A Pictorial Series of Disease Assessment Keys for Bacterial Leaf Streak of Cereals

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ABSTRACT

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A series of disease assessment keys based on the percent affected leaf area at flowering stage is proposed as a tool to better evaluate bacterial leaf streak symptoms in barley, bread wheat, durum wheat, triticale, and rye. Streak symptoms are more distinct in barley, triticale, and rye than in wheat. The series of standard area diagrams is based on disease patterns on leaves from naturally infected fields and shows that symptoms progress from the central part of the leaf, where free water remains longer in the morning, and not only from the tips of the leaves downward, as suggested previously. Also, the study of bread wheat genotypes that vary in resistance to bacterial leaf streak indicates that stripes are a bit more conspicuous in susceptible genotypes than in resistant ones.

Additional keywords: black chaff, disease scales, *Xanthomonas campestris* pv. *translucens*, *X. c. undulosa*

Bacterial leaf streak of cereals, or black chaff, is caused by *Xanthomonas campestris* pv. *translucens* (Jones, Johnson, and Reddy) Dye and a group of other closely related *X. campestris* pathovars, including *X. c. undulosa* (Smith, Jones, and Reddy) Dye, *X. c. secalis* (Reddy, Godkin, and Johnson) Dye, and *X. c. cerealis* (Hagborg) Dye (2). The use of a standardized assessment method is essential to correctly evaluate disease resistance and yield losses. Disease assessment keys based on the host leaf area infected have been proposed for many diseases (3,12,21). The only key available for bacterial leaf streak has been prepared for wheat (*Triticum aestivum* L.) (12). This scale, however, is not representative of the patterns commonly found in the crop (5,7) and suggests that the disease progresses only from the leaf tip downward. Moreover, the leaf symptoms are less distinct on wheat than on triticale (×*Triticosecale* Wittmack) and barley (*Hordeum vulgare* L.) (19), and the appearance of the disease in wheat has been reported to vary according to genotype (1).

No illustrated disease assessment scales have been prepared to evaluate bacterial leaf streak in barley, rye (*Secale cereale* L.), durum wheat (*T. turgidum* L. var. *durum*), or triticale. The purpose of this work was to observe the range of variation in bacterial leaf streak symptoms in small grains, particularly in selected wheat genotypes, with the aim to develop more representative disease assessment scales based on the percentage of leaf area diseased (disease severity) and, eventually, to better understand symptom development.

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MATERIALS AND METHODS

A total of 695 leaves of small grain cereals naturally infected with bacterial leaf streak were collected at random between August 1987 and August 1990 at Zadoks's growth stage 60–70 (23,24) at three locations (El Batan, Toluca, and Papalotla) in the state of Mexico. These leaves (mostly flag) were from bread wheat, durum wheat, triticale, barley, and rye. The genotype was not considered except in bread wheat, where leaves were collected principally from the susceptible genotypes Alondra and Anahuac and the resistant genotypes Pavon and Thornbird to see whether symptom patterns differed. For the other crops, leaves were sampled at random among approximately 10 different genotypes, although most rye leaves came from the genotype Prolific.

The leaves were dried in newspaper and kept in a herbarium. Leaves were drawn at a 1:1 ratio on sheets of tracing paper, and necrotic areas, i.e., light or dark brown diseased areas, were colored black. The percentage area covered with lesions was calculated. The leaf drawings were cut with scissors and scanned with a Delta-T area meter system (4). The scanner consisted of a conveyor belt, a standard RCA camera, and an area meter connected to a monitor. The camera scanned the object line by line to build up a picture on the monitor, and the user was able to check the actual area measured (4). The area meter was calibrated after every 10 samples by scanning a 10 × 10 cm reference square. The total leaf area and the necrotic leaf area were measured independently by adjusting the detection threshold gradually from zero until the darkened area visible on the video corresponded to the area of interest.

The distribution of samples in categories of increasing percent leaf area damaged was evaluated. Drawings corresponding to 1, 5, 10, 25, 50, and 75% of the area covered by lesions were selected to prepare standard assessment keys.

