



Response of gladiolus (*Gladiolus hybridus*) genotypes to two diverse cultures of *Fusarium* and their agronomic performance

AMREEN TAJ¹, T MANJUNATHA RAO², H ANSAR³, S SRIRAM⁴ and RAJIV KUMAR⁵

ICAR-Indian Institute of Horticultural Research, Hesaraghatta Lake Post, Bengaluru, Karnataka 560 089

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ABSTRACT

A set of eight gladiolus genotypes, viz. Arka Amar, Arka Gold, Arka Kesar, Arka Naveen, Pink Friendship, Arka Aayush, IIHRG-12 and *Psittacinus* hybrid were tested for agronomic performance and resistance to *Fusarium* wilt under pot culture. The genotypes were assessed for resistance to two geographically diverse cultures of *Fusarium*, viz. IIHR culture (*Fusarium oxysporum* f. sp. *gladioli* - culture 1) and Solan culture (*Fusarium oxysporum* f. sp. *gladioli* - culture 2). Among the eight genotypes screened for resistance, *Psittacinus* hybrid was resistant to *Fusarium* inoculation as there was no disease incidence and mortality, whereas Arka Naveen was susceptible with 100 per cent disease incidence. The genotype IIHRG-12 followed by Arka Amar was early for spike emergence and opening of first floret. The *Psittacinus* hybrid followed by Arka Amar recorded highest number of flowers per corm. Arka Naveen produced significantly longest spike and rachis in control, however, susceptible to *Fusarium*. The genotypes Arka Gold, IIHRG-12, Arka Amar produced bigger sized florets. The present study concludes that the genotypes *Psittacinus* hybrid, Arka Amar and IIHRG-12 are superior gladiolus genotypes having best floral characteristics and resistance against *Fusarium* wilt.

Key words: Disease resistance, *Fusarium* wilt, *Fusarium oxysporum* f. sp. *gladioli*, Gladiolus, Screening

Gladiolus (*Gladiolus hybridus* Hort.) is a bulbous flower known for its attractive flower spikes with exhaustive range of colours, different shades, varying number of florets and size, wide range of keeping quality and adaptability to different seasons. In recent years, its acreage is steadily growing due to increase in demand for its flowers. It is vegetatively propagated by corms and cormels.

Cultivation of gladiolus is influenced by various biotic and abiotic factors. *Fusarium* wilt is one of the most serious diseases of gladiolus, affecting plants in the field and corms in storage (Sharma and Tripathi 2008, Riaz *et al.* 2009, 2010). This disease causes considerable crop losses each year. In addition to direct economic losses, quality of the economic product also decreases with even moderate levels of disease infestation. Resistance and susceptibility are the two ends of the disease spectrum.

Vascular corm rot is also called “yellows” on infected plants in the field. The causal organism is *Fusarium oxysporum* Schlecht. f. sp. *gladioli* (Masey) Snyder and

Hans., which deteriorates its quality and market value (Chandel and Bhardwaj 2000). The fungus survives in infected corms and in the soil as mycelium, chlamydospores, macroconidia and microconidia. The infected corms show brownish to black dry rot symptoms. Pathogen attack results to decrease in yield which is due to yellowing of leaves, stunted plant growth, discoloured flowers and even destruction of the corms (Ram *et al.* 2004). Despite many attempts to control this disease, the problem is still widespread.

Soil fumigation is the most common approach to control soil-borne diseases over the years. Unfortunately, certain fumigants possess negative attributes, such as health hazards, environmental pollution and even potential atmospheric ozone depletion (Gamliel *et al.* 2000). Increased environmental concern has been a major factor in triggering regulatory restrictions on the use of soil fumigants. Thus, the requirement for distribution, evaluation of each variety with regard to lasting quality, colours and resistance to biotic and abiotic stress are of prime importance. When different cultivars are grown under identical conditions, it is the genetic factor that expresses the morphological differences. Hence, selection of a resistant variety is an important criterion for successful cultivation of any flower crop.

MATERIALS AND METHODS

Corms from the infected plants showing typical

^{1,3}Ph D Scholars (e mail: amreentajald@gmail.com and ansarhort@gmail.com), University of Horticultural Sciences, Bagalkot, College of Horticulture, GKVK Campus, Bengaluru; ²Principal Scientist (e mail: tmrao@iihr.ernet.in), ⁵Senior Scientist (e mail: rajiv@iihr.ernet.in), Division of Ornamental Crops, ⁴Principal Scientist (e mail: sriram@iihr.ernet.in), Division of Plant Pathology, ICAR-Indian Institute of Horticultural Research, Hesaraghatta Lake Post, Bengaluru, Karnataka 560 089

symptoms of wilt disease were used for the isolation of pathogen. The standard tissue isolation procedure was followed. The infected corms were cut into small pieces and surface disinfected by immersing in 1% sodium hypochlorite solution for one minute and was rinsed thrice in sterilized water. The surface sterilized pieces were placed on Potato Dextrose Agar (PDA) medium in petri plates and were incubated at 25°C for 7 days and observed periodically for the growth of pure colonies. Further, purification of the fungus was done and the pure culture was incubated in PDA slants for future studies.

F. oxysporum f. sp. *gladioli* were mass multiplied on sorghum grains according to Riaz *et al.* (2007). Healthy sorghum seeds were soaked overnight and packed in transparent polythene bags (40 × 28 cm) whose open ends were passed through a plastic pipe of 6 cm with 3 cm diameter plugged with cotton. Each bag containing 200 g of sorghum was autoclaved at 121°C under 1.035 × 105 Pa pressure for 30 min and cooled at room temperature. Five mycelial discs of 5 mm diameter from periphery of actively growing 7 days old *F. oxysporum* f. sp. *gladioli* culture were introduced into each bag under aseptic conditions and bags were kept at room temperature in the dark for 10 days.

