Evaluation of Resistance in Gladiolus sp. to Fusarium oxysporum f. sp. gladioli

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ABSTRACT

Nineteen selections, nine commercial gladiolus cultivars, *Gladiolus Hookerii,* and *G. gladanthera* were evaluated for resistance to *Fusarium oxysporum* f. sp. *gladioli* by inoculating dormant corms. *Gladiolus gladanthera,* North Carolina selections 63-5-1 and 66-109-5, and cultivars Follies Bergere, Prince Bernhart, Fiat Lux, and Beverly Ann appeared resistant. Nineteen selections, eight cultivars, and *G. Hookerii,* evaluated for resistance in sterile sand in the greenhouse, varied from highly resistant to highly susceptible. All cultivars tested carried latent infections. Wounding or inoculating corms increased disease severity and decrased the number of apparently healthy new corms. Four different types of host responses were observed. Roots were the most susceptible plant part. Foliage symptoms were not always good indicators of disease severity. Two advanced selections from the breeding program showed a high level of resistance in all tests and appeared more resistant than any cultivar tested.

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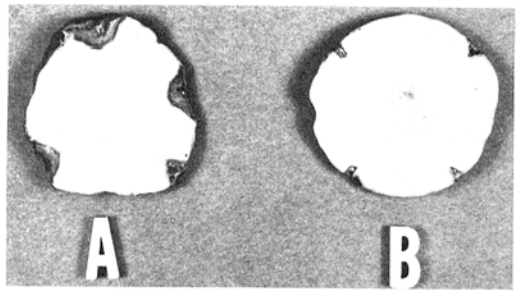
In developing new gladiolus (*Gladiolus* sp.) cultivars, breeders have been concerned primarily with horticultural characters such as size and shape of flower spikes, color and quality of florets, and the production of corms and cormels. Less attention has been given to resistance to diseases such as Fusarium corm rot caused by *Fusarium oxysporum* f. sp. *gladioli* Snyd. & Hans., the most important gladiolus disease in North Carolina (3).

In 1958, Palmer and Pryor (5) reported that 10% of 160 gladiolus cultivars were resistant to *F. oxysporum,* and in a later experiment, that 24% of the cultivars tested were resistant. No immunity was found among the 211 cultivars and three species examined. Corms from all sources carried latent *F. oxysporum* infection. McClellan and Pryor (4) tested 183 cultivars for resistance to three isolates of *F. oxysporum;* most were highly susceptible. Jenkins (2) reported seedling resistance to one to three isolates of *F. oxysporum,* which suggested that there was a good possibility of obtaining resistant selections from a planned breeding program. Such a program was initiated in 1962 at the Horticultural Crops Research Station, Castle Hayne, North Carolina: This paper reports the level of resistance in selections from crosses as well as in commercial cultivars.



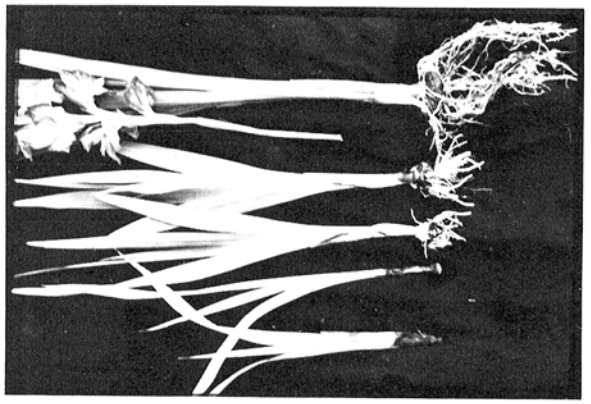


Fig. 1-(A to C). (A-B) Gladiolus corms sectioned transversely 42 days after inoculation with *Fusarium oxysporum* f. sp. *gladioli* (top). Each corm was inoculated four times; **A)** susceptible cultivar Beverly Ann, and **B)** resistant *G. gladanthera*). **C)** Five gladiolus plants showing susceptible (bottom) to resistant (top) disease reaction in the plant inoculation test.

MATERIALS AND METHODS.—Selections used were developed during a 10-year breeding program including the cultivars Valeria, Snow Princess, Traveler, Beverly Ann, Jubilee, Hopman's Glory, Early Red, and unnamed selections from several sources. Selections from crosses were tested, and the best were backcrossed to each parent. Seedlings were grown in fields heavily infested with *F. oxysporum,* and resistant individuals were selected and increased.

From approximately 500,000 seedlings grown during the breeding project, only ~ 1% was saved for increase and further testing. These selections exhibited good commercial potential as well as some degree of disease resistance in the field.

