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Tests of standard diagrams for field use in assessing the tarspot disease complex of maize (*Zea mays*)

(*Keywords:* Disease assessment, tarspot disease complex, maize, standard diagrams)

J. HOCK†, J. KRANZ‡, and B. L. RENFRO†

†*International Maize and Wheat Improvement Center (CIMMYT), Lisboa 27, Apdo. Postal 6-641, 06600 Mexico D.F., Mexico.*
‡*Tropeninstitut, University of Giessen, Schottstrasse 2, Germany*

Abstract. *Zea mays* in Latin America is affected by a disease complex known as tarspot caused by *Phyllachora maydis, Monographella maydis* and *Coniothyrium maydis.* Two series of pictorial standard diagrams were developed for field assessment, one for *P. maydis* and the other for *P. maydis* + *M. maydis.* The disease severity depicted on the 72 diagrams was assessed for the number of lesions and the percentage disease severity by 36 volunteers of diverse professional backgrounds without prior experience in assessing crop diseases. The assessment error for the *P. maydis* diagrams included a 17–38% underestimation of number of lesions and a 184–330% overestimation of disease severity. For the *P. maydis* + *M. maydis* diagram, overestimation for the classes with 1·0–4·5% disease severity was relatively high, whereas the error diminished with a higher proportion of larger lesions. In general, regular distribution of disease tends to be overestimated, in this case by 10–71%. The greatest assessment error was, however, related to the inappropriate choice of assessment scale, particularly for lesions smaller than 3·5 mm.

1. Introduction

Standard diagrams for disease assessment are often used in field experiments for convenience and for achieving better agreement between assessments done by cooperating experimenters (James, 1971). Based on principles described by Horsfall and Barrat (1945), Kranz (1970), Analytis (1976) and Hau *et al.* (1989), we developed standard diagrams for assessing the tarspot disease complex (TDC) of maize (*Zea mays L.*). The first TDC fungus to invade maize is *Phyllachora maydis* Maubl. The second one, *Monographella maydis* Müller and Samuels, usually shows up a week after *P. maydis* appears, forming the typical 'fisheye' symptom and resulting in extensive leaf necrosis. A third fungus, *Coniothyrium phyllachorae* Maubl., has frequently been observed invading the common lesion of the first two pathogens (Hock *et al.* 1992).

In this study we elucidate main sources of errors in disease assessment, particularly those related to TDC. Two series of pictorial standard diagrams were developed, each depicting nine classes of progressive disease severities (Hock, 1989). In tests with volunteers of diverse professional backgrounds with no previous experience scoring crop diseases, number of lesions and percentage disease severity were estimated using 36 individual models of standard diagrams. The diagrams were produced by photographed paper pieces representing the respective disease entities as described by Hock (1989). Here, we report on differences between estimates of number of lesions and percent disease severity on the effect of assessment precision of regular versus irregular lesion distribution and a varying proportion of small versus large lesions.

2. Materials and methods

Two tests were made, each using a series of 36 diagrams. One depicted the symptoms of *P. maydis* (PM) and the second the combined symptoms of *P. maydis* + *M. maydis* (TDC). Lesions of *C. phyllachorae* are not shown separately because that fungus forms a common lesion with the latter ones. The original size of each model is 9 × 20 cm, one-third the size of an average maize leaf. Based on the Weber–Fechner law we designed nine classes with a maximum disease severity of 18 and 40% for PM and TDC, respectively, using disease patterns observed in the field. This excludes leaf destruction, which is caused by factors apart from the disease complex. Each of the nine classes represents the mean disease severity following a logarithmic scale (Kranz, 1988). The logarithmic ordering of the mean disease severities ranges from 0·5 to 18% and 1·0 to 40% for PM and TDC, respectively, divided into nine classes (Table 1).

Four versions exist in each class: regular and irregular lesion distribution and varying percentages of predominantly small (version 'a') and large (version 'b') lesions. Figure 1 shows eight examples of the 72 PM and TDC models that were given in randomized order to 36 volunteers. Volunteers were asked to estimate within 60 min

Table 1. Logarithmic class means (%) for nine-class standard diagrams for Phyllachora maydis *(PM) and* P. maydis + Monographella maydis *(TDC)*

Disease	Mean in class (%)								
	1	2	3	4	5	6	7	8	9
PM	0·5	1·0	2·0	4·0	6·0	9·0	12·0	15·0	18·0
TDC[a]	1·0	2·0	3·0	4·5	7·0	11·0	17·0	25·0	40·0

[a] Differential proportions of disease of *P. maydis* and *M. maydis* for the class means of the TDC standard diagram of predominantly small lesions (version a) are 0·5, 1·0, 1·5, 2·0, 3·0, 4·0, 6·0, 8·0 and 6·0%, respectively.