A set of eight gladiolus genotypes, viz. Arka Amar, Arka Gold, Arka Kesar, Arka Naveen, Pink Friendship, Arka Aayush, IIHRG-12 and *Psittacinus* hybrid were tested for resistance to *Fusarium* wilt. These genotypes were assessed for their resistance to two geographically diverse cultures of *Fusarium*, viz. IIHR culture (*Fusarium oxysporum* f. sp. *gladioli* - culture 1) and Solan culture (*Fusarium oxysporum* f. sp. *gladioli* - culture 2). Screening for resistance was undertaken in pot culture experiment. The pot culture experiment was carried out during 2013-14 in the polyhouse of Division of Ornamental Crops, ICAR-Indian Institute of Horticultural Research, Hesaraghatta, Bengaluru located at an altitude of 890 meters above mean sea level and has latitude of 13° 58' North and longitude of 77° 37' East. Experiment was laid down in a Factorial CRD and unequal CRD. A sterilised mixture of soil, sand and well decomposed farmyard manure (FYM) in the ratio of 2:1:1 was used to fill the plastic pots each containing 2 kg growing media. The filled pots were kept in polyhouse. Twenty seven uniform sized corms of the genotypes Arka Amar, Arka Gold, Arka Kesar, Arka Naveen, Pink Friendship, Arka Aayush, IIHRG-12 and *Psittacinus* hybrid with average diameter of 6.65 cm, 7.3 cm, 6.9 cm, 6.3 cm, 6 cm, 6.4 cm, 6.45 cm and 4.65 cm, respectively were planted in replicated trials. One corm was planted in each pot. Sorghum based *F. oxysporum* f. sp. *gladioli* inoculum was mixed in the soil at 4 g per 100 g of soil one day before planting and watering was done. Each treatment was replicated 9 times. The data regarding disease incidence and mortality were recorded using following formulae:

$$\text{Disease incidence per cent} = \frac{\text{Number of diseased plants}}{\text{Total number of plants}} \times 100$$

$$\text{Mortality per cent} = \frac{\text{Number of plants died due to disease}}{\text{Total number of plants}} \times 100$$

The data on various biometrical parameters recorded were subjected to statistical analysis as per the procedure given by Panse and Sukhatme (1967). The results have been presented and discussed at the probability level of one per cent.

RESULTS AND DISCUSSION

Disease incidence and mortality

The data on per cent disease incidence and mortality as influenced by inoculation of *Fusarium oxysporum* f. sp. *gladioli* are presented in Table 1. There was no disease incidence (0.00%) in *Psittacinus* hybrid. However, genotype Arka Naveen recorded highest (40.75 %) disease incidence which was on par with Pink Friendship (33.33 %) and Arka Gold (29.63 %). Different cultures of *Fusarium* showed highly significant effects on disease incidence per cent in gladiolus genotypes. Maximum disease incidence (54.17 %) was recorded in plants inoculated with isolate of *F. oxysporum* f. sp. *gladioli* from IIHR (i.e. culture 1), whereas there was no disease incidence in control plants which were not inoculated with *Fusarium*. Higher disease incidence was recorded in Arka Naveen, Pink Friendship and Arka Gold which were found to be susceptible genotypes. This may be due to the influence of genetic makeup of the genotypes. Similar work was also reported by Chandra *et al.* (1985), Palmer and Pryal (1958) and Riaz *et al.* (2010).

There was highly significant difference for interaction effects between different genotypes of gladiolus and inoculation with diverse cultures of *Fusarium*. However, highest disease incidence (100.00 %) was recorded in treatment G₄ × F₁ (Arka Naveen × culture 1) followed by 88.89 per cent in G₅ × F₁ (Pink Friendship × culture 1) and G₂ × F₁ (Arka Gold × culture 1). There was no disease incidence in treatment G₈ × F₁ (*Psittacinus* hybrid × culture 1).

The genotype Arka Gold recorded maximum mortality per cent (25.93%) on par with Arka Naveen (18.52%) and Pink Friendship (18.52%). There was no mortality (0.00%) in *Psittacinus* hybrid. Highly significant differences were observed with regard to the influence of different cultures of *Fusarium*. Inoculation with isolate of *F. oxysporum* f. sp. *gladioli* from IIHR (i.e. culture 1) recorded maximum (27.78%) mortality, while, there was no mortality in control plants which were not inoculated with *Fusarium*. The interaction effects between different genotypes of gladiolus and inoculation with different cultures of *Fusarium* recorded highly significant effects on mortality of gladiolus. However, maximum mortality (77.78%) was recorded in treatment G₂ × F₁ (Arka Gold × culture 1) followed by 55.56 per cent in G₄ × F₁ (Arka Naveen × culture 1), whereas, there was no mortality in treatment G₈ × F₁ (*Psittacinus* hybrid × culture 1). This increase in disease incidence and mortality in the plants inoculated with *Fusarium* isolate of IIHR might be due to its virulence. These results are in accordance with the

Table 1 Per cent disease incidence and mortality as influenced by genotypes and *Fusarium* cultures in gladiolus genotypes

