Common Hosts for Fusarium oxysporum formae speciales spinaciae and betae

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ABSTRACT

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Inoculations of cultivars of spinach, beet, mangel, and Swiss chard with *Fusarium oxysporum* f. sp. *spinaciae* and f. sp. *betae* revealed common hosts in cultivars of sugar and garden beet. Due to common hosts, the wilt *Fusarium* from spinach and the one from beet are classified as race 1 and race 2, respectively, of *F. oxysporum* f. sp. *spinaciae*. Mangel and cultivars of Swiss chard were resistant to race 1 but susceptible to race 2. Cultivars of spinach and *Lychnis chalcedonica* were susceptible only to race 1. No external symptoms of wilt were noted on plants of spinach and sugarbeet after inoculation with 50 other ff. sp. and races of *F. oxysporum*. Forma specialis *spinaciae* race 1 was nonpathogenic on plants in 45 different species and cultivars of numerous genera, which have been useful in separating forms and races of *F. oxysporum;* f. sp. *spinaciae* race 2 was nonpathogenic on plants in 44 of these species and cultivars. All isolates of the sugarbeet *Fusarium* (race 2) from Colorado failed to produce macrospores in culture unless exposed to fluorescent light. This character was found in three collections made during a period of 26 years.

Additional key words: light, sporulation.

A *Fusarium* wilt disease of spinach (*Spinacia oleracea* L.) was first described in 1923 in Idaho by Hungerford, and the fungus was identified by Sherbakoff [C. D. Sherbakoff, *personal communication* as quoted by Hungerford (20)] as a new species, *Fusarium spinaciae* (20), which is *F. oxysporum* Schlecht. f. sp. *spinaciae* (Sherb.) Snyd. & Hans. in the revised classification (22). The disease was reported in Virginia in 1938 (14). Later a wilt-resistant cultivar was developed (15), and a comprehensive study of the disease was made (13). Spinach wilt has been reported in the United States in California, Connecticut, Idaho, Maryland, New York, Texas, Virginia (25), and Arkansas (18).

A vascular disease of sugarbeet (*Beta vulgaris* L.), which was first reported in 1931 in Colorado by Stewart as sugarbeet yellows is caused by *Fusarium conglutinans* var. *betae* Stewart (23) [which is now classified as *F. oxysporum* Schlecht. f. sp. *betae* (Stewart) Snyd. & Hans. (22)]. Wilt resistance was found in several lines of sugarbeet (1, 11, 16). Seed from plants in severely affected fields carried the pathogen (19). Some factors affecting the growth of the fungus were studied (24), and a nutrient deficiency in some isolates was reported (8), which later proved to be an inability to produce biotin. The disease has been reported in the United States in Colorado, Montana, Nebraska, New Mexico, South Dakota, Wyoming (25), and Oregon (19).

Our first inoculations of spinach with f. sp. *spinaciae* were in 1948 and those of beet with f. sp. *betae* in 1952. A preliminary report on some host relationships of the organisms has been presented (7). *Lychnis chalcedonica* L. has been reported to be a common host of the spinach-wilt *Fusarium* (4), the cabbage-wilt *Fusarium* [*F. oxysporum* Schlecht. f. sp. *conglutinans* (Wr.) Snyd. & Hans. race 1 Armst. & Armst.] (4), and the carnation-wilt *Fusarium* [*F. oxysporum* Schlecht. f. sp. *dianthi* (Prill. & Del.) Snyd. & Hans.] (6).

Since ff. sp. *spinaciae* and *betae* cause wilt of plants in the family Chenopodiaceae, inoculations with these ff. sp. were made on plants in this family as well as plants in numerous other genera to see if common hosts could be found. Fifty other different wilt fusaria also were used to determine possible host relationships. Observations on a peculiarity in spore production by f. sp. *betae* are also noted.