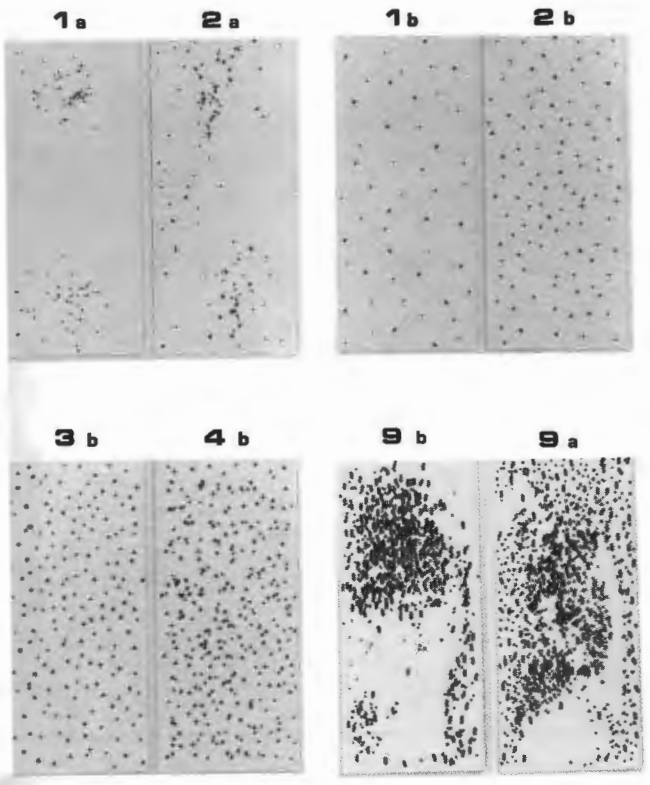


Figure 1. Eight diagrams of class means for P. maydis *classes 1 (0·5%), 2 (1·0%), 3b (2·0%), 4b (4·0%) and 9 (18·0%) for a regular and irregular lesion distribution and many small (a, 0·5–2·0 mm) or large (b, 1·5–3·5 mm) lesions.*

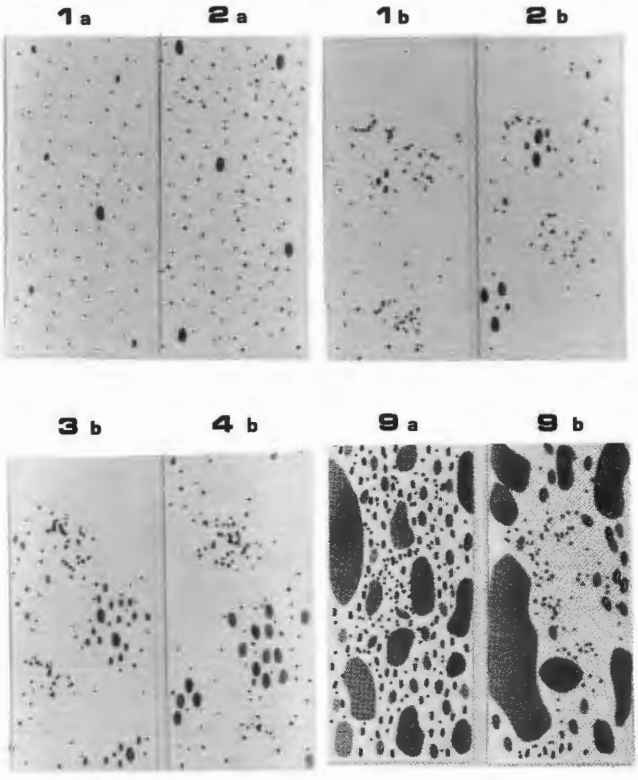


Figure 2. Eight diagrams of class means for P. maydis + M. maydis *(TDC), classes 1 (1·0%), 2 (2·0%), 3 (3·0%), 4 (4·5%) and 9 (40·0%) for a regular and irregular lesion distribution and many small (a 3·0–4·0 mm) or large (b, 5·0–9·0 mm) lesions, as well as large blotches of confluent lesions.*

the percentage disease severity and number of lesions and to assign the number of lesions to the nearest means of a class (abscissa, Figures 3 and 4).