Treatment	Disease incidence (per cent)	Mortality (per cent)
<i>Genotypes (G)</i>		
G1- Arka Amar	18.52 (18.47)	14.82 (15.35)
G2- Arka Gold	29.63 (27.83)	25.93 (24.71)
G3- Arka Kesar	18.52 (18.47)	11.11 (12.22)
G4- Arka Naveen	40.75 (37.19)	18.52 (18.47)
G5- Pink Friendship	33.33 (30.95)	18.52 (18.47)
G6- Arka Aayush	18.52 (18.47)	0.00 (2.87)
G7- IIHRG-12	14.82 (15.35)	3.71 (5.98)
G8- <i>Psittacinus</i> hybrid	0.00 (2.87)	0.00 (2.87)
SEm±	3.46	3.14
CD (P=0.01)	20.63	18.70
<i>Fusarium cultures (F)</i>		
F0- control	0.00 (2.87)	0.00 (2.87)
F1- IIHR culture	54.17 (48.51)	27.78 (26.28)
F2- Solan culture	11.11 (12.22)	6.94 (8.72)
SEm±	5.66	5.14
CD (P=0.01)	12.64	11.46
<i>Interaction effects (G × F)</i>		
G1×F0	0.00 (2.87)	0.00 (2.87)
G1×F1	33.33 (30.96)	22.22 (21.59)
G1×F2	22.22 (21.60)	22.22 (21.59)
G2×F0	0.00 (2.87)	0.00 (2.87)
G2×F1	88.89 (77.78)	77.78 (68.41)
G2×F2	0.00 (2.87)	0.00 (2.87)
G3×F0	0.00 (2.87)	0.00 (2.87)
G3×F1	33.33 (30.95)	11.11 (12.22)
G3×F2	22.22 (30.953)	22.22 (21.59)
G4×F0	0.00 (2.87)	0.00 (21.59)
G4×F1	100.00 (87.13)	55.56 (49.68)
G4×F2	22.22 (21.59)	0.00 (2.87)
G5×F0	0.00 (2.87)	0.00 (2.87)
G5×F1	88.89 (77.78)	44.44 (40.31)
G5×F2	11.11 (12.22)	11.11 (12.22)
G6×F0	0.00 (2.87)	0.00 (2.87)
G6×F1	44.44 (40.314)	0.00 (2.87)
G6×F2	11.11 (12.220)	0.00 (2.87)
G7×F0	0.00 (2.869)	0.00 (2.87)
G7×F1	44.44 (40.31)	11.11 (12.22)
G7×F2	0.00 (2.87)	0.00 (2.87)
G8×F0	0.00 (2.87)	0.00 (2.87)
G8×F1	0.00 (2.87)	0.00 (2.87)
G8×F2	0.00 (2.87)	0.00 (2.87)
SEm±	9.81	8.89
CD (P=0.01)	35.73	32.41

Fusarium cultures: F₀- No inoculation, F₁- Inoculation with *Fusarium oxysporum* f. sp. *gladioli* isolate from IIHR and F₂- Inoculation with *Fusarium oxysporum* f. sp. *gladioli* isolate from Solan. Values within parenthesis are arc sign transformed values

findings of Rao *et al.* (2009) and Riaz *et al.* (2010).

Morphological characters

There was 100% sprouting of all the corms in control and pathogen challenged plants. The perusal of data presented in Table 2 revealed that there was highly significant difference in days to sprouting of corms influenced by different genotypes of gladiolus. Among the genotypes, Arka Amar was earliest to sprout (7.44 days), on contrary, *Psittacinus* hybrid sprouted late (16.29 days).

Different cultures of *Fusarium* showed highly significant effects on days to sprouting of corms in gladiolus genotypes. Earliness for sprouting (11.69 days) was recorded in plants inoculated with isolate of *F. oxysporum* f. sp. *gladioli* from Solan (i.e. culture 2). Whereas, plants inoculated with isolate of *F. oxysporum* f. sp. *gladioli* from IIHR (i.e. culture 1) took maximum (13.38) number of days for sprouting of the corms. There was no significant difference for interaction effects between different genotypes of gladiolus and inoculation with diverse cultures of *Fusarium*. However, treatment G₁ × F₂ (Arka Amar × culture 2) recorded minimum days (6.67 days) for sprouting of the corms. On contrary, treatment G₈ × F₁ (*Psittacinus* hybrid × culture 1) recorded the maximum days to sprouting (17.78 days). This character may be attributed to the inherent growth character of the genotype.

There was no significant difference for plant height in the control and plants inoculated with *F. oxysporum* f. sp. *gladioli* from IIHR. Different gladiolus genotypes have shown highly significant differences inoculated with *F. oxysporum* f. sp. *gladioli* from Solan. Plant height ranged from 86.66 cm (Pink Friendship) to 118.42 cm (Arka Amar) (Table 3, 4 and 5). This character may be attributed to the inherent growth character of the genotype. This result was in accordance with reports of Kishan and Singh (2005).

Floral characters

Data pertaining to floral traits of different genotypes of gladiolus in control, inoculated with *Fusarium oxysporum* f. sp. *gladioli* culture 1 and culture 2, are presented in Table 3, 4 and 5, respectively.

