Epidemiological Factors of Sugar Beet Powdery Mildew

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ABSTRACT

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Susceptibility to powdery mildew (caused by *Erysiphe polygoni*) in sugar beet inoculated 2, 4, 8, 12, and 16 wk after planting increased with plant age. Of 33 plant species representing 19 genera in nine families, only *Beta atriplicifolia, B. lomatogona, B. macrocarpa, B. macrorhiza, B. maritima, B. patula, B. trigyna,* and *B. vulgaris* (red beet, sugar beet, Swiss chard) were highly susceptible to the fungus from sugar beet; *B. patellaris* was highly resistant. Atypical infection spots occurred on senescent leaves on one *Chenopodium capitatum* and two *Rumex crispus* plants, but the hyphae did not spread, sporulation was minimal or nonexistent, and the fungus ultimately disappeared. Powdery mildew conidia (*Erysiphe* spp.) from *Amarathus retroflexus*, *R. crispus*, and *Solanum sarachoides* growing in sugar beet fields did not infect sugar beet in the greenhouse. Vegetative mycelia or conidia of the fungus remained infectious in sugar beet leaf debris buried outdoors in soil for 60, but not 90, days. Infected leaf debris stored at room temperature, in a refrigerator at 3-4 C, or in a protected area outdoors over winter was noninfectious when tested after 60 days of storage. *Erysiphe polygoni*-infested seed yielded healthy seedlings, and inoculum prepared from infested seed was noninfectious to sugar beet. The brief life of the fungal vegetative stage, the absence of the perfect stage, specificity for the genus *Beta*, and the yearly sequential spread of the disease support the theory that overwintering of the fungus mainly occurs in the southwest and that conidia are carried northward and eastward by prevailing winds.

Additional key words: *Erysiphe betae*, *Erysiphe polygoni*, hosts.

The onset of a powdery mildew epidemic in sugar beet (*Beta vulgaris* L.) in 1974 (7) and its recurrence in 1975 prompted several questions concerning the epidemiology of the disease and its causal fungus, which has been identified as an *Erysiphe polygoni* DC. "type" (7) Weltzien (10) renamed the fungus *E. betae*, but Coyier et al. (3), basing their decision on cleistothecia found in Washington, believed the pathogen to be *E. polygoni*. In this paper, *E. polygoni* will be used as the epithet for the fungus that causes powdery mildew of sugar beet.

The sequential northward and eastward spread of the disease in the USA in 1974 has been reported (8). The same pattern of spread occurred in 1975, with additional outbreaks in North Dakota, Minnesota, Ohio (E. G. Ruppel, *unpublished*), in Michigan, and an experimental plot in Indiana (9). To learn more about the epidemiology of sugar beet mildew in this country, the present study was conducted to determine the relationship between plant age and susceptibility, the host range of the pathogen, the overwintering capability of vegetative mycelia and condidia, and the role of *E. polygoni*-infested sugar beet seed in the dissemination of the fungus.

MATERIALS AND METHODS

To maintain conditions which favored sugar beet powdery mildew development, environmental plant growth chambers were used for all tests. Temperature and light in the chambers were alternated and maintained at 15 ± 1 C during the 8-hr dark period and at 25 ± 1 C during the 16-hr-light (11,840 lx) period; relative humidity was held constant at 50 ± 5% (5).

Stock cultures of *E. polygoni* isolated from sugar beet growing in a field near Fort Collins, Colorado, were maintained on sugar beet cultivar S-301H in a growth chamber. This cultivar also was used in all tests involving sugar beet as a host. To remove older conidia and assure a supply of fresh conidia for inoculations (5), stock plants were shaken vigorously 48 hr before use as inoculum sources.

In the plant-age and host-range experiments, inoculations were performed by dusting conidia from the leaves of stock plants onto the test plants. Infected stock plants also were kept in the test chamber to supply a constant source of air-blown inoculum via air circulation within the chamber.

To determine relative susceptibility of sugar beet at different plant ages, plants were inoculated at 2, 4, 8, 12, and 16 wk after planting. Powdery mildew severity was evaluated 21 days after inoculation on a scale of 0 to 5, with 0 = no visible symptoms and 5 = severe infection, 100% of the leaves with visible fungus. A randomized complete block design was used with four replications in each of two trials.

