion fruit crop, the impact of bacterial spot on the Brazilian passion fruit production, and the lack of standardized methods to quantify the severity of this disease in entire-margined leaves of this crop, this study aimed to: (1) develop and validate a SADs for evaluating the severity of bacterial spot in entire-margined leaves of sour passion fruit; (2) compare the accuracy, precision, and agreement of disease severity estimates, with and without the aid of the SADs; (3) compare the accuracy, precision, and agreement of the estimates from inexperienced and experienced raters.

2. Method

Fifty entire-margined leaves of sour passion fruit (BRS Gigante Amarelo, Yellow Master FB200, and genotypes in breeding process) showing symptoms of bacterial spot were collected from 3-month-old seedlings kept under protected cultivation at University of Brasilia's (UnB) Experiment Station (15°44′13″ S and 47°52′57″ W, 1010 m), located in Brasilia, DF, Brazil. The procedures of image obtention, SADs development and validation, as well as data analyses were performed as stated by Costa, Pires, Peixoto, Blum, & Faleiro (2018).

The adaxial surface of each leaf was photographed and total leaf and the diseased areas (necrotic + chlorotic) were measured by the image analysis software IMAGE J (Schneider, Rasband, & Eliceiri, 2012). The percent of leaf area affected by the bacterial spot disease (disease severity) was determined by the diseased area in relation to the total surface area of the leaf. Disease severity was considered the actual (true) disease severity and used as a reference for evaluating the accuracy and precision of rater estimates with and without the use of the SADs.

The lower and upper limits of the SADs were related to the minimum and maximum bacterial spot severities recorded in the image analysis of the 50 leaves. Intermediate levels were calculated following logarithmic increments (Nutter & Schultz, 1995).

The SADs was validated by 20 raters (ten with previous experience and ten without previous experience in disease quantification) who assessed the images of 50 leaves with different severity intensities of bacterial spot. The first disease severity evaluation was accomplished without the aid of the SADs (non-aided evaluation). In the second evaluation, raters were divided into four groups of five raters per group (G1 and G3, inexperienced; G2 and G4, experienced). The same images were presented to G1 and G2, who performed another non-aided evaluation, and to G3 and G4, who completed the evaluation using the proposed SADs (SADs-aided evaluation).

The accuracy, precision, absolute errors, agreement, and inter-reliability of estimates were compared without and with the use of the SADs for both inexperienced and experienced raters. The accuracy and precision of the raters were determined by linear regression between the actual severity (independent variable) and the visually estimated severity (dependent variable).

The accuracy of estimates of each rater was determined by a t-test applied to the intercept of linear regression (a) to validate the hypothesis H_o: $a = 0$, and to the slope coefficient of the line (b) to test the hypothesis H_o: $b = 1$ (P

≤ 0.05). Intercept values significantly different from 0 imply overestimation (> 0) or underestimation (< 0) of actual severity at low severity levels (constant error). Values of the slope coefficient different from 1 point to systematic overestimation (> 1) or underestimation (< 1) of actual severity in all disease intensities (systematic error) (Nutter & Schultz, 1995).

The values of the coefficient of determination of the regression analysis (R^2) and the variance of absolute errors (the difference between estimated and actual severities) were used to calculate rater precision (KRANZ, 1988). The highest precision was recorded in raters showing greater R^2 and lower absolute error values. The mean maximum error (absolute value) was also determined for each group and represent the difference of the group's farthest estimate to the actual severity value.

The reproducibility was determined by the R^2 values for each pair of raters, based on estimates of non-aided and SADs-aided evaluations (Nutter & Schultz, 1995).

Accuracy and precision of the estimates of each rater, in non-aided and SADs-added evaluations, were also calculated using the Lin's concordance correlation coefficient (LCCC; ρ_c), which combines measures of accuracy (C_b) and precision (r), and is expressed by $\rho_c = C_b \cdot r$. Based on the LCCC, there is a perfect agreement between estimated and actual severity when $r = 1$, $C_b = 1$, and $\rho_c = 1$ (Lin, 1989; Bock, Poole, Parker, & Gottwald, 2010).

Linear regressions and absolute errors analyses were performed using the Genes software (v. 1990.2017.37). The LCCC was calculated using the MedCalc software (v. 17.9.7).