3. Results and discussion

The results of the assessment tests for 36 persons are expressed as the deviation from the true means for the model diagrams as shown in Figure 3. The number of *P. maydis* lesions in class 9b was 730, equivalent to 18% diseased leaf area (Figure 2) and the maximum disease severity of *P. maydis* observed during fieldwork by the authors around the time of the present study. The results of these two series are shown in Figures 3 and 4.

The results of these tests show opposing trends of assessment errors by the 36 volunteers. The number of *P. maydis* lesions was underestimated, whereas for percentage disease severity the reverse is true. Relative deviations from true values, however, are smaller for number of lesions than for percentage disease severity (Table 2).

Another contrast exists between estimates of number of lesions for diagrams representing a regular versus an irregular distribution on the leaves. The mean relative errors in assessing percentage severity are greater for small lesions (71%) than for larger ones (10%) between the regular and irregular distribution. In contrast we found a lower mean error in assessing number of lesions in the regular distribution. In general, there is a higher mean error related with smaller lesion size and greater number of lesions. Assessment of both *M. maydis* and TDC was more accurate for diagrams consisting of 3–75 larger lesions (Table 3).

Estimates in the case of smaller lesions have a mean error of 211% for the regular and 164% for the irregular distribution, which is consistently higher than for larger lesions (Table 3). This agrees with the results of *P. maydis* assessment, in that the distribution of the lesions has less effect on assessment precision. Precision of estimates was also tested by a regression analysis following the method of Hau *et al.* (1989). Entries for the analysis were the mean estimates of all volunteers. As the values for the *y* intercept *a* approach 0 and for the regression coefficient *b*, 1·0, the estimated values tend toward the true values (Table 4). The results of the regression analysis agree with the analysis of mean errors (Table 3).

Despite the choice of a logarithmic scale for the diagrams, results here suggest that assessment errors do not follow a logarithmic pattern. As shown in Figures 3 and 4, individual deviations from true severity values are an important source of error. However, it is crucial to choose an assessment method that takes into account the properties of the disease (Hau *et al.* 1989). Our results demonstrate that, particularly for diseases causing small lesions, human error in assessment may be significant and it thus important to use an appropriate assessment scale. We therefore developed two sets of TDC assessment keys; one for the case of predominantly small lesions caused by *P. maydis* (Figure 1), and the other for large lesions due to TDC, i.e. when *P. maydis* and *M. maydis* are joint pathogens (Figure 2).