Highly significant differences were recorded among different genotypes for the days taken to spike emergence in control pots, culture 1 and culture 2. In control, genotype IIHRG-12 found to be early for spike emergence (79.11 days) followed by Pink Friendship (79.40 days), Arka Amar (81.57 days) and was statistically on par with each other, while, *Psittacinus* hybrid took maximum number of days (90.55 days) to emergence of spikes. In culture 1, the genotype IIHRG-12 took minimum number of days to spike emergence (78.80 days) followed by Arka Amar (80.00 days), Arka Kesar (81.33 days), *Psittacinus* hybrid (83.77 days), Arka Aayush (83.80 days) and were statistically on par with each other, whereas, Pink Friendship took maximum number of days to emergence of spikes (92.00 days). In culture 2, the genotype IIHRG-12 was recorded early spike emergence (70.00 days) followed by Arka Amar (75.57

Table 2 Days to sprouting of corms as influenced by genotypes and *Fusarium* cultures in gladiolus

Treatment	Days to sprouting of corms
<i>Genotypes (G)</i>	
G1- Arka Amar	7.44
G2- Arka Gold	13.25
G3- Arka Kesar	13.44
G4- Arka Naveen	11.71
G5- Pink Friendship	13.63
G6- Arka Aayush	12.40
G7- IIHRG-12	13.11
G8- <i>Psittacinus</i> hybrid	16.29
SEm±	0.25
CD (P=0.01)	1.468
<i>Fusarium cultures (F)</i>	
F0- control	12.94
F1- IIHR culture	13.38
F2- Solan culture	11.69
SEm±	0.40
CD (P=0.01)	0.90
<i>Interaction effects (G × F)</i>	
G1×F0	7.11
G1×F1	8.56
G1×F2	6.67
G2×F0	12.89
G2×F1	14.22
G2×F2	12.67
G3×F0	15.44
G3×F1	13.67
G3×F2	11.22
G4×F0	12.67
G4×F1	11.67
G4×F2	10.78
G5×F0	13.67
G5×F1	14.44
G5×F2	12.78
G6×F0	12.56
G6×F1	12.33
G6×F2	12.33
G7×F0	13.00
G7×F1	14.33
G7×F2	12.00
G8×F0	16.11
G8×F1	17.78
G8×F2	15.00
SEm±	0.70
CD (P=0.01)	NS

Fusarium cultures: F₀- No inoculation, F₁- Inoculation with *Fusarium oxysporum* f. sp. *gladioli* isolate from IIHR and F₂- Inoculation with *Fusarium oxysporum* f. sp. *gladioli* isolate from Solan

days), Arka Kesar (76.00 days), Arka Naveen (76.85 days) and were statistically on par with each other. However, Pink Friendship took maximum number of days (87.33 days) to spike emergence. The results indicated that there is a

particular set of period for each genotype for flowering. The above results are in conformity with the findings of Shaukat *et al.* (2012) and Poonam (2012) in gladiolus (Table 3, 4 and 5).

Highly significant differences were recorded among different genotypes for the days to opening of first floret in control pots, culture 1 and culture 2. In control pots, the genotype IIHRG-12 recorded early (89.66) opening of first floret followed by Arka Amar (91.14 days), Pink Friendship (91.60 days), Arka Aayush (93.55 days), Arka Naveen (94.14 days) and were statistically on par with each other. However, the genotype *Psittacinus* hybrid was late (99.22) opening of first floret. In culture 1, the genotype Arka Kesar significantly took minimum (90.33) days for opening of first floret followed by Arka Amar (91.00 days), IIHRG-12 (91.60 days), Arka Aayush (92.60 days), and were statistically on par with each other. While, Pink Friendship took maximum (106.00) number of days to opening of first floret compared to other genotypes. In culture 2, the genotype IIHRG-12 was early (82.00 days) for opening of first floret and was on par with Arka Amar (85.28 days) and Arka Kesar (85.85 days), while Arka Gold flowered late (99.77 days) compared to other genotypes (Table 3, 4 and 5).

Yield and quality characters

The genotypic difference existed with regard to production of spikes per corm in control pots, culture 1 and culture 2. Highly significant variation was recorded for number of spikes/corm among the different genotypes inoculated with culture 1 and culture 2. In culture 1, the genotype, *Psittacinus* hybrid yielded higher (2.77) number of spikes/corm followed by Arka Amar (1.50) and were statistically on par exhibiting superiority over other genotypes. However, Arka Gold, Pink Friendship and IIHRG-12 yielded less number of spikes (1.00) compared to other genotypes. In culture 2, it was recorded maximum (2.88) in *Psittacinus* hybrid and is on par with Arka Aayush (2.00). However, minimum spikes per corm was recorded in Pink Friendship (1.00) (Table 4 and 5). Similar results were also obtained by Gupta *et al.* (2001).

Spike characters are important ones with regard to cut flower production in gladiolus. The genotypes have shown highly significant differences with respect to spike length which is one of the important characters for quality assessment. The genotype Arka Naveen possessed the longest spikes which is a desirable character for cut flower in control plants. The genotype Arka Amar recorded longest spike in plants inoculated with diverse cultures of *Fusarium*. In contrast, *Fusarium* inoculation significantly reduced spike length in Arka Naveen, Pink Friendship and Arka Gold. Arka Naveen was found to be the most susceptible genotype to *Fusarium* (Table 3, 4 and 5). The result is in accordance with the findings of Nair and Shiva (2003) in gladiolus.

Rachis length is another important crucial trait for cut flower genotype. There was no significant difference among the genotypes for this character in control plants. Whereas, there were highly significant differences were recorded in

Table 3 Morphological and floral characteristics of different genotypes of gladiolus in control plants