3. Results and Discussion

The maximum bacterial spot severity value reported in the 50 entire-margined leaves naturally infected under protected cultivation was 88%, and the lowest value was 3%. The SADs was set up using seven levels of severity represented by the values 3; 6; 12; 25; 50; 77; and 88% (Figure 1). The lesions observed showed typical symptomatic patterns of the disease, with initial small spots, usually initiated at the margins, which grow, coalesce, and may cover the entire leaf area.

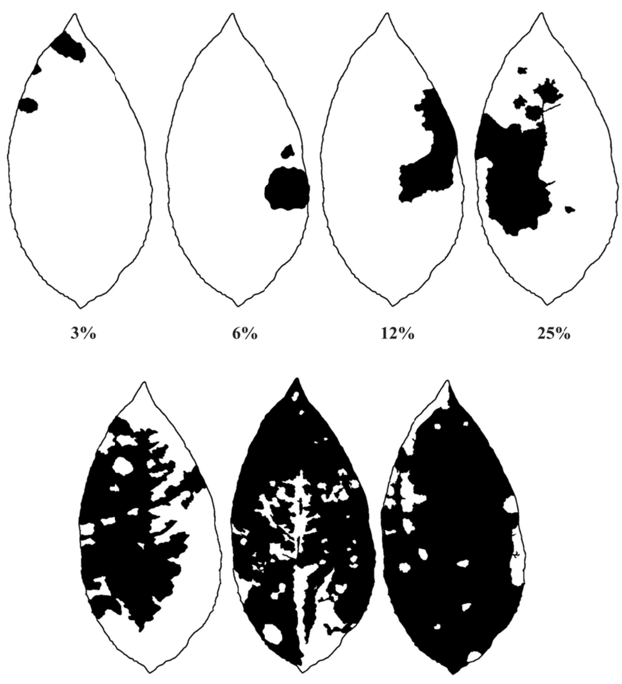

Figure 1. Standard area diagram set (SADs) for bacterial spot severity assessment in entire-margined leaves of sour passion fruit (*Passiflora edulis* Sims). Numbers in the diagrams represent the leaf area with necrotic symptoms of the disease (%). Brasilia, DF, Brazil, 2018

High severity values are commonly observed in the field and protected cultivation due to the difficult control of this disease and the high susceptibility of the current cultivars to this bacterium (Ishida & Halfeld-Vieira, 2009). SADs with severity levels above 50% have already been reported for different pathosystems involving

Xanthomonas spp. (Citadin et al., 2008; Duan et al., 2015), suggesting that this genus may cause severe damages when not adequately controlled. Severity values above 88% are rarely observed in sour passion fruit since they result in rapid leaf senescence.

Accuracy refers to the similarity between the estimated and the actual disease severity and can be measured by analyzing the intercept and the slope coefficient of the linear regression. The intercept, if significantly different from 0, indicates the amount of constant error of the rater (positive or negative). In its turn, a slope coefficient significantly different from 1 indicates a systematic error of the rater, which affects the accuracy of the estimate in relation to the actual value (Nutter & Schultz, 1995).

In the first evaluation, performed without the SADs, a certain level of accuracy was observed in the raters of all groups since 40% (G1, G2, and G3) and 20% (G4) of them did not present constant and systematic errors in their estimates ($P \leq 0.05$) (Table 1). In the second evaluation of G1, 60% and 100% of the raters presented intercept values and angular coefficients equal to 0 and 1 ($P \leq 0.05$), respectively, resulting in enhanced accuracy in this group. However, this improvement was not recorded in G2, in which an undesired increase of the intercept mean value was detected. Although a higher percentage of raters with slope coefficient values equal to 1 were verified in G2, this increase did not affect the slope coefficient mean value when compared to the first evaluation.

Table 1. Intercepts (*a*), slope coefficients (*b*), and coefficients of determination (R^2) of linear regression for actual severity versus estimated severity of bacterial spot (*Xanthomonas axonopodis* pv. *passiflorae*) in entire-margined leaves of sour passion fruit (*Passiflora edulis* Sims). Brasilia, DF, Brazil, 2018