Thirty-three plant species representing 19 genera in nine families were inoculated with *E. polygoni* conidia and observed for 30-60 days for the development of the

disease. Species tested included *Amaranthus retroflexus* L., *A. torreyi* (Gray) Benth., *Beta atriplicifolia* Rouy, *B. lomatogona* Fisch. & Mey., *B. macrocarpa* Guss., *B. macrorhiza* Stev., *B. maritima* L., *B. patellaris* Moq., *B. patula* Ait., *B. trigyna* Wald. & Kit., *B. vulgaris* L. (red beet, sugar beet, Swiss chard), *Brassica nigra* (L.) Koch, *Capsella bursa-pastoris* (L.) Medik., *Celosia* sp., *Chenopodium album* L., *C. amaranticolor* Coste & Reyn., *C. capitatum* (L.) Asch., *C. murale* L., *C. quinoa* Willd., *Cucumis sativa* L., *Daucus carota* L. var. *sativa* DC., *Gomphrena globosa* L., *Lycopersicon esculentum* Mill., *Medicago sativa* L., *Phaseolus vulgaris* L., *Petunia hybrida* Vilm., *Pisum sativum* L., *Rumex crispus* L., *Solanum dulcamara* L., *S. sarachoides* Sendtner, *Spinacia oleracea* L., *Tetragonia expansa* Murr., and *Trifolium pratense* L. Five to 10 plants of most species were inoculated; however, only two plants of *B. patula* were available for testing. In addition, powdery mildew conidia (*Erysiphe* spp.) from plants of *Amaranthus retroflexus*, *Rumex crispus*, and *Solanum sarachoides* growing in sugar beet fields were inoculated to sugar beet and healthy plants of *A. retroflexus, R. crispus,* and *S. sarachoides* in the greenhouse.

Longevity of conidia and mycelia was determined by collecting heavily infected sugar beet leaves from the field in October. Spores from these leaves were inoculated to sugar beet and their viability was confirmed. The leaves were air-dried for 48 hr, and aliquots were placed in paper bags at room temperature (20-22 C) and in a protected area outdoors. A third aliquot was placed between aluminum screens and buried 15 cm deep in soil outdoors. In a second trial, leaves also were stored in a refrigerator at 3-4 C. Each month, from December through May, samples of each aliquot were ground and dusted on two leaves of 2-mo-old sugar beets. The plants were observed for 30 days for the development of powdery mildew. A randomized complete block design with four replications was used in each of two trials conducted in 1974-75 and 1975-76.

In another test, heavily infected sugar beet leaves were quick-frozen at -33 C for 24, 48, 72, and 96 hr. After each period, a sample of frozen leaves was ground and dusted on four sugar beet plants. Conidia from the frozen samples also were distributed on water agar and incubated for 16 hr at 25 C to determine viability. Two trials were conducted.

Sugar beet seed from plants heavily infected with powdery mildew in Arizona were supplied 2 mo after harvest by the Holly Sugar Corporation. Each month, from November through April, samples of this seed were planted in six 10-cm diameter pots of steamed soil (10 seeds/pot). An additional sample of seed was ground with a mortar and pestle and dusted on the foliage of four 2-mo-old sugar beets. Emerging seedlings and inoculated plants were observed for 30 days for the development of powdery mildew. Two trials were conducted with seed lots produced in 1974 and 1975.

RESULTS

Plant age.—Disease severity increased with age of the plant at inoculation. Analysis of variance of both trials indicated highly significant differences in mean disease severity among sugar beets inoculated at varied ages. Bartlett's test showed that error variances of both trials were homogeneous and, therefore, an analysis was performed on the combined data. Mean disease indices from the combined analysis were 3.5 for 16-, 2.5 for 12-, 1.8 for 8-, 0.7 for 4-, and 0.3 for 2-wk-old plants. Duncan's multiple range test ($P = 0.01$) indicated that the disease index of 16-wk-old plants was significantly greater than those of the other age groups. There was no significant difference between the 12- and 8-wk groups, but these groups had significantly more disease than the 4- and 2-wk groups. Disease indices of 2- and 4-wk-old seedlings were not significantly different; however, plants in the latter group had one or two typical, sporulating infection spots, whereas the 2-wk-old seedlings had one spot on a cotyledon in which sporulation was minimal or nonexistent.