Genotype (Treatment)	Control (without inoculation)													
	Plant height (cm)	Days to spike emergence	Days to opening of first floret	Number of spikes/corm	Spike length (cm)	Rachis length (cm)	Floret diameter (cm)	Number of florets/spike	Number of florets remain open at a time	Number of corms/corm	Number of corms/corm	Number of corms/corm	Number of corms/corm	Number of corms/corm
	<i>S</i> <i>Ed</i> <i>CD</i> at <i>I</i> % ±	<i>S</i> <i>Ed</i> <i>CD</i> at <i>I</i> % ±	<i>S</i> <i>Ed</i> <i>CD</i> at <i>I</i> % ±	<i>S</i> <i>Ed</i> <i>CD</i> at <i>I</i> % ±	<i>S</i> <i>Ed</i> <i>CD</i> at <i>I</i> % ±	<i>S</i> <i>Ed</i> <i>CD</i> at <i>I</i> % ±	<i>S</i> <i>Ed</i> <i>CD</i> at <i>I</i> % ±	<i>S</i> <i>Ed</i> <i>CD</i> at <i>I</i> % ±	<i>S</i> <i>Ed</i> <i>CD</i> at <i>I</i> % ±	<i>S</i> <i>Ed</i> <i>CD</i> at <i>I</i> % ±	<i>S</i> <i>Ed</i> <i>CD</i> at <i>I</i> % ±	<i>S</i> <i>Ed</i> <i>CD</i> at <i>I</i> % ±	<i>S</i> <i>Ed</i> <i>CD</i> at <i>I</i> % ±	<i>S</i> <i>Ed</i> <i>CD</i> at <i>I</i> % ±
Arka Amar	103.00	81.57	91.14	1.85	83.14	53.57	8.50	11.42	3.14	2.28	5.42			
Arka Gold	104.44	85.11	99.00	1.66	83.50	54.50	8.77	8.66	2.22	2.00	0.44			
Arka Kesar	97.37	86.25	98.50	1.62	81.93	54.25	8.25	11.25	2.62	1.75	1.50			
Arka Naveen	108.57	86.28	94.14	1.42	87.42	56.14	8.50	11.42	3.00	2.00	0.00			
Pink Friendship	100.60	79.40	91.60	1.00	82.80	53.60	7.20	12.20	2.60	3.00	3.80			
Arka Aayush	96.55	85.33	93.55	2.00	71.22	52.44	7.50	11.77	3.33	2.22	1.88			
IHRG-12	101.33	79.11	89.66	1.88	80.77	52.77	8.66	11.33	2.55	2.11	0.44			
<i>Psittacinus</i> hybrid	93.33	90.55	99.22	2.33	69.72	52.38	7.11	8.88	3.44	3.33	1.77			
<i>Genotype combination</i>	<i>S</i> <i>Ed</i> <i>CD</i> at <i>I</i> % ±	<i>S</i> <i>Ed</i> <i>CD</i> at <i>I</i> % ±	<i>S</i> <i>Ed</i> <i>CD</i> at <i>I</i> % ±	<i>S</i> <i>Ed</i> <i>CD</i> at <i>I</i> % ±	<i>S</i> <i>Ed</i> <i>CD</i> at <i>I</i> % ±	<i>S</i> <i>Ed</i> <i>CD</i> at <i>I</i> % ±	<i>S</i> <i>Ed</i> <i>CD</i> at <i>I</i> % ±	<i>S</i> <i>Ed</i> <i>CD</i> at <i>I</i> % ±	<i>S</i> <i>Ed</i> <i>CD</i> at <i>I</i> % ±	<i>S</i> <i>Ed</i> <i>CD</i> at <i>I</i> % ±	<i>S</i> <i>Ed</i> <i>CD</i> at <i>I</i> % ±	<i>S</i> <i>Ed</i> <i>CD</i> at <i>I</i> % ±	<i>S</i> <i>Ed</i> <i>CD</i> at <i>I</i> % ±	<i>S</i> <i>Ed</i> <i>CD</i> at <i>I</i> % ±
1 and 2	4.62 12.36 11.90	5.09 1.74 4.65	4.65 1.74 4.65	0.22 0.61 4.02	10.75 3.68 9.85	3.68 9.85 10.11	0.17 0.47 0.47	0.71 1.90 0.28	0.76 0.76 0.76	0.40 1.07 1.07	NS NS NS			
1 and 3	4.75 12.69 11.95	5.23 1.79 4.78	4.78 1.79 4.78	0.23 0.62 4.13	11.04 3.78 10.11	3.78 10.11 10.45	0.11 0.48 0.49	0.73 1.95 2.02	0.29 0.78 0.81	0.41 1.10 1.14				
1 and 4	4.91 13.11 2.02	5.40 1.84 4.94	4.94 1.84 4.94	0.24 0.64 4.27	11.40 3.91 10.45	3.91 10.45 11.44	0.18 0.49 0.20	0.75 2.02 0.82	0.30 0.81 0.89	0.42 1.14 1.25				
1 and 5	5.37 14.36 2.21	5.91 2.02 5.41	5.41 2.02 5.41	0.26 0.70 4.67	12.49 4.28 11.44	4.28 11.44 9.85	0.20 0.54 0.17	0.82 2.21 0.71	0.33 0.89 0.76	0.46 1.25 1.07				
1 and 6	4.62 12.36 1.90	5.09 1.74 4.65	4.65 1.74 4.65	0.22 0.61 4.02	10.75 3.68 9.85	3.68 9.85 10.11	0.17 0.47 0.47	0.71 1.90 0.28	0.76 0.76 0.76	0.40 1.07 1.07				
1 and 7	4.62 12.36 1.90	5.09 1.74 4.65	4.65 1.74 4.65	0.22 0.61 4.02	10.75 3.68 9.85	3.68 9.85 10.11	0.17 0.47 0.47	0.71 1.90 0.28	0.76 0.76 0.76	0.40 1.07 1.07				
1 and 8	4.62 12.36 1.90	5.09 1.74 4.65	4.65 1.74 4.65	0.22 0.61 4.02	10.75 3.68 9.85	3.68 9.85 10.11	0.17 0.47 0.47	0.71 1.90 0.28	0.76 0.76 0.76	0.40 1.07 1.07				