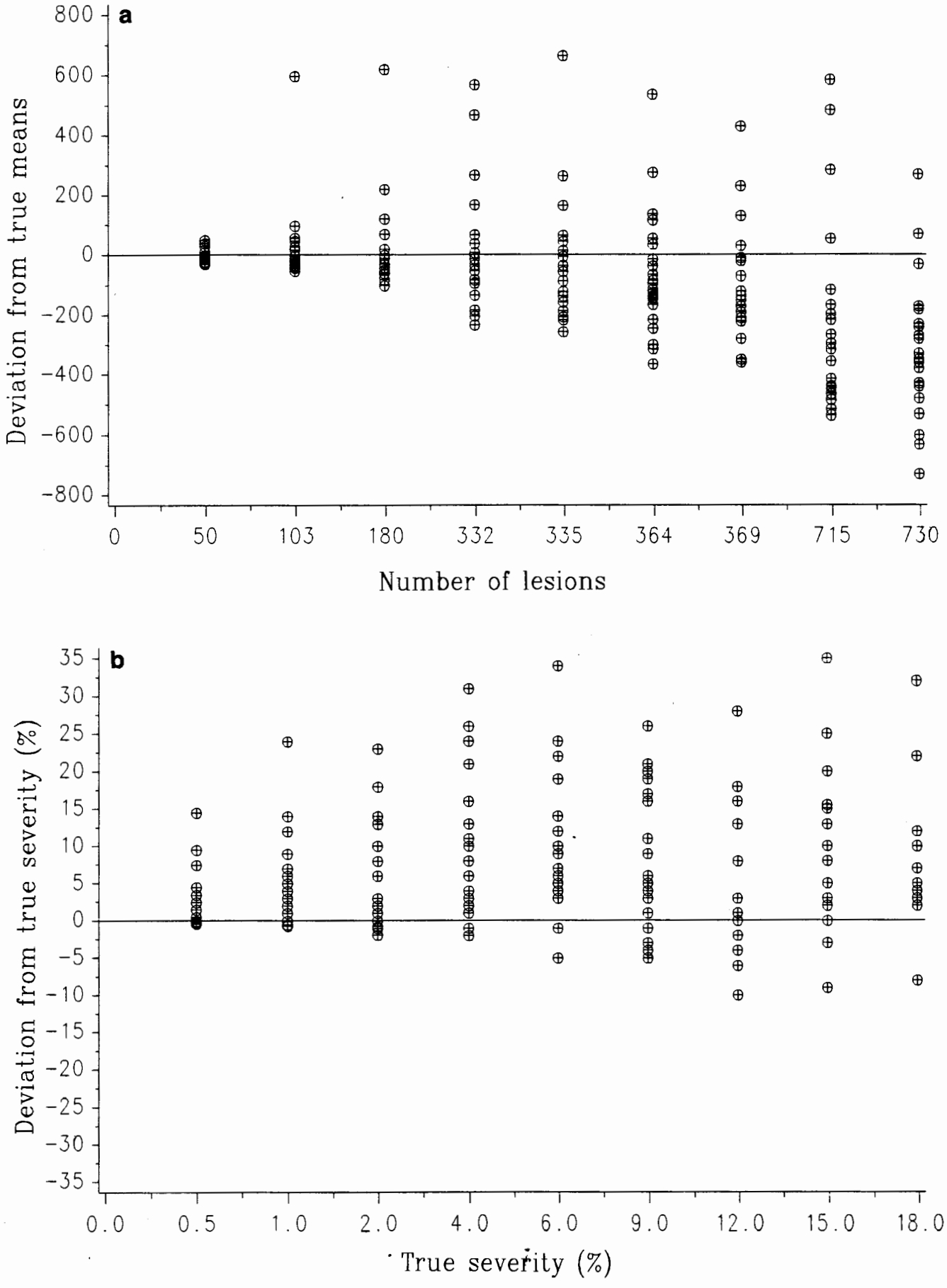