The *F. oxysporum* isolate used was isolated in 1971 from diseased White Friendship corms and maintained on potato dextrose agar (PDA). The pathogenicity of the isolate was checked and maintained by inoculating White Friendship corms and re-isolating the fungus.

Dormant corm inoculation test.—Each corm was inoculated by inserting mycelium and spores into four 3 × 5 mm wounds. Inoculum was scraped from the surface of a 7-day-old culture grown on PDA at 25 C. Twenty corms of each of 30 cultivars were inoculated, held at 25-30 C in plastic bags for 3 days, then removed from the bags and held at 25-30 C. Ten corms of each cultivar were scored 21 days after inoculation and the remainder after 42 days. Each corm was scored by cutting it in half transversely and measuring the rotted area (Fig. 1-A, B). The disease index was calculated by multiplying width × depth of the rotted area.

Plant inoculation test.—Twenty-nine cultivars were grown in methyl bromide-treated builders' sand in 21 × 22.5 cm plastic pots, with five corms per pot replicated four times. At planting, half of the noninoculated and inoculated corms were wounded by scratching on two sides with a stiff wire brush. Corms were inoculated by pouring 50 ml of inoculum, consisting of spores and mycelium prepared by growing the fungus in potato dextrose broth for 10 days on a shaker at room temperature (25 C), over them immediately after planting and before covering with sterile sand. Inoculations were repeated 10 days later and the pots filled with sterile sand.

The foliage, corms, and roots were rated separately according to the following 0-3 disease index: for the foliage (leaves and stems above the new corm), 0 = no visible symptoms; 1 = slight stunting, chlorosis or curved foliage, 0-10% necrosis; 2 = 11-50% of foliage necrotic, severe chlorosis; 3 = 50% or more of foliage necrotic. For the corm (cut in half transversely), 0 = 0-5% visible rot; 1 = 6-30% rot; 2 = 31-60% rot; 3 = 61-100% rot. For the root system, 0 = extensive white root system with 0-5% decay; 1 = 6-30% of root system rotted; 2 = 31-60% root system rotted; 3 = 61-100% of root system rotted. The number of healthy new corms was recorded at harvest. After 60 days of storage at 25 C, another count of the healthy corms was made.

Field plots were maintained 2 years on a light, sandy soil heavily infested with *F. oxysporum*. Three replicates of five corms of each line were planted the first year, and all surviving corms were planted the second year. At the end of the second growing season, all plants were dug and scored on the above scale. New corms were cleaned,

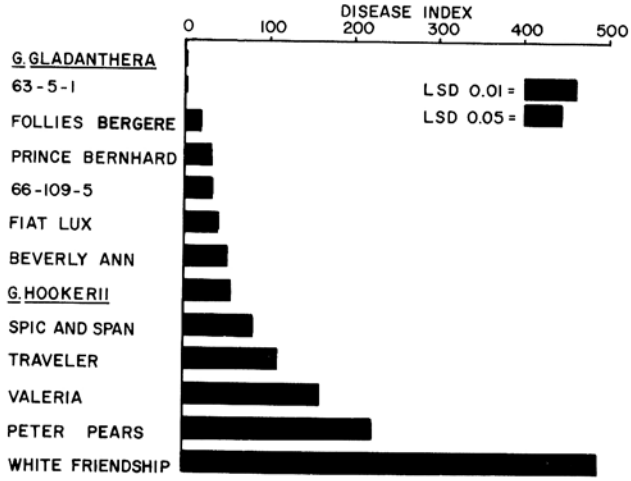


Fig. 2. Disease indices for 13 of 30 representative gladiolus cultivars tested 42 days after inoculating dormant corms with *Fusarium oxysporum* f. sp. *gladioli*. Each bar gives the average of four inoculations on each of 10 corms of each cultivar. Disease index is width × depth of the rotted area measured in mm after the corm was cut in half [Fig. 4-(A,B)].

counted, stored 60 days, and evaluated for disease.

RESULTS.—*Dormant corm inoculation test.*—Disease indices for 13 of 30 cultivars tested are shown in Fig. 2. Nine selections had disease indices between those of *G. Hookerii,* Spic and Span, Traveler, and Valeria. Disease indices for six other selections were between those of Valeria, Peter Pears, and White Friendship. Virtually no rot developed on *G. gladanthera* and a North Carolina selection, 63-5-1, 42 days after inoculation as indicated by disease indexes of 3.7 and 11.9, respectively. White Friendship, a susceptible cultivar, had a disease index of 484 42 days after inoculation. Disease indexes from 3.7 to 484 indicate a wide range of susceptibility in the cultivars tested. Cultivars Follies Bergere, Prince Bernhart, Fiat Lux, and Beverly Ann showed high-to-moderate resistance, but White Friendship, Peter Pears, Valeria, Traveler, and Spic and Span were more susceptible. Comparable index ratings, though not as high, were obtained at the end of the 21-day storage period.