Groups	Raters	Evaluation 1			Evaluation 2		
	Inexperienced	No SADs			No SADs		
		a	*b*	R^2	*a*	*b*	R^2
1	1	4.36*	1.13*	0.87	1.69	0.97	0.91
	2	-0.14	1.02	0.93	-0.12	0.99	0.94
	3	4.06*	1.09	0.91	4.08*	1.02	0.90
	4	5.41*	0.92*	0.96	5.24*	0.92	0.92
	5	-3.13	1.08	0.89	-3.11	1.06	0.89
	Mean	2.11	1.05	0.91	1.56	0.99	0.91
2	Experienced	No SADs			No SADs		
	6	0.13	0.85*	0.94	5.36*	0.82*	0.95
	7	1.23	0.94*	0.96	0.45	0.98	0.95
	8	3.32*	0.94*	0.97	3.22*	0.95*	0.97
	9	-2.30	0.94	0.93	-1.07	0.94	0.94
	10	-0.88	1.03	0.96	-2.39*	1.03	0.97
	Mean	0.30	0.94	0.95	1.11	0.94	0.96
3	Inexperienced	No SADs			With SADs		
	11	8.16*	0.87*	0.84	1.42	0.97	0.96
	12	2.81	1.09	0.86	2.49	1.00	0.92
	13	4.23*	1.06	0.93	1.68	1.03	0.96
	14	-1.17	1.18*	0.95	-3.10*	1.04	0.93
	15	1.78	1.04	0.91	1.94	1.02	0.96
	Mean	3.16	1.05	0.90	0.88	1.01	0.95
4	Experienced	No SADs			With SADs		
	16	-0.47	1.01	0.95	3.13*	0.95	0.96
	17	0.52	0.90*	0.97	0.45	0.91*	0.97
	18	6.87*	0.98	0.96	2.18	1.01	0.95
	19	8.51*	1.03	0.84	1.62	0.96	0.94
	20	12.57*	1.04	0.95	1.74	1.02	0.95
	Mean	5.60	0.99	0.93	1.82	0.97	0.95

Note. * indicates that the null hypothesis ($a = 0$ or $b = 1$) was rejected by t-test ($P \leq 0.05$).

Nevertheless, the use of the SADs improved the accuracy of the estimates since 80% of the raters in G3 and G4 presented intercept values equal to 0 ($P \leq 0.05$). For 100% (G3) and 80% (G4) of the raters, the values of the slope coefficient were equal to 1 ($P \leq 0.05$) (Table 1). Therefore, the increase in accuracy in the SADs-aided groups was more expressive than that observed in G1. Consequently, the values of estimated severity were close to the actual severity values. In other words, the estimated severity trend lines determined for each rater in the SADs-aided evaluations were always closer to the 1:1 line (actual severity equals to the estimated severity) when compared to the non-aided evaluation.

In addition to accuracy, precision must also be considered in the validation of SADs. Precision is defined as the exactness of an operation where there is rigor or refinement in the measure (Bergamin Filho & Amorim, 1996). It may be evaluated using the regression coefficient (R^2) and the variations in the absolute errors (Nutter & Schultz, 1995). Without the use of the SADs, the raters in G3 obtained R^2 values between 0.84 and 0.95 (mean 0.90) and between 0.84 and 0.97 (0.93) in G4. Using the SADs, R^2 values ranged from 0.92 to 0.96 (0.95) and 0.94 to 0.97 (0.95) for the inexperienced and experienced raters, respectively. Since mean values equal to or greater than 0.95 indicate precise estimates, these findings indicate that the estimates were systematically related to the actual values when the SADs was used (Kranz, 1988). Although the highest precision was observed in G2, the increase in precision in G3 (5.6%) and G4 (2.2%) was higher than that observed in G2 (1%) (Table 1). In this context, the use of the SADs can minimize the errors of estimates due to the use of individual methods by different researchers.

The use of the SADs also resulted in significant reductions in the absolute errors compared to the non-aided evaluations. These reductions were more expressive than those observed in the groups that performed double non-aided evaluations (Table 2, Figure 2). As a consequence, a lower dispersion of data in the linear regression was observed. While G1 and G2 presented reductions of 16.7% and 6.2%, respectively, in the mean absolute error in the second non-aided evaluation, G3 and G4 showed reductions of up to 51.8% with the proposed SADs (Table 2).