RESULTS AND DISCUSSION

Table 1 shows the minimum, maximum, and average percentages of diseased leaf area observed in the sample sets, and Figure 1 shows the distribution of leaves across disease severity categories. More than 90% of the leaves in the nine sets of samples scored below 50% area damaged, with the exceptions of rye (80%) and the highly susceptible wheat genotype Alondra (88%). In durum wheat, 90% of the 43 samples scored below 30%; this result is consistent with field observations over years in Mexico, where disease severity is usually characterized by less than 50% leaf area attacked (*unpublished*).

For leaf rust, the maximum infection possible in the field was designated to be less than 37%, and this figure was consequently assigned a 100% value to actual leaf area in a modification of Cobb's scale (16,17). Similarly, Eyal and Brown (8) found that the maximal actual coverage by pycnidia per unit area of leaf in Septoria leaf blotch was 22.9%, and this value was rescaled to give 100%. In bacterial leaf streak, 100% diseased leaf area is not observed either, except in very susceptible genotypes under severe epidemic conditions in breeding stations. However, it is not necessary to use 100% as maximum when relating disease severity or incidence to yield losses (13), and there is no disadvantage to using standard area diagrams where the percentage of infection recorded always represents the actual covered area.

Saari and Prescott (18) have developed whole-plant diagrams for foliage diseases of wheat. Their scale was recently improved by the use of two digits representing the vertical disease progress and an estimate of severity. The first digit gives the relative height of the disease, using the original 0–9 Saari-Prescott scale as a measure, and the second digit shows the disease severity as a percentage but in terms of 0–9 (9). This two-digit scale is useful for screening germ plasm for resistance to foliar blights, including bacterial leaf streak (6). However, the data are difficult to analyze because both digits should be analyzed separately and scores should not be averaged. In addition, severity represents an overall score of 10–20 plants. Since specific levels of disease, i.e., on the flag and flag-1 leaves, must be defined to run epidemiology and yield loss trials, the help of standard area diagrams is necessary to score individual leaves (14). A limitation of this procedure is that the observer cannot evaluate how close the estimated severity is to the correct severity. Any assessment is limited by visual acuity, and the scores of two investigators will differ even when they use the same scale. Consequently, training people through a computer program such as DISTRAIN to assess disease severity is invaluable (22), but no subroutine is available for bacterial leaf streak in this program.

The standard area diagrams for barley, rye, triticale, durum wheat, and bread wheat (Figs. 2 and 3) show typical streak lesions in all crops. Stripes are more elongated and conspicuous in barley, rye, and triticale than in wheat, which tends to show blotches. This confirms other observations (19). In barley, 10- to 15-cm streaks commonly spread between the veins, whereas in wheat, lesions coalesce rapidly to form solid blotches. For all crops, the series of diagrammatic scales show that lesions start principally from the central part of the blade where the leaf bends and where dew remains longer in the morning and also where moisture remains longer after a rainfall, leading to the production of exudates (*unpublished*). Apparently, free water is important to release of bacteria from the leaf and to penetration of bacteria through the stomata. The key proposed by James (12) does not show this characteristic and suggests that the infection is progressing from the leaf tips, possibly through guttation. The epidemiological importance of guttation pores in the progress of bacterial leaf streak was not substantiated in our study. It is possible that disease induction and progress differ among geographic areas.

Table 1. Origin of leaves and ranges of leaf area in samples used to prepare standardized disease assessment keys for bacterial leaf streak of small grains

Crop Genotypes	No. of samples	Location	Leaf area diseased (%) Min.	Max.	Av.
Barley	91	Toluca	1	56	21.4
Triticale	96	Toluca	1	67	17.7
Rye	56	El Batan	1	63	22.5
Durum wheat	43	Toluca	1	36	17.7
Bread wheat					
Several	51	Toluca and Papalotla	1	62	20.7
Alondra	143	El Batan and Toluca	1	83	23.3
Anahuac	82	El Batan	1	51	13.3
Pavon	71	El Batan	1	53	17.2
Thornbird	62	El Batan	1	55	7.1