Plant inoculation test.—Disease indices of seven representative cultivars from the plant inoculation studies are presented in Fig. 3. Six selections not shown in Fig. 2 had disease indices similar to that of Fiat Lux. Disease indices for fourteen selections were similar to those of Beverly Ann, Valeria, and White Friendship.

The mean disease index for all cultivars was highest for roots, intermediate for corms, and lowest for foliage. The highest mean disease index for treatments was for wounded-plus-inoculated, while the lowest was for the nonwounded noninoculated. Between treatments, the lower the disease index for the old corm and roots, the higher the number of apparently healthy new corms. Selections 66-109-5, 63-5-1, 62-2-4-1, and 66-15-26 produced 1.5 to 2.25 new corms for each corm planted.

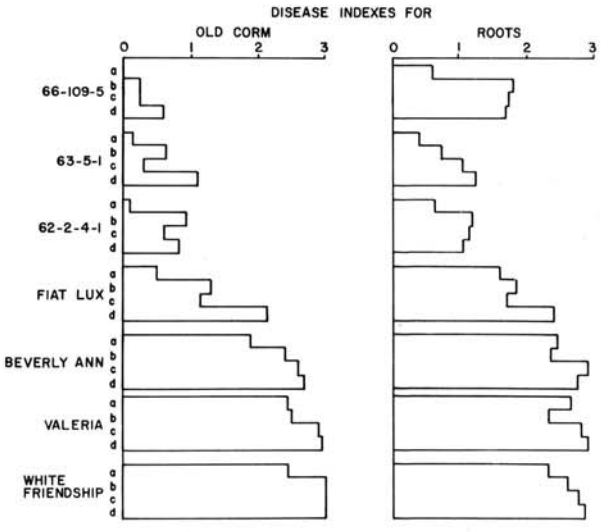


Fig. 3. Disease indices for old corms and roots for seven representative cultivars of gladiolus of 28 tested in the plant inoculation test. Each bar shows the average of four replications of each treatment (a = noninoculated check, b = wounded noninoculated, c = inoculated nonwounded, and d = wounded inoculated). Disease index (0 = 0-5% decay, 1 = 6-30% decay, 2 = 31-60% decay, and 3 = 61-100% decay).

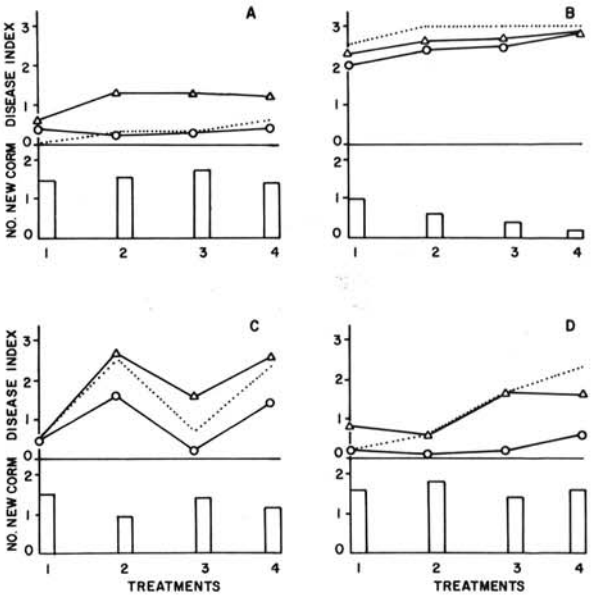


Fig. 4-(A to D). Disease indexes for foliage (0——0), old corm (△——△), roots (. . . .) and number of new corms (bars) for four cultivars of gladiolus in the plant inoculation test: **A)** 66-109-5, **B)** White Friendship, **C)** 66-140-51, and **D)** Traveler. The treatments are: 1 = noninoculated check, 2 = wounded noninoculated, 3 = inoculated nonwounded, and 4 = inoculated wounded.

Fourteen selections or commercial cultivars produced 1.0 - 1.5 new corms for each corm planted. Nine produced less than one new corm for each corm planted. White Friendship and Spic and Span produced the lowest number of new corms.