Host range.—Typical and severe powdery mildew developed only on *Beta atriplicifolia, B. lomatogona, B. macrocarpa, B. macrorhiza, B. maritima, B. patula, B. trigyna*, and *B. vulgaris* (red beet, sugar beet, Swiss chard). A small infection spot developed on one senescent leaf of a *Chenopodium capitatum* plant, and on one leaf of two *Rumex crispus* and two *B. patellaris* plants. The infection spots on these plants were similar to those seen on 2-wk-old sugar beet seedlings; the spots of hyphae did not enlarge, sporulation was minimal, and the fungus ultimately disappeared. In another test, 53 plants from four seed lots of *B. patellaris* did not become infected.

Conidia of *Erysiphe* spp. from *A. retroflexus*, *R. crispus*, and *S. sarachoides* growing in sugar beet fields failed to infect sugar beet, but did infect healthy seedlings of their corresponding species in the greenhouse.

Longevity of vegetative stage.—In both trials (1974 and 1975), inoculum prepared from leaves infected with *E. polygoni* and which had been buried 15 cm in soil for 60 days resulted in infection of two of four sugar beets. All other inocula, including subsequent monthly samples of buried inocula, were noninfectious.

Inocula prepared from frozen infected leaves were noninfectious. Conidia frozen for 24 hr or more failed to germinate on water agar.

Infested seed.—Seed infested with *E. polygoni* yielded healthy sugar beet seedlings. Inoculum prepared from infested seed was noninfectious.

DISCUSSION

Observations in the field indicated that susceptibility of sugar beet to *E. polygoni* seemed to be associated with plant age. In a 1974 survey across 13 states, the disease first appeared 2.5 to 6 (mean = 4.4) months after planting (8). The onset of infection as related to plant age could be partially due to reduced light, temperature, and air circulation, and an increase in humidity under the denser crop canopy of older, as compared with younger, beets (12). However, our results conclusively showed that susceptibility increased with age of plant. Thus, chemical control measures before the crop is 2 mo old would seem to be unnecessary

Of 52 species tested by Drandarevski (4), only those in the genus *Beta* were susceptible to the powdery mildew fungus from sugar beet in Europe. Likewise, only *Beta* species were highly susceptible in our tests. The questionable and extremely mild reaction that we

obtained on two non-*Beta* species may have been due to the continued exposure of the plants to abundant conidia under long periods of environmental conditions exceptionally favorable for mildew development.

Christias (1) and Drandarevski (4) reported that *B. patellaris* was suceptible to sugar beet powdery mildew, but this species was highly resistant in our test. This apparent discrepancy could be due to different strains of the fungus or variability within seed collections of *B. patellaris*. Many additional plants need to be tested to determine if genetic resistance to *E. polygoni* exists in this species; however, all species within the Section Patellares of the genus *Beta* have shown resistance to other sugar beet pathogens (2). Further, one plant each of *B. procumbens* Chr. Sm. and *B. webbiana* Moq. of the Section Patellares also remained free of powdery mildew although surrounded by heavily infected sugar beets in the greenhouse. Should searches for resistance within existing sugar beet cultivars fail, species in the Section Patellares may prove to be important sources of powdery mildew-resistant germ plasm.

Reports of powdery mildew fungi overwintering as haustoria,. as conidia, or in seeds are questionable according to Yarwood (12). Our results showed that, in Colorado, mycelia, haustoria, or conidia of the sugar beet powdery mildew fungus did not survive long enough in plant debris or on seed to serve as primary inoculum for subsequent beet crops. If the fungus could overwinter in the vegetative stage in cold climates, one would expect the disease to occur much earlier in the growing season. Although environmental conditions are suitable for the disease in most sugar beet growing areas within 2 mo of planting, powdery mildew usually has occurred when the crop was 3 to 4 mo old. Further, cleistothecia have been reported only from one Washington field in 1974 (3) and have not been found again. Thus, the sexual stage of the fungus cannot at this time be implicated in survival over winter.

The short-lived nature of the fungal vegetative stage, the absence of the sexual stage, the apparent specificity for the genus *Beta*, and the yearly south-to-north spread of the disease, support the theory that the fungus overwinters in warm southwestern areas and that conidia are carried northward and eastward by prevailing winds. Similar theories have been proposed for other powdery mildews (6, 11). Overwintered infected sugar beets grown for roots or seed in warmer areas of Arizona, California, Oregon, Utah, and Washington would be potential sources of primary inoculum.

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