Streaking of Lily Leaves Associated with Infection by *Botrytis elliptica*

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ABSTRACT

Doss, R. P., Chastagner, G. A, and Riley, K. L. 1988. Streaking of lily leaves associated with infection by *Botrytis elliptica*. Plant Disease 72:859-861.

Infection of leaves of Easter lily (*Lilium longiflorum*) with *Botrytis elliptica*, the causative agent of fire, sometimes resulted in the development of prominent yellow streaks that appeared distally and, to a lesser extent, proximally from the site of the lesion. Streaks that formed on leaves of Asiatic hybrid lilies were red instead of yellow. With Easter lilies, streaking occurred most frequently on older leaves of postanthesis plants. Wounding rarely resulted in streaks. Although *B. elliptica* was the only organism associated with streaks under natural field conditions, streaks also occurred when leaves were wound-inoculated with several microorganisms not usually pathogenic on lily leaves. This indicates that this symptom is not specific with respect to *B. elliptica*.

Fire, or Botrytis blight, caused by *Botrytis elliptica* (Berk.) Cooke, is a serious foliar disease of ornamental lilies (*Lilium* sp.) (2,9,10). The symptoms of the disease usually include development of brown or reddish-brown spots that, in severe attacks, coalesce to kill an entire leaf (2). Infection can also occur on flowers and stems.

Another symptom that we observed in greenhouse studies of resistance of Easter lilies to *B. elliptica* (4) was the development of prominent yellow streaks that sometimes appeared distally and, to a lesser extent, proximally from the point of infection. Similar streaks form in daffodil (*Narcissus* sp.) upon infection with *B. polyblastis* Dowson (1). Our study concerns the factors affecting development of this symptom on lilies.

MATERIALS AND METHODS

Field and greenhouse studies. Isolates of *B. elliptica* were obtained from infected lily leaves collected from a commercial field planting (3). Conidia were produced by culturing the fungus on potato-dextrose agar (PDA) under near-UV light (3). Conidial suspensions were formulated using sterile deionized water that contained 0.02% (v/v) of Tween 20.

Scientific paper 7601, Project 0496 of the College of Agriculture and Home Economics, Washington State University, Pullman 99164.

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Accepted for publication 28 April 1988 (submitted for electronic processing).

A field study was carried out with a sample of 11 lily clones. Bulbs of five *L. longiflorum* Thunb. cultivars (Ace, Croft, Harbor, Nellie White, and virus-free Nellie White) and six Asiatic hybrid (8) lilies (Gold Medal, Gold Rush, Peach Blush, Prelude, Red Carpet, and Sunkissed) were planted in a randomized complete block design with five single-row blocks, on 0.9-m centers near Puyallup, WA. Within each row, five bulbs of each cultivar, except Ace, which had three bulbs, were planted in a 7-cm-deep furrow on 22 April. Before hilling soil over the bulbs, a mixture of PCNB (3.6 mg a.i. ml^{-1}), ferbam (3.6 mg a.i. ml^{-1}), and benomyl (1.2 mg a.i. ml^{-1}) was sprayed over the bulbs in the equivalent of 100 ml of water per meter of row.

After emergence of the lilies, diuron (1.8 kg a.i. ha^{-1}) was applied to the soil and irrigated in on 14 June to control weed growth. On 16 June, 17.8 g of air-dried wheat seed that had been colonized by isolates of *B. elliptica* was uniformly spread over the soil next to the lilies in each row. To provide conditions favorable for disease development, the entire plot was automatically and intermittently misted between 2000 and 0800 hr daily. Periods of leaf moisture were monitored with a leaf wetness meter. The plants were examined between 8 July and 14 September, and any streaks were noted. Isolations were made periodically from leaves with symptoms to confirm the presence of *B. elliptica* (3). This field study was done primarily to obtain information on disease incidence and severity that is presented elsewhere (4), but also served to determine whether streaking is a symptom of infection by *B. elliptica* on lilies growing in the field. Easter lily leaves from several commercial plantings in the Brookings, OR area were also examined for the presence of yellow streaks associated with infections of *B. elliptica*.