Disease indexes for the foliage, old corms and roots, and the number of new corms for four cultivars are presented in Fig. 4. These illustrate four types of host response to the four treatments. Fig. 4-A shows the highly resistant reaction of selection 66-109-5. There was little difference between treatments, and the number of new corms was unaffected by the treatments. White Friendship is an example of the susceptible reaction (Fig. 4-B). Selection 66-140-51 had a low disease index when not wounded, both inoculated and not inoculated (Fig. 4-C). However, the index was high when the corms were wounded, both inoculated and noninoculated. The increase in the disease index for Traveler as a result of the wounding and inoculation treatments is shown in Fig. 4-D.

When the four treatments were combined, selections 63-5-1, 62-2-4-1, and 66-15-26 had the lowest disease index for the foliage while selections 66-109-5, 63-5-1, and 62-2-4-1 had the lowest disease index for the old corms. Selections 63-5-1, 66-21-26, and 62-2-4-1 had the lowest disease index for the roots.

DISCUSSION.—Selections varied considerably in disease reaction from highly resistant to highly susceptible (Fig. 1). The disease index ratings for foliage, corms, and roots were significantly lower for selection 66-109-5, 63-5-1, and 66-21-26 than for White Friendship, Valeria, Beverly Ann, Traveler, Fiat Lux, Prince

Bernhart, Follies Bergere, and Spic and Span, indicating that these selections are more resistant to *F. oxysporum* f. sp. *gladioli*.

The high disease indices for the noninoculated plants indicates the presence of latent *Fusarium* infection in the corms and supports the findings of Palmer, Pryor, and Steward (6). Wounding corms before planting increased the mean disease index of both the noninoculated and the inoculated plants showing the importance of not wounding corms during digging and subsequent handling.

The apparent resistance of some cultivars varied among tests. Prince Bernhart and Follies Bergere were relatively resistant in the corm inoculation test but they were susceptible in the plant inoculation test. Two North Carolina selections, 66-109-5 and 63-5-1, were highly resistant in both tests. The cultivars White Friendship, Spic and Span, and Valeria were susceptible in both tests and have been observed to have a high incidence of *Fusarium* corm rot in commercial plantings. McClellan and Pryor (4) have also shown Friendship and Spic and Span to be highly susceptible.

Cultivars that were resistant in field tests were usually resistant under the conditions of the inoculation tests. Selections 66-109-5 and 63-5-1 were among the most resistant in 3 years of field testing on soil infested with *F. oxysporum*.

Both of the highly resistant selections, 66-109-5 and 63-5-1, apparently derived much of their resistance from Snow Princess. Snow Princess appeared to be disease resistant in early tests and was used as a parent in many crosses. N.C. selection 66-109-5 was derived from a cross of a resistant selection 62-5-1 with susceptible Valeria. The parent selection, 62-5-1, was a F_1 selection from a cross between Snow Princess and Traveler. Selection 63-5-1 was a F_1 selection from a cross between Beverly Ann and Snow Princess.

Foliage symptoms of *F. oxysporum* infection were not always correlated with corm and root reactions. Plants with badly diseased corms and roots often produced relatively symptomless foliage. In many cases, foliage symptoms appeared to result from root decay. However, the foliage of some plants showed no symptoms of disease even though the roots had been destroyed.

Plant inoculation tests showed that some selections were resistant, even when wounded and inoculated, while others were resistant only if they were not wounded. This indicates that resistance in gladiolus may be due either to a surface barrier or chemical inhibition of fungus growth within the plant. Selection 66-140-51 (Fig. 4-C) is an example of the surface type of resistance. These plants developed little disease when the corms were not wounded, whether inoculated or not. When wounded, either inoculated or not inoculated, they developed more disease. This may indicate that 66-140-51 can form a wound-periderm or suberized layer on the surface, but is highly susceptible to the fungus beneath the surface layer of cells (1). Selection 66-109-5 is an example of a possible chemical type of resistance. This selection has proven to be highly resistant in field tests, and was uniformly resistant under all conditions of the experiment. This type of resistance would be especially desirable in a commercial cultivar because of the difficulty of digging and handling large numbers of corms without causing some injury. Also, when the corms are cleaned, new wounds are created that expose them to infection. Resistance of this type might reduce the need for fungicidal corm dips at harvest and should reduce the incidence of serious *F. oxysporum* infection.

In gladiolus breeding programs, more emphasis should be placed on disease resistance. Since plant breeders are constantly introducing new gladiolus cultivars, there is need for a standardized inoculation technique and evaluation method to compare new cultivars for disease resistance under similar conditions. The more resistant cultivars should be tested further for resistance to several *F. oxysporum* f. sp. *gladioli* isolates.

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