Table 2. Absolute errors (estimated severity-actual severity) of bacterial spot (*Xanthomonas axonopodis* pv. *passiflorae*) severity estimates in entire-margined leaves of sour passion fruit (*Passiflora edulis* Sims). Brasilia, DF, Brazil, 2018

Groups	Raters	Evaluation 1	Evaluation 2
	Inexperienced	**No SADs**	**No SADs**
	1	8.9 b	5.3 a
	2	4.6 a	3.4 a
1	3	7.6 a	5.9 a
	4	4.5 a	5.6 a
	5	6.1 a	6.2 a
	Mean	6.3 a	5.3 a
	Experienced	**No SADs**	**No SADs**
	6	4.9 a	4.7 a
	7	3.3 a	3.5 a
2	8	3.4 a	3.5 a
	9	5.0 a	3.9 a
	10	3.6 a	3.2 a
	Mean	4.0 a	3.8 a
	Inexperienced	**No SADs**	**With SADs**
	11	7.5 b	3.3 a
	12	6.8 a	5.6 a
3	13	6.8 b	3.7 a
	14	5.4 a	4.7 a
	15	5.8 b	3.9 a
	Mean	6.5 b	4.2 a
	Experienced	**No SADs**	**With SADs**
	16	3.7 a	3.6 a
	17	3.2 a	3.1 a
4	18	6.8 b	4.0 a
	19	11.1 b	3.7 a
	20	13.6 b	4.1 a
	Mean	7.7 b	3.7 a

Note. Different letters in the same row indicate significant differences (Student´s t-test, P ≤ 0.05).