2 and 3	4.46 11.92 1.83	4.91 1.68 4.49	4.49 1.68 4.49	0.22 0.58 3.88	10.37 3.55 9.50	3.55 9.50 10.11	0.17 0.45 0.17	0.68 1.83 0.27	0.74 0.74 0.74	0.38 1.04 1.04				
2 and 4	4.62 12.36 1.90	5.09 1.74 4.65	4.65 1.74 4.65	0.22 0.61 4.02	10.75 3.68 9.85	3.68 9.85 10.11	0.17 0.47 0.47	0.71 1.90 0.28	0.76 0.76 0.76	0.40 1.07 1.07				
2 and 5	5.12 13.68 2.11	5.63 1.93 5.15	5.15 1.93 5.15	0.25 0.67 4.45	11.90 4.08 10.90	4.08 10.90 11.44	0.19 0.52 0.19	0.78 2.10 0.31	0.85 0.85 0.85	0.44 1.19 1.19				
2 and 6	4.33 11.56 1.78	4.76 1.63 4.35	4.35 1.63 4.35	0.21 0.57 3.76	10.06 3.45 9.21	3.45 9.21 10.06	0.16 0.44 0.16	0.66 1.78 0.26	0.71 0.71 0.71	0.37 1.00 1.00				
2 and 7	4.33 11.56 1.78	4.76 1.63 4.35	4.35 1.63 4.35	0.21 0.57 3.76	10.06 3.45 9.21	3.45 9.21 10.06	0.16 0.44 0.16	0.66 1.78 0.26	0.71 0.71 0.71	0.37 1.00 1.00				
2 and 8	4.33 11.56 1.78	4.76 1.63 4.35	4.35 1.63 4.35	0.21 0.57 3.76	10.06 3.45 9.21	3.45 9.21 10.06	0.16 0.44 0.16	0.66 1.78 0.26	0.71 0.71 0.71	0.37 1.00 1.00				
3 and 4	4.75 12.69 1.95	5.23 1.79 4.78	4.78 1.79 4.78	0.23 0.62 4.13	11.04 3.78 10.11	3.78 10.11 11.44	0.18 0.48 0.19	0.73 1.95 0.29	0.78 0.78 0.78	0.41 1.10 1.10				
3 and 5	5.23 13.98 2.15	5.76 1.97 5.26	5.26 1.97 5.26	0.25 0.69 4.55	12.16 4.17 11.44	4.17 11.44 11.44	0.19 0.53 0.19	0.80 2.15 0.32	0.86 0.86 0.86	0.45 1.22 1.22				
3 and 6	4.46 11.92 1.83	4.91 1.68 4.49	4.49 1.68 4.49	0.22 0.58 3.88	10.37 3.55 9.50	3.55 9.50 10.11	0.17 0.45 0.17	0.68 1.83 0.27	0.74 0.74 0.74	0.38 1.04 1.04				
3 and 7	4.46 11.92 1.83	4.91 1.68 4.49	4.49 1.68 4.49	0.22 0.58 3.88	10.37 3.55 9.50	3.55 9.50 10.11	0.17 0.45 0.17	0.68 1.83 0.27	0.74 0.74 0.74	0.38 1.04 1.04				
3 and 8	4.46 11.92 1.83	4.91 1.68 4.49	4.49 1.68 4.49	0.22 0.58 3.88	10.37 3.55 9.50	3.55 9.50 10.11	0.17 0.45 0.17	0.68 1.83 0.27	0.74 0.74 0.74	0.38 1.04 1.04				
4 and 5	5.37 14.36 2.21	5.91 2.02 5.41	5.41 2.02 5.41	0.26 0.70 4.67	12.49 4.28 11.44	4.28 11.44 9.85	0.20 0.54 0.17	0.82 2.21 0.71	0.33 0.89 0.46	0.46 1.25 1.25				
4 and 6	4.62 12.36 1.90	5.09 1.74 4.65	4.65 1.74 4.65	0.22 0.61 4.02	10.75 3.68 9.85	3.68 9.85 10.11	0.17 0.47 0.47	0.71 1.90 0.28	0.76 0.76 0.76	0.40 1.07 1.07				
4 and 7	4.62 12.36 1.90	5.09 1.74 4.65	4.65 1.74 4.65	0.22 0.61 4.02	10.75 3.68 9.85	3.68 9.85 10.11	0.17 0.47 0.47	0.71 1.90 0.28	0.76 0.76 0.76	0.40 1.07 1.07				
4 and 8	4.62 12.36 1.90	5.09 1.74 4.65	4.65 1.74 4.65	0.22 0.61 4.02	10.75 3.68 9.85	3.68 9.85 10.11	0.17 0.47 0.47	0.71 1.90 0.28	0.76 0.76 0.76	0.40 1.07 1.07				
5 and 6	5.12 13.68 2.11	5.63 1.93 5.15	5.15 1.93 5.15	0.25 0.67 4.55	11.90 4.08 10.90	4.08 10.90 11.44	0.19 0.52 0.19	0.78 2.10 0.31	0.85 0.85 0.85	0.44 1.19 1.19				
5 and 7	5.12 13.68 2.11	5.63 1.93 5.15	5.15 1.93 5.15	0.25 0.67 4.55	11.90 4.08 10.90	4.08 10.90 11.44	0.19 0.52 0.19	0.78 2.10 0.31	0.85 0.85 0.85	0.44 1.19 1.19				
5 and 8	5.12 13.68 2.11	5.63 1.93 5.15	5.15 1.93 5.15	0.25 0.67 4.55	11.90 4.08 10.90	4.08 10.90 11.44	0.19 0.52 0.19	0.78 2.10 0.31	0.85 0.85 0.85	0.44 1.19 1.19				
6 and 7	4.33 11.56 1.78	4.76 1.63 4.35	4.35 1.63 4.35	0.21 0.57 3.76	10.06 3.45 9.21	3.45 9.21 10.06	0.16 0.44 0.16	0.66 1.78 0.26	0.71 0.71 0.71	0.37 1.00 1.00				
6 and 8	4.33 11.56 1.78	4.76 1.63 4.35	4.35 1.63 4.35	0.21 0.57 3.76	10.06 3.45 9.21	3.45 9.21 10.06	0.16 0.44 0.16	0.66 1.78 0.26	0.71 0.71 0.71	0.37 1.00 1.00				
7 and 8	4.33 11.56 1.78	4.76 1.63 4.35	4.35 1.63 4.35	0.21 0.57 3.76	10.06 3.45 9.21	3.45 9.21 10.06	0.16 0.44 0.16	0.66 1.78 0.26	0.71 0.71 0.71	0.37 1.00 1.00				