Lilium longiflorum 'Ace' was used throughout the greenhouse study. Lily bulbs were stored in moist peat moss or sawdust at 1 C until planting. Single bulbs were planted in 13 × 13 cm pots and grown in a greenhouse maintained with a 21 C maximum and a 10 C minimum temperature. Natural photoperiods were supplemented with 16 hr (0600–2200) of light (115 $\mu E \cdot m^{-2} \cdot s^{-1}$), delivered by F96T12CW 1,500W fluorescent tubes suspended about 1 m above the upper surface of the pots. The planting medium was a commercial peat-vermiculite mix (Redi-Earth) and nutrients were provided by weekly irrigation with 0.2 strength Hoagland's solution (5), with additional nutrients provided by application of 14:14:14 slow-release fertilizer.

Effect of leaf age and position. To determine the influence of plant age and leaf position on leaf yellowing, leaves on intact Easter lily plants were inoculated on the abaxial surface with 5-μl drops of spore suspensions containing 10^4 spores ml^{-1}. Ten plants were used per treatment per date, with inoculation of two leaves per leaf position per plant. Half of the leaves at each position were wounded by cutting an 'X' about 2 mm across with a sterile scalpel through the leaf. The other 10 leaves were left unwounded. Plants were then placed in a dew chamber at 20 C and saturated humidity under 12 hr light/12 hr dark photoperiodic cycles (40–50 $\mu E \cdot m^{-2} \cdot s^{-1}$) for 48 hr. After incubation, plants were returned to the greenhouse and examined for lesion formation and yellow streaking 1 wk after inoculation. The percentage of infected leaves with yellow streaks was computed for each leaf portion at each sampling date. Because wounding did not influence infection or development of yellowing, data were pooled from wounded and nonwounded treatments.

Specificity of symptoms. To determine whether organisms not naturally pathogenic on lily leaves were able to induce yellow streaking on Easter lily, leaves on postanthesis greenhouse-grown plants were wounded by scratching their adaxial surface with a dissecting needle. They were then inoculated by placing PDA plugs obtained from the edges of actively growing colonies of *B. tulipae* Lind, *B. cinerea* Pers. ex Fr., *Leptosphaeria korrae* Walker & Smith, *Stagonospora curtisii* (Berk.) Sacc.,

Rhizoctonia sp., and *Xanthomonas* sp. on the wounded tissue. Wounded leaves were also inoculated with mycelial plugs from PDA cultures of *B. elliptica*. Noninoculated wounded leaves on which PDA plugs were placed served as checks. Single leaves in the lower and upper portions of five plants were inoculated with each organism. Inoculated plants were placed in a dew chamber maintained at 20–23 C for 72–76 hr and then removed to a greenhouse. Leaves were examined for symptoms after 5 days. The experiment was repeated twice with similar results.

RESULTS AND DISCUSSION

Field and greenhouse studies. Mature leaves of both field- and greenhouse-grown Easter Lily naturally infected or artificially inoculated with conidia of *B. elliptica* not only had lesions at the point of infection, but prominent yellow streaks sometimes appeared both distally to, and to a lesser extent, proximally from the infection site (Fig. 1A,B). Green islands often separated the infected tissue from the yellow streaks (Fig. 1B). Streaks on Asiatic hybrid lilies were red instead of yellow (Fig. 1A). Prominent streaks sometimes formed while lesions were still very small. Yellow streaks were also seen on infected leaves obtained from commercial plantings of Easter lilies. These streaks were always associated with lesions from which *B. elliptica* was isolated, suggesting that streaks are a normal symptom of infection.