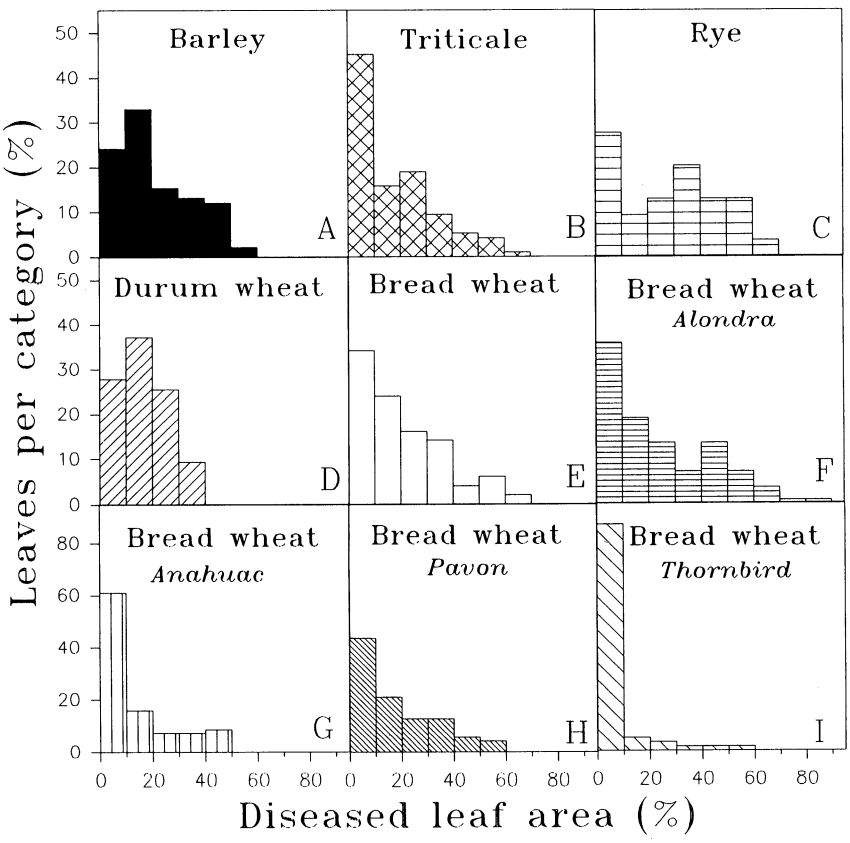

Fig. 1. Percentage of leaf samples per category of diseased leaf area in five cereal crops.

The detailed analysis carried out with four reference genotypes of bread wheat (Fig. 3) showed that symptom patterns are similar in resistant and susceptible genotypes. These patterns are representative of symptoms generally observed in bread wheat stocks at CIMMYT. Although stripes are a bit more conspicuous in Alondra and Anahuac (Fig. 3), resistant and susceptible types of symptom expression do not exist. In bacterial leaf streak, differences in symptom patterns on the leaves are limited to the more typical streak development in barley, rye, and triticale and the streak coalescence in wheat to form blights. Exudates may not always be seen in the field. In this case, microscopic observation is necessary to confirm diagnosis because bacterial leaf streak can be confused with other leaf diseases such as spot blotch caused by *Cochliobolus sativus* (Ito & Kuribayashi) Drechs. ex Dastur (anamorph = *Bipolaris sorokiniana* (Sacc.) Shoemaker, synonym = *Helminthosporium sativum* Pammel, C.M. King, & Bakke) or with the early stages of yellow rust caused by *Puccinia striiformis* Westend. f. sp. *tritici*, the blotches caused by *Septoria* spp., and tan spot caused by *Drechslera tritici-repentis* (Died.) Shoemaker (teleomorph = *Pyrenophora tritici-repentis* (Died.) Drechs.). Finally, a yellow mottling is sometimes observed at the edge of the lesions in durum wheat. Although the keys proposed here were prepared from samples collected at the flowering stage when bacterial leaf streak is in maximum development in the field, the scales can be used earlier in the cropping season if the growth stage is noted (15,23,24).

Keys based on a percentage scale offer many advantages: 1) The upper and lower limits of a percentage scale are always uniquely defined, 2) the scale can be easily divided and subdivided, 3) interpolation can be made (e.g., 15%, 40%), 4) the scale can be used universally, and 5) the scale can be transformed for any subsequent epidemiological analysis (14). Horsfall and Barratt (11) pointed out that the grades of disease detected by the human eye are equal divisions on a log scale and follow the Weber-Fechner law, i.e., the response increases linearly as the stimulus increases logarithmically. A system with 12 categories of damaged leaf areas was proposed (11) but was not