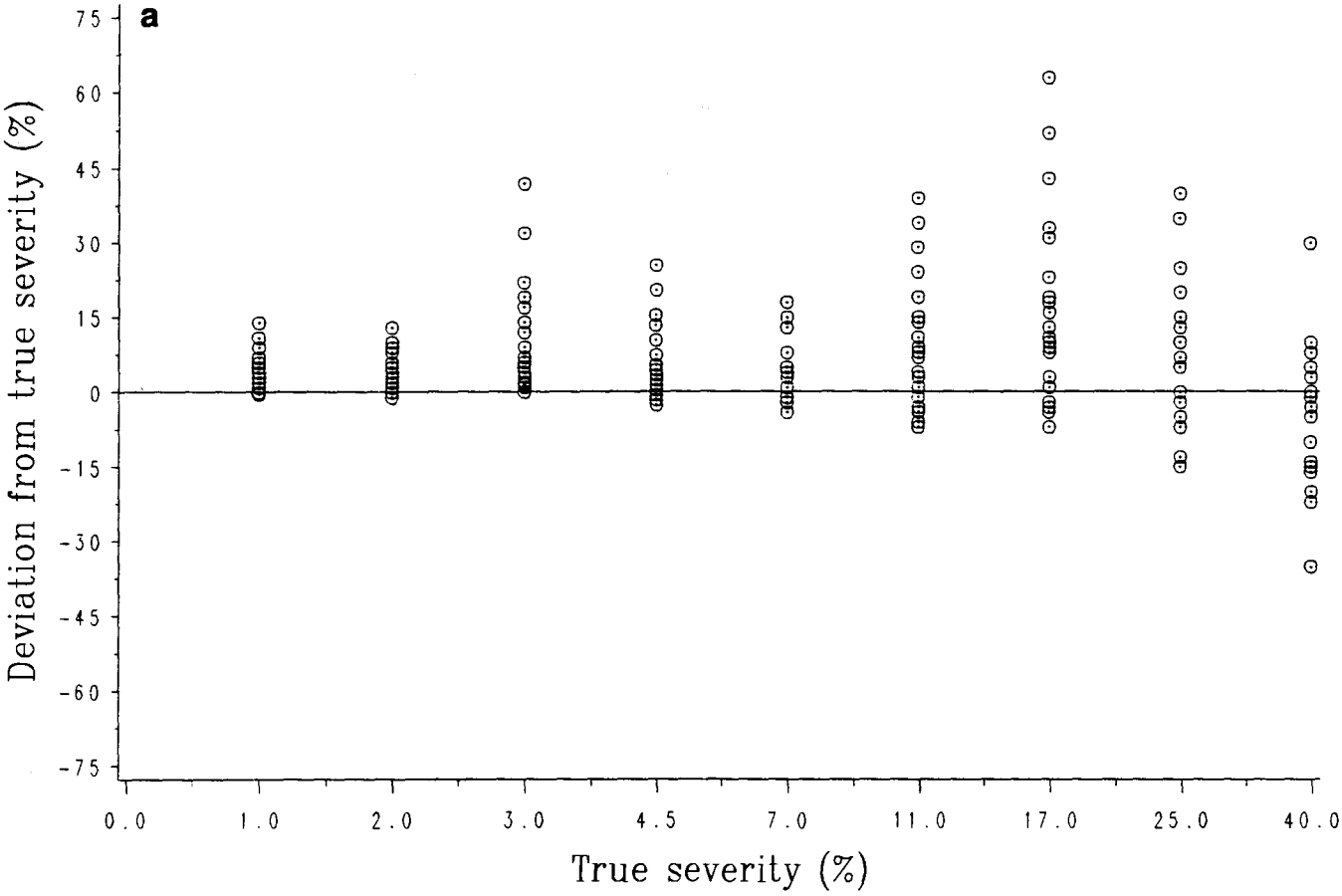