Effect of leaf age and position. Leaf yellowing in greenhouse-grown plants in response to infection by *B. elliptica* occurred more frequently on older plants and on lower leaves than on young plants and upper leaves (Fig. 2). Yellowing did not occur as a result of wounding alone, nor did it occur on all leaves of any treatment class, with the exception of the lowest leaves where sample size was greatly reduced before the end of the study by leaf senescence (*data not shown*). Infected leaves on young (rosette) plants often showed no yellowing. Although *B. elliptica* was consistently isolated from necrotic spots, no successful isolation from a yellow area was ever made.

The pattern of yellowing relative to plant age and leaf position suggests that inoculation of leaves with *B. elliptica* hastens leaf senescence in regions of the

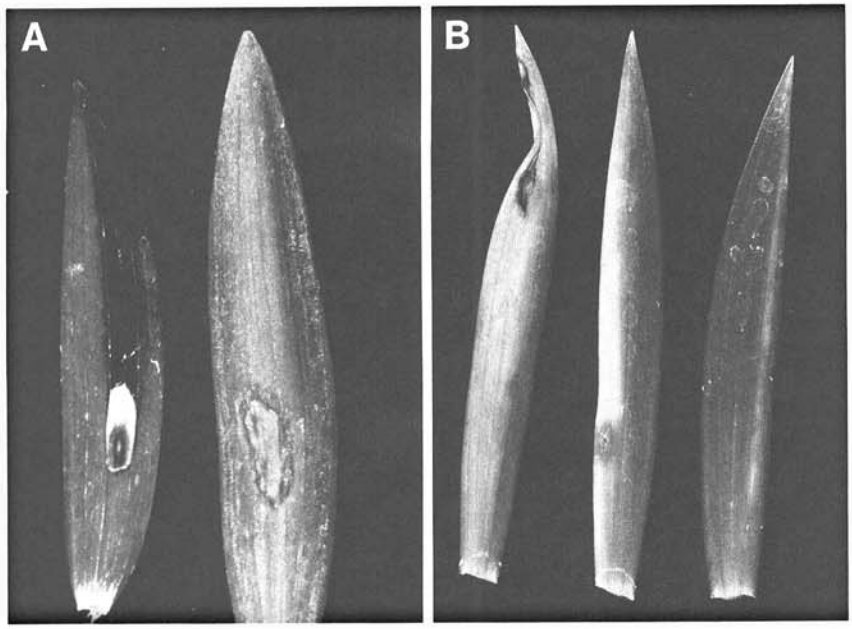

Fig. 1. Streaks associated with infection of **(A)** field-grown cv. Prelude Asiatic lily (left), and cv. Nellie White Easter lily (right) plants, and **(B)** greenhouse-grown cv. Ace Easter lily plants by *Botrytis elliptica*. Leaves are about 1.5 cm wide. Note green island on one leaf in (B). Residues are salts from irrigation water that was splashed onto leaves.