Table 4 Morphological and floral characteristics of gladiolus genotypes in plants inoculated with *Fusarium oxysporum* f.sp. gladioli isolate from IIHR (culture 1)

Genotype (Treatment)	Inoculation with <i>Fusarium oxysporum</i> f.sp. gladioli isolate from IIHR													
	Plant height (cm)	Days to spike emergence	Days to opening of first floret	Number of spikes/corm	Spike length (cm)	Rachis length (cm)	Floret diameter (cm)	Number of florets/spike	Number of florets remain open at a time	Number of corms/corm	Number of corms/corm	Number of corms/corm	Number of corms/corm	Number of corms/corm
Arka Amar	102.66	80.00	91.00	1.50	85.33	58.91	8.25	10.83	3.66	2.67	2.00	2.00	2.00	2.00
Arka Gold	109.00	85.00	100.00	1.00	84.00	61.00	8.50	8.00	3.00	2.00	2.00	2.00	2.00	2.00
Arka Kesar	97.66	81.33	90.33	1.16	79.50	57.83	8.16	10.33	2.66	1.67	0.00	0.00	0.00	0.00
Pink Friendship	100.00	92.00	106.00	1.00	78.00	52.00	7.00	10.00	2.00	6.00	11.30	11.30	11.30	11.30
Arka Aayush	92.40	83.80	92.60	1.80	68.00	48.80	7.00	9.80	3.40	1.80	0.80	0.80	0.80	0.80
IIHRG-12	95.00	78.80	91.60	1.00	67.80	48.40	8.60	9.20	3.00	1.80	1.80	1.80	1.80	1.80
<i>Psittacium</i> hybrid	94.33	83.77	95.88	2.77	69.33	50.88	7.05	8.66	3.22	3.33	2.11	2.11	2.11	2.11
Genotype combination	S Ed	CD at	S Ed	CD at	S Ed	CD at	S Ed	CD at	S Ed	CD at	S Ed	CD at	S Ed	CD at
1 and 2	7.45	20.72	3.87	10.76	3.78	10.50	0.45	1.27	8.45	23.48	5.07	14.09	0.62	1.27
1 and 3	3.98	11.07	2.07	5.75	2.02	5.61	0.24	0.68	4.51	12.55	2.71	7.53	0.33	0.92
1 and 4	7.45	20.72	3.87	10.76	3.78	10.50	0.45	1.27	8.45	23.48	5.07	14.09	0.62	1.27
1 and 5	4.18	11.62	2.17	6.03	2.11	5.89	0.25	0.71	4.73	13.16	2.84	7.89	0.34	0.96
1 and 6	4.18	11.62	2.17	6.03	2.11	5.89	0.25	0.71	4.73	13.16	2.84	7.89	0.34	0.96
1 and 7	3.63	10.11	1.89	5.25	1.84	5.12	0.22	0.62	4.12	11.45	2.47	6.87	0.30	0.84
2 and 3	7.45	20.72	3.87	10.76	3.78	10.50	0.45	1.27	8.45	23.48	5.07	14.09	0.62	1.27
2 and 4	9.76	27.13	5.07	14.09	4.95	13.75	0.60	1.66	11.06	30.74	6.63	18.44	0.81	2.26
2 and 5	7.56	21.02	3.92	10.91	3.83	10.65	0.46	1.29	8.57	23.81	5.14	14.29	0.63	1.75
2 and 6	7.56	21.02	3.92	10.91	3.83	10.65	0.46	1.29	8.57	23.81	5.14	14.29	0.63	1.75
2 and 7	7.27	20.22	3.78	10.50	3.69	10.25	0.44	1.24	8.24	22.91	4.94	13.75	0.60	1.68
3 and 4	7.45	20.72	3.87	10.76	3.78	10.50	0.45	1.27	8.45	23.48	5.07	14.09	0.62	1.72
3 and 5	4.18	11.62	2.17	6.03	2.11	5.89	0.25	0.71	4.73	13.16	2.84	7.89	0.34	0.96
3 and 6	4.18	11.62	2.17	6.03	2.11	5.89	0.25	0.71	4.73	13.16	2.84	7.89	0.34	0.96
3 and 7	3.63	10.11	1.89	5.25	1.84	5.12	0.22	0.62	4.12	11.44	2.47	6.87	0.30	0.84
4 and 5	7.56	21.02	3.92	10.91	3.83	10.65	0.46	1.29	8.57	23.81	5.14	14.29	0.63	1.75
4 and 6	7.65	21.02	3.92	10.91	3.83	10.65	0.46	1.29	8.57	23.81	5.14	14.29	0.63	1.75
4 and 7	7.27	20.22	3.78	10.50	3.69	10.25	0.44	1.24	8.24	23.91	4.94	13.75	0.60	1.68
5 and 6	4.36	12.13	2.46	6.30	2.21	6.15	0.26	0.74	4.94	13.75	2.96	8.25	0.36	1.01
5 and 7	3.85	10.70	2.00	5.55	1.95	5.42	0.23	0.65	4.36	12.12	2.61	7.27	0.32	0.89
6 and 7	3.85	10.70	2.00	5.55	1.95	5.42	0.23	0.65	4.36	12.12	2.61	7.27	0.32	0.89