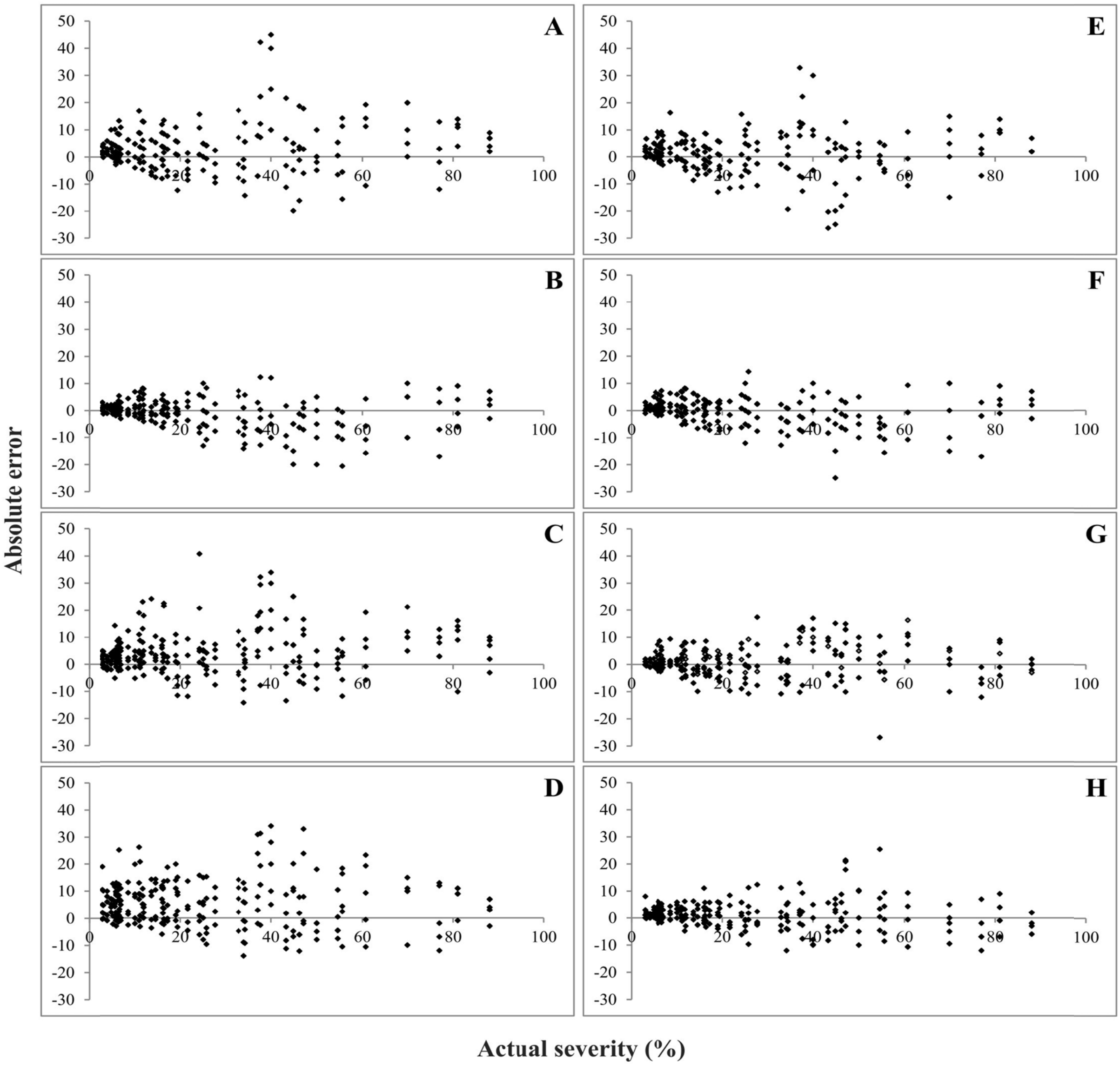

Figure 2. Distribution of absolute errors (estimated severity-actual severity) of the bacterial spot (*Xanthomonas axonopodis* pv. *passiflorae*) estimates in entire-margined leaves of sour passion fruit (*Passiflora edulis* Sims) in the first evaluation, without aid of the standard area diagram set (SADs), in groups 1 (A), 2 (B), 3 (C), and 4 (D); and in the second evaluation, without the aid of the SADs, in groups 1 (E) and 2 (F), and with the aid of the SADs, in groups 3 (G) and 4 (H). Brasilia, DF, Brazil, 2018

The mean maximum error reduced by 10.9% in G1 and increased by 1.6% in G2 in the second evaluation. In contrast, the mean maximum error reduced with the use of the SADs, corresponding to a 40.9%-lower value for the inexperienced raters and 9.9%-lower value for the experienced raters (Table 3). Using the SADs, 91.2% (G3) and 94.4% (G4) of the estimates presented absolute errors within the 10% range (-10 to +10). These values indicate an increase of 13.3% (G3) and 30.5% (G4) in the number of estimates with errors within this variation range as compared to the first evaluation. Although G1 and G2 also presented a high percentage of estimates with errors within the 10% range in the second evaluation, the increase in the estimates within this range was not as expressive than that observed in the SADs-aided groups. Similarly, the increase observed in the percentage of estimates with errors within the 5% range (-5 to +5) was more pronounced in G3 and G4 as compared to G1 and G2 (Table 3).

Table 3. Mean maximum error in absolute value (MEAV), 10% (x±10) and 5% (x±5) error range of the severity estimates in relation to the actual severity of bacterial spot (*Xanthomonas axonopodis* pv. *passiflorae*) in entire-margined leaves of sour passion fruit (*Passiflora edulis* Sims). Brasília, DF, Brazil, 2018

Evaluation	**Parameter**	**Group**			
		1	**2**	**3**	**4**
1	**MEAV**	28.4	15.2	30.7	21.7
	%x±5	55.2	70.4	56.4	43.2
	%x±10	81.2	92.8	82.8	70.4
2	**MEAV**	25.3	15.5	18.2	19.5
	%x±5	61.6	73.6	68.0	76.4
	%x±10	88.8	96.0	91.2	94.4

The presence of absolute errors is common in visual estimates of severity, and its reduction is indispensable in disease quantification (Ortega-Acosta, Velasco-Cruz, Hernández-Morales, Ochoa-Martínez, & Hernández-Ruiz, 2016; Santos et al., 2017). The absolute error values obtained in the SADs-aided evaluations may be considered suitable since more than 91% were concentrated within the acceptable range of 10% (Tomerlin & Howell, 1988; Nutter & Worlwitlikit, 1989).

According to Nutter and Schultz (1995), solutions to correct or minimize non-accurate severity estimates may vary according to the magnitude of the error and the amount of training received by the raters. The use of SADs and specific training through computer programs might improve visual estimation by reducing errors and thus, lead to better results and more reliable conclusions (Bardsley & Ngugi, 2013; Sachet, Citadin, Danner, Guerrezi, & Pertille, 2017). In addition to increasing the accuracy of the estimates, the use of SADs can also reduce the time of evaluation and assist in the standardization of results between raters and experiments (Yadav, Vos, Bock, & Wood, 2013).

When the SADs was not used, only 20% (G3) and 60% (G4) of the estimates from pairs of raters presented R^2 values above 0.90. Conversely, 80% and 90% of the pairwise combinations presented R^2 values above 0.90 in G3 and G4, respectively, in the SADs-aided evaluations. These results demonstrate an increase in the reproducibility of the estimates among raters due to the SADs use. From a practical viewpoint, this result proves the subjectivity reduction in severity estimates among raters (Fischer et al., 2009). Therefore, it allows different experiments conducted by different raters to be compared using the proposed SADs.