MATERIALS AND METHODS

Ten monoconidial isolates of f. sp. *spinaciae* from microspores were used in the inoculations, four each derived from isolates received in 1948 and 1954 from Virginia, and, in limited tests, two isolates received in 1971 from Arkansas. One line was singlespored four times and another three times after several passages through a host in our constant search for isolates of high virulence. Twelve monoconidial isolates of f. sp. *betae,* including one that was singlespored four times, and thirteen mass isolates were included in the inoculations. The isolates were from sugarbeets grown in Colorado and Montana. Plants of spinach and beet were inoculated with 50 other forms and races of *F. oxysporum.* Seed, except two lines of sugarbeet, GW395 and A-1140-52L (the latter hereafter called A-52L), were from commercial sources.

Plants were grown in sterilized sand supplemented with a nutrient solution in 8-liter glazed pots in a glasshouse. Seed were sown in a circle about 2.5 cm from the rim of the pot. At inoculation, roots were cut by pressing an inverted Büchner funnel into the center of the pot, and a

3-day-old liquid inoculum was poured around the roots. Further details of methods (Method A) are found elsewhere (3), but the following corrections of a misprint in the composition of the culture solution should be noted: KH_2PO_4, 0.008M and $Ca(NO_3)_2$, 0.0346M. To obtain consistent and reproducible results in inoculations with the wilt fusaria, especially with those that have hosts of appreciable resistance, the inoculations should be made when the plants are young but beyond the stage when damping-off may occur. For example, the age of the sugarbeet plants inoculated with the spinach-wilt *Fusarium* was in the range of 18 to 33 days after planting, which varied with the season, but all were at about the same stage of development.

To obtain spores of the beet *Fusarium*, cultures were placed 40 cm below a stand containing four 121.6-cm (48-inch) fluorescent tubes, one GE F40B1 black light and three GE F40CW cool-white. Cultures were irradiated during the daylight working hours.

RESULTS

Forma specialis *spinaciae* from Virginia was pathogenic on a wider range of hosts than f. sp. *betae* from Colorado (Table 1). It was virulent on three cultivars of spinach and on sugarbeet A-52L but less virulent than f. sp. *betae* on other cultivars of beet and Swiss chard [*Beta vulgaris* var. *cicla* (L.) Moq.]. When sugarbeet seed were planted in pots where spinach plants had wilted, 26% to 100% postemergence damping-off was noted, but such results were not included in Table 1. In single-pot tests with two spinach-wilt isolates from Arkansas, 100% and 94%, respectively, of plants of spinach cultivar Bloomsdale Savoy Leaved were severely diseased. Plants of sugarbeet cultivar A-52L inoculated with these isolates were, respectively, 35% and 53% diseased. Other plants in Table 1 were not inoculated with these isolates.

Kochia scoparia (L.) Schrad. and mangel (*Beta vulgaris* var. *macrorhiza*) were resistant to f. sp. *spinaciae*. The isolates of f. sp. *spinaciae* from Virginia were highly virulent on *Lychnis chalcedonica* 'Scarlet', causing wilt of 96% of the plants. Seven clones of this fungus were highly virulent on *Lychnis* in seven tests conducted during eight years. The average time for severe wilt of *Lychnis* by f. sp. *spinaciae* was 29 days, about twice that for f. sp. *dianthi*.

Forma specialis *betae* from Colorado caused wilt of plants of two lines of sugarbeet and four other cultivars of beet and mangel (Table 1). It was less virulent on four cultivars of Swiss chard but caused wilt of over 50% of the plants of three of these cultivars. It was nonpathogenic on *Kochia*, spinach, and *Lychnis*. Since the beet-wilt isolates from Montana were low in virulence, they were used only in limited tests.

Gerhold (16) reported cultivar GW359 to be the most resistant of several cultivars of sugarbeet in a field test at Ames, Iowa. This resistance to f. sp. *betae* was not evident in our experiments in the glasshouse, but it was more resistant to f. sp. *spinaciae* than was cultivar A-52L (Table 1).