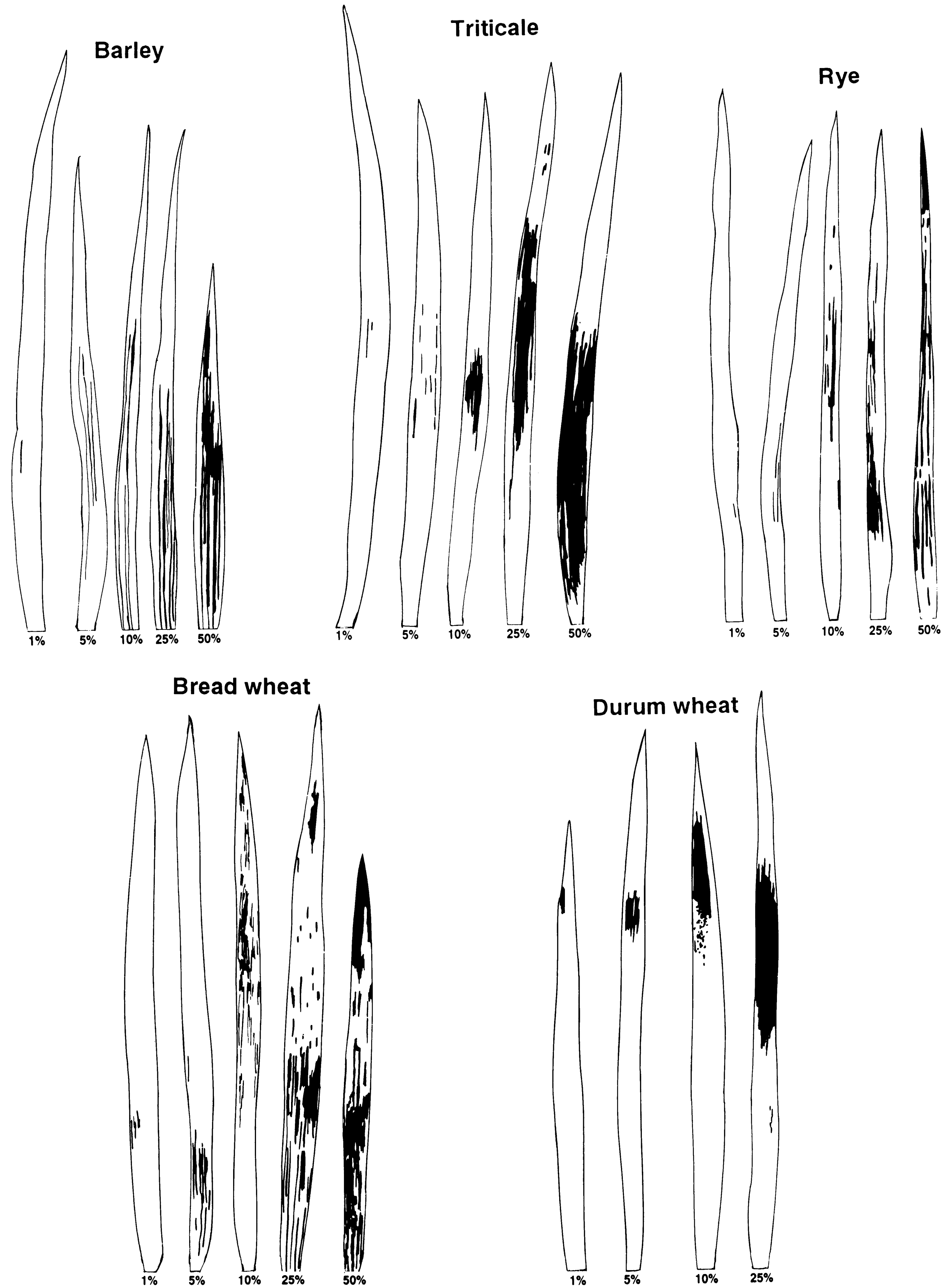

Fig. 2. Standard disease assessment keys showing different percentages of the leaf surface with bacterial leaf streak symptoms at flowering in five cereal crops.

always easy to use; consequently, a 1–5 scale with a reduced number of disease rating categories has been implemented for rapid scoring in the field (20). The rationale for the Horsfall-Barratt scale has been questioned, and there appear to be no convincing experimental data demonstrating that this system is better than the use of standard area diagrams based on actual leaf areas diseased (10). It also seems advisable to always use a linear scale with equal divisions, but assessors often do better when using standard area diagrams than when attempting to record equal divisions on a log scale (13).