The LCCC was developed to validate measures of new instruments by comparing the resulting measures to others which were generated by already established methods (gold standards). Therefore, it is used to verify the similarity between two measurement pairs of the same sample at different times. The LCCC can vary from -1 to +1, indicating maximum positive agreement when the value is 1.0 (Lin, 1989). Since its creation, this coefficient has been used to validate SADs for different diseases (Yadav et al., 2013; Nicoli et al., 2015; Sachet, Danner, Citadin, Pertille, & Guerrezi, 2017).

The Lin's correlation analysis confirmed the previously presented results, proving that the SADs leads to improvements in the accuracy and precision of the raters. According to the correction factor (C_b), the SADs provided an accuracy enhancement from 0.97 to 0.99 in G3 and from 0.94 to 1.00 in G4. Likewise, based on the correlation coefficient (r), precision increased from 0.95 to 0.97 in G3 and from 0.97 to 0.98 in G4. The SADs use also led to increases of 5.4% (G3) and 6.6% (G4) in ρ_c values for 100% and 60% of G3 and G4 raters, respectively (Table 4). Additionally, the SADs-aided groups had more expressive increments than G1 and G2.

As a result, the SADs proposed may be used to improve the quality of disease severity estimates in scientific research. Most of these studies require accuracy and precision in bacterial spot severity assessments, such as experiments carried out to understand the bacterial spot behavior under the influence of environmental factors, to evaluate host resistance levels, and to verify the efficiency of control methods. Due to the susceptibility of sour passion fruit to bacterial spot and the need to launch new cultivars resistant to this disease, the proposed SADs will play a crucial role in the selection of seedlings and plants developed by the genetic breeding programs.

Table 4. Correlation coefficient between estimated severity and actual severity (r), bias correction factor (C_b), and Lin's concordance correlation coefficient (ρ_c) for bacterial spot (*Xanthomonas axonopodis* pv. *passiflorae*) severity estimates in entire-margined leaves of sour passion fruit (*Passiflora edulis* Sims). Brasilia, DF, Brazil, 2018

Group	Raters	Evaluation 1			Evaluation 2		
		No SADs			No SADs		
1	Inexperienced	r	C_b	ρ_c	r	C_b	ρ_c
	1	0.94	0.94	0.88	0.96	1.00	0.95
	2	0.96	1.00	0.96	0.97	1.00	0.97
	3	0.95	0.96	0.91	0.95	0.98	0.93
	4	0.98	0.99	0.97	0.96	0.99	0.95
	5	0.95	0.99	0.94	0.94	0.99	0.94
	Mean	0.96	0.97	0.93	0.96	0.99	0.95
2	Experienced	No SADs			No SADs		
	6	0.97	0.97	0.94	0.98	0.98	0.96
	7	0.98	1.00	0.98	0.98	1.00	0.98
	8	0.99	1.00	0.98	0.98	1.00	0.98
	9	0.97	0.98	0.95	0.97	0.99	0.96
	10	0.98	1.00	0.98	0.99	1.00	0.98
	Mean	0.98	0.99	0.97	0.98	0.99	0.97
3	Inexperienced	No SADs			With SADs		
	11	0.92	0.97	0.90	0.98	1.00	0.98
	12	0.93	0.97	0.90	0.96	0.99	0.95
	13	0.97	0.97	0.93	0.98	0.99	0.97
	14	0.97	0.97	0.95	0.96	0.99	0.96
	15	0.96	0.99	0.95	0.98	0.99	0.97
	Mean	0.95	0.97	0.92	0.97	0.99	0.97
4	Experienced	No SADs			With SADs		
	16	0.98	1.00	0.98	0.98	1.00	0.97
	17	0.99	0.99	0.98	0.99	0.99	0.98
	18	0.98	0.96	0.94	0.98	0.99	0.97
	19	0.92	0.92	0.85	0.97	1.00	0.97
	20	0.97	0.85	0.83	0.97	0.99	0.97
	Mean	0.97	0.94	0.91	0.98	1.00	0.97

4. Conclusion

The SADs developed and validated in this study increased the ability of the raters to accurately and precisely estimate the bacterial spot severity in entire-margined leaves of sour passion fruit. The SADs also increased the reproducibility of estimates among raters and proved to be efficient on increasing the agreement between the estimated and the actual values.

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