Plants inoculated with f. sp. spinaciae and f. sp. betae.—The plants of species and cultivars in numerous genera that were inoculated are given in another publication (4, page 528) under "Inoculation of plants other than the Cruciferae". However, banana and Arlington cowpea should be omitted from the list since they were not inoculated. There were no symptoms of wilt on any of these plants except sugarbeet, spinach, and *Lychnis* inoculated with f. sp. *spinaciae;* and only on sugarbeet inoculated with f. sp. *betae*. Additional plants that showed no external symptoms were cabbage (*Brassica oleracea* var. *capitata* L. 'Copenhagen Market'), lily (*Lilium longiflorum* Thunb. 'Harson'), narcissus (*Narcissus pseudonarcissus* L. 'Golden Harvest'), passion vine (*Passiflora edulis* Sims), radish (*Raphanus sativus* L. 'Long White Icicle'), stock [*Matthiola incana* (L.) R. Br. var. *annua* (L.) Voss 'Bright Pink'], and Bambarra groundnut (*Voandzeia subterranea* L. 'BA/4/1').

Forma specialis *spinaciae* did not cause wilt of flax (12); eggplant (21); 21 common garden plants (13); garden beet, cabbage, cantaloupe, chard, cotton, cucumber, lettuce, pigweed, pumpkin, squash, tomato, watermelon (2); and green beans and corn (18).

Forma specialis *betae* did not cause wilt of aster, alfalfa, string bean, lima bean, cabbage, cantaloupe, or cucumber (23).

Spinach and beet inoculated with other wilt fusaria.—Forty forms and races of *F. oxysporum* that were used to inoculate sugarbeet cultivars GW359 or A-52L and spinach Bloomsdale Savoy Leaved are given elsewhere (4, page 528); omitting ff. sp. *betae* and *spinaciae* from the list, 38 of these did not cause wilt. The twelve additional forms and races used were *chrysanthemi; conglutinans* races 1, 2, 3, and 4; *fragariae; gladioli; lili; narcissi; ricini; tulipae;* and *voandzeae*. Thus,

TABLE 1. Percentages of wilted plants (external symptoms only) and number of plants inoculated with wilt fusaria from spinach and beet

Host	Fusarium from:			
	Spinach		Beet	
	(%)	(Total no.)	(%)	(Total no.)
Beet				
Sugar, GW395	39	156	85	276
Sugar, A-1140-52L	81	340	74	454
Detroit	52	345	83	211
Lutz Green Leaf	12	86	85	66
White	26	129	94	49
Swiss chard				
Lucullus	2	49	63	38
Rhubarb	12	97	45	55
Large-Ribbed White	17	86	54	47
Perpetual	0	35	68	37
Mangel				
Mammoth Prize, Long Red	0	14	70	20
Spinach				
Bloomsdale Savoy Leaved	99	908	0	111
Aragon	94	35	0	49
Nobel	100	24	0	37
Lychnis				
Lychnis chalcedonica 'Scarlet'	96	56	0	31
Kochia				
Kochia scoparia 'Burning Bush'	0	17	0	23

50 other wilt fusaria caused no external symptoms of wilt on the above cultivars of spinach and beet.

Fusarium redolens f. sp. *dianthi* Gerlach did not cause wilt of spinach (17). Neither *F. oxysporum* f. sp. *lathyri* (9), f. sp. *lini* (12), nor f. sp. *spinaciae* (2) caused wilt of garden beet.

DISCUSSION

Stewart in 1931 noted the absence of macroconidia in cultures of the wilt *Fusarium* from beet (23). Sherbakoff [C. D. Sherbakoff, *personal communication* as quoted by Hungerford (20)], likewise, found no macroconidia in the culture that was sent to him. In 1952, an isolate received from Twomey at Fort Collins, Colorado, also produced no macrospores. No macrospores and few microspores were produced by 25 mass and monoconidial isolates prepared in 1957 from diseased sugarbeets in fields near Longmont, Colorado. Thus, this aberrant spore production seemed characteristic of the isolates in all collections. If isolates on slants of potato-dextrose agar were placed under the fluorescent lights, an abundance of macrospores, microspores, and chlamydospores were produced after a few days. All isolates of f. sp. *betae* grew slowly in the mineral nutrient solution used in the experiments, but there was abundant mycelial growth when a small amount of yeast extract was added to the solution in the preparation of the inoculum.