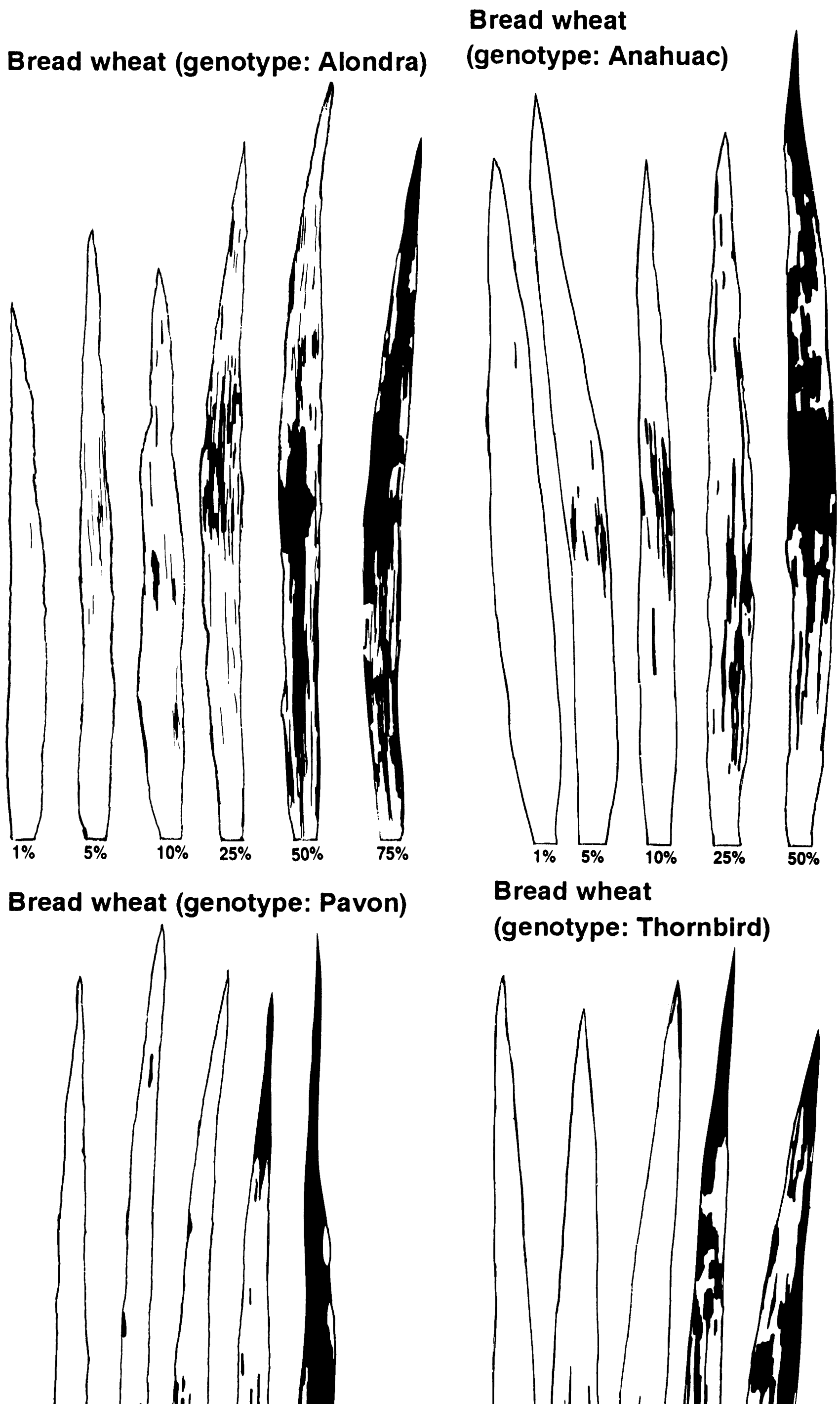

Fig. 3. Standard disease assessment keys showing different percentages of the leaf surface covered with bacterial leaf streak symptoms at flowering in four bread wheat genotypes. Alondra and Anahuac are susceptible, and Pavon and Thornbird are tolerant.

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