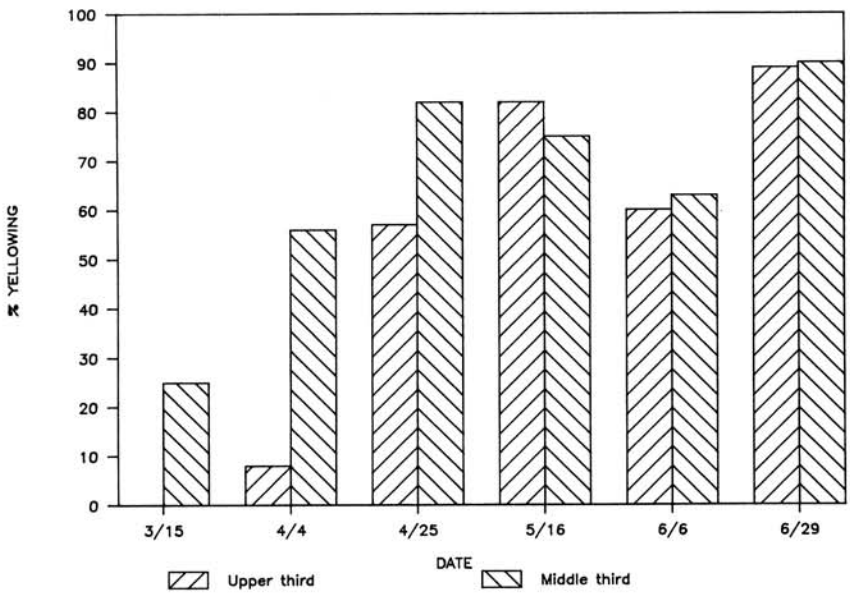

Fig. 2. Percentage of infected Easter lily leaves (N = 7–12 infected leaves with 1 inoculated leaf per plant) that exhibited yellow streaks 1 wk after inoculation with *Botrytis elliptica*. Results are with leaves from upper third and middle third of plant. Planting date was 29 November 1982. Half of the plants had undergone anthesis by 2 May 1983, and all plants by 23 May 1983.

Table 1. Lesion development and yellowing of cv. Ace lily leaves in response to wound inoculation with *Botrytis elliptica* or other microorganism not naturally pathogenic on lily leaves[y]

Organism	Percentage with lesions[z]	Percentage with yellowing[z]
Botrytis elliptica	100 a	100 a
B. cinerea	90 a	70 abc
B. tulipae	83 a	83 ab
Leptosphaeria korrae	0 c	70 abc
Rhizoctonia sp.	90 a	100 a
Stagonospora curtisii	50 b	60 bc
Xanthomonas sp.	0 c	40 cd
Wounded/ noninoculated	0 c	20 d

[y] Leaves were examined 5 days after inoculation. Data were subjected to analysis of variance (results of individual inoculations were considered as variates) after coding lesion development (0 = no lesion, 1 = lesion) and yellowing counts (0 = no streak, 1 = streak). Data are pooled from two experiments, and means are either for 10 or 20 (*B. tulipae, S. curtisii*) inoculations. In the 2 out of 10 cases where yellowing occurred on the noninoculated plants, it was very slight and may have been caused by natural leaf senescence.

[z] Values within columns followed by different letters represent significantly different effects as determined by Duncan's multiple range test.

leaf adjacent to the point of infection. In one study, removal of a 5-mm disk from leaves did not result in yellowing (*data not shown*). Wounding without inoculation with a pathogen rarely caused streaks (Table 1), indicating that vascular interruption alone is not responsible for this symptom. Farkas (6) has discussed the idea that disease can induce plant senescence, and, with others (7), has suggested that leaf removal often induces the same enzymatic changes that follow infection with a pathogen. In this regard, it was noteworthy that yellow streaking arising from infection by *B. elliptica* was difficult to demonstrate in detached lily leaves because it was masked by the rapid general leaf yellowing that occurred on removal of the leaves.

Specificity of symptoms. Results observed upon inoculation of lily with a group of organisms not naturally pathogenic on lily leaves demonstrated that the response was not specific to *B. elliptica* (Table 1). Lily leaves responded to almost all of the organisms by development of yellow streaks similar to those associated with infections by *B. elliptica*. Lesions appeared on at least some of the leaves wound-inoculated with each of the fungi, with the exception of *L. korrae*. None of the leaves inoculated with a *Xanthomonas* sp. developed lesions, and with this organism, a bacterial foliar pathogen, the percentage of leaves with yellowing was not significantly different from the wounded/noninoculated check.

Although *B. elliptica* was the only organism associated with streaks under natural field conditions, these results suggest that the yellowing response of lily leaves is not specific to *B. elliptica*. Rather, the premature senescence exhibited by many plants on attack by pathogens (6) may, with lilies, be manifested by the formation of yellow streaks. It is probable that the streak pattern of chlorosis seen in lily relates to the parallel leaf venation.

ACKNOWLEDGMENTS

Financial support from the Fred C. Gloeckner Foundation and the Pacific Bulb Growers Association is acknowledged. We thank Lee Riddle and Edward McRae for providing lily bulbs.

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