Although the exact locations from which the collections of Stewart and Twomey were made are unknown, it is striking that only isolates with the aberrant spore forming characters were found in the collections during a period of 26 years. Did this variant originate from a single stable clone, and what is its distribution throughout the sugarbeet-producing areas?

A search for a common host in the family Chenopodiaceae for the wilt fusaria from spinach and beet seemed plausible since common hosts for the wilt fusaria from cabbage, radish, and stock had been found, resulting in their classification as races of f. sp. *conglutinans* (4). It was not surprising, therefore, to find susceptible common hosts for f. sp. *betae* and f. sp. *spinaciae* in sugarbeet and other cultivars of beet, although these were less susceptible to f. sp. *spinaciae* than to f. sp. *betae*. However, their classification as races of f. sp. *spinaciae* on the basis of selective pathogenicity for closely related plants became complicated since *Lychnis* in an unrelated family was a common host for ff. sp. *spinaciae, dianthi,* and *conglutinans* race 1. A more complex situation existed with ff. sp. *pisi* and *apii* (5). The former caused wilt only of pea. Since *apii* caused wilt of celery, pea, and a diverse range of plants that were hosts of other ff. sp., it seemed impractical to classify *apii* as a race of f. sp. *pisi*. Nevertheless, if two or more ff. sp. have been classified with the supposition of their selective pathogenicity and are not closely related to other ff. sp. of *Fusarium oxysporum,* we believe that they should be classified as races of one form. Therefore, ff. sp. *betae* and *spinaciae,* which seem (with one exception) to be restricted in pathogenicity to plants in the Chenopodiaceae and have common hosts among cultivars of beet, should be considered pathogenic races of one form. Since f. sp. *spinaciae* was described first and attacks both spinach and beet, it is proposed that f. sp. *betae* be redefined as a race of f. sp. *spinaciae*.

Fusarium oxysporum Schlecht. f. sp. *spinaciae* (Sherb.) Snyd. & Hans. race 1.

Syn. *F. spinaciae* Sherb. (20).

A *Fusarium* of the section Elegans (26) or *Fusarium oxysporum* Schlecht. sensu Snyder & Hansen (22) causing a vascular wilt disease of spinach often with rotting of roots, and other symptoms described elsewhere (20). Also pathogenic on sugarbeet, causing a yellows or wilt disease similar in symptoms to that originally described (23). Less virulent on some cultivars of beet and Swiss chard than race 2. Also causes a yellows or wilt disease of *Lychnis chalcedonica* L. similar to that caused by ff. sp. *dianthi* and *conglutinans* race 1. Nonpathogenic on plants of 45 species and cultivars of numerous genera which have been useful in separating forms and races of *Fusarium oxysporum.*

Fusarium oxysporum Schlecht. f. sp. *spinaciae* (Sherb.) Snyd. & Hans. race 2.

Syn. *F. conglutinans* var. *betae* Stewart (23).

F. conglutinans (Wr.) var. *betae* Stewart (26).

F. oxysporum f. sp. *betae* (Stewart) Snyd. & Hans. (22).

F. oxysporum Schl. var. *orthocerans* (App. & Wr.) Bilai (10).

A *Fusarium* of the section Elegans (26) or *Fusarium oxysporum* Schlecht. sensu Snyder & Hansen (22) causing a yellows or wilt of sugarbeet (23), other cultivars of beet, and Swiss chard but more virulent on most of them than race 1. Nonpathogenic on spinach and *Lychnis chalcedonica* L. and plants of 44 other species and cultivars of numerous genera.

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