Figure 3. Results of assessment of standard diagrams for P. maydis *disease severity (%) and number of lesions for a regular disease distribution, predominantly large lesions (dots = estimates made by individual assessors; line parallel to x-axis = 0 deviations from the actual values).*



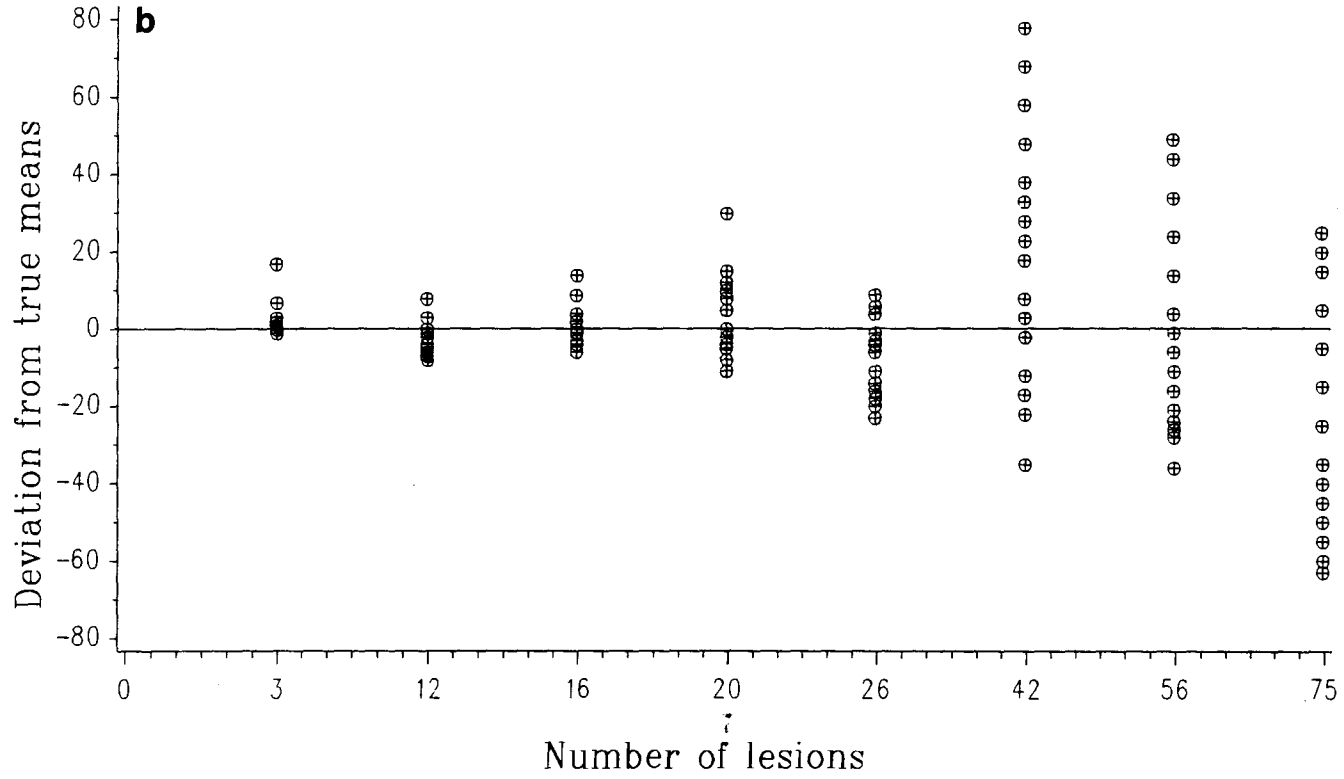


Figure 4. Results of assessment of standard diagrams for P. maydis ± M. maydis *(TDC) disease severity (%) and number of lesions for a regular disease distribution, predominantly large (4–9 mm) lesions (dots = estimates made by individual assessors; line parallel to x-axis = 0 deviations from the actual values).*

Table 2. Mean relative errors in estimating number of lesions and percent disease severity of Phyllachora maydis *in nine-class diagrams with a regular and irrregular distribution of small and large lesions*

Class	No. of lesions				Severity (%)			
	Regular		Irregular		Regular		Irregular	
	a	b	a	b	a	b	a	b
1	−9[a]	−4	−4	−17	775	618	492	688
2	2	14	−18	−14	649	510	403	263
3	−10	17	−40	−27	566	437	234	277
4	−20	−4	−33	−28	265	277	206	131
5	−12	−8	−46	−23	245	188	143	127
6	−26	−21	−49	−25	178	103	88	73
7	−38	19	−49	−37	128	61	62	21
8	−38	28	−55	−43	107	79	62	54
9	−41	36	−39	−39	60	61	59	26
Mean[b]	17	22	37	28	330	194	259	184

[a] Percentage deviation from the true value for the respective class.
[b] The mean is claculated regardless of the ±sign.

Table 3. Mean relative errors in estimating number of lesions and percentage disease severity in nine-class diagrams representing large (4–9 mm) Monographella maydis *and tarspot disease complex (TDC) lesions with a regular and irregular distribution*

Class	*M. maydis*				TDC	
	No. of lesions		Severity (%)		Severity (%)	
	Reg.	Irr.	Reg.	Irr.	Reg.	Irr.
1	2·1[a]	5·4	70	179	468	498
2	−1·4	−1·3	−11	12	195	221
3	−5·4	−0·8	−20	−3	306	247
4	0·2	−3·0	1	−14	148	156
5	1·8	−0·1	10	−0·6	86	66
6	−4·1	−5·4	−7	−9	66	40
7	−22·2	−21·0	−29	−28	88	49
8	28·6	16·0	68	38	24	20
9	2·7	2·8	13	14	−1	−8
Mean[b]	7·6	6·2	25	33	153	145

[a] Percentage deviation from the value for the respective class.
[b] The mean is calculated regardless of the ±sign.
Reg., regular; Irr., irregular.

Table 4. Parameters of the linear regressions on the precision of 36 volunteers assessing tarspot disease complex in standard diagrams

Proportion of *P. maydis*	Distribution of lesions	Regression parameters		
		a	*b*	R^2
Version a (high)	regular	10·4	0·96	0·44
	Irregular	8·1	0·97	0·50
Version b (low)	Regular	7·7	0·89	0·50
	Irregular	6·9	0·82	0·49

Our results point to various biases resulting from differences in size and distribution of lesions, as well as estimates of number of lesions and percentage disease severity. This information can be used to help minimize error in field assessment of TDC.

Acknowledgement

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