Table 5 Morphological and floral characteristics of gladiolus genotypes in plants inoculated with *Fusarium oxysporum* f.sp. *gladioli* isolate from Solan (culture 2)

Genotype (Treatment)	Inoculation with <i>Fusarium oxysporum</i> f.sp. <i>gladioli</i> isolate from Solan															
	Traits															
	Plant height (cm)	Days to spike emergence	Days to opening of first floret	Number of spikes/ corm	Spike length (cm)	Rachis length (cm)	Floret diameter (cm)	Number of florets/ spike	Number of florets remain open at a time	Number of corms/ corm	Number of corms/ corm	Number of corms/ corm				
Arka Amar	118.42	75.57	85.28	1.42	95.85	65.78	9.28	14.00	4.00	1.28	10.29					
Arka Gold	100.66	86.88	99.77	1.55	74.77	51.11	7.33	7.55	2.66	2.00	0.55					
Arka Kesar	104.35	76.00	85.85	1.85	83.21	61.57	8.57	12.71	3.28	1.57	0.57					
Arka Naveen	110.71	76.85	89.14	1.85	80.42	61.00	8.78	12.71	3.14	1.71	0.29					
Pink Friendship	86.66	87.33	98.16	1.00	65.33	46.50	7.16	8.16	2.16	3.00	2.17					
Arka Aayush	101.31	77.00	88.62	2.00	79.62	57.87	8.06	12.62	3.25	1.75	4.75					
IIHRG-12	112.33	70.00	82.00	1.66	82.22	58.11	9.37	11.55	2.88	2.11	5.78					
<i>Psittacinus</i> hybrid	100.00	84.22	93.77	2.88	78.00	52.55	7.55	9.77	3.11	3.55	2.22					
<i>Genotype combination</i>	<i>S Ed</i>	<i>CD at</i>	<i>S Ed</i>	<i>CD at</i>	<i>S Ed</i>	<i>CD at</i>	<i>S Ed</i>	<i>CD at</i>	<i>S Ed</i>	<i>CD at</i>	<i>S Ed</i>	<i>CD</i>				
1 and 2	± 1%	± 1%	± 1%	± 1%	± 1%	± 1%	± 1%	± 1%	± 1%	± 1%	± 1%	± 1%				
1 and 3	4.39	2.42	2.24	0.64	3.76	3.83	0.28	0.67	0.24	0.50	1.33	2.12				
1 and 4	4.66	2.57	2.37	0.68	3.99	4.06	0.30	0.71	0.25	0.53	1.41	2.25				
1 and 5	4.66	2.57	2.37	0.68	3.99	4.06	0.30	0.71	0.25	0.53	1.41	2.25				
1 and 6	4.85	2.67	2.47	0.71	4.15	4.23	0.31	0.84	0.26	0.55	1.47	2.34				
1 and 7	4.51	2.48	2.30	0.66	3.86	3.93	0.29	0.78	0.24	0.51	1.37	2.18				
1 and 8	4.39	2.42	2.24	0.64	3.76	3.83	0.28	0.76	0.24	0.50	1.33	2.12				
2 and 3	4.39	2.42	2.24	0.64	3.76	3.83	0.28	0.76	0.24	0.50	1.33	2.12				
2 and 4	4.39	2.42	2.24	0.64	3.76	3.83	0.28	0.76	0.24	0.50	1.33	2.12				
2 and 5	4.59	2.53	2.34	0.67	3.94	4.01	0.30	0.80	0.25	0.52	1.39	2.22				
2 and 6	4.23	2.33	2.16	0.62	3.63	3.69	0.27	0.73	0.23	0.48	1.28	2.04				
2 and 7	4.11	2.26	2.09	0.60	3.52	3.58	0.26	0.71	0.22	0.46	1.25	1.98				
2 and 8	4.66	2.26	2.09	0.60	3.52	3.58	0.26	0.71	0.22	0.46	1.25	1.98				
3 and 4	4.85	2.57	2.37	0.68	3.99	4.06	0.31	0.81	0.25	0.53	1.41	2.25				
3 and 5	4.51	2.67	2.47	0.71	4.15	4.23	0.31	0.84	0.26	0.55	1.47	2.34				
3 and 6	4.39	2.48	2.30	0.66	3.86	3.93	0.28	0.78	0.24	0.51	1.37	2.18				
3 and 7	4.39	2.42	2.24	0.64	3.76	3.83	0.28	0.76	0.24	0.50	1.33	2.12				
3 and 8	4.39	2.42	2.24	0.64	3.76	3.83	0.28	0.76	0.24	0.50	1.33	2.12				
4 and 5	4.85	2.67	2.47	0.71	4.15	4.23	0.31	0.84	0.26	0.55	1.47	2.34				
4 and 6	4.51	2.48	2.30	0.66	3.86	3.93	0.28	0.78	0.24	0.51	1.37	2.18				
4 and 7	4.39	2.42	2.24	0.64	3.76	3.83	0.28	0.76	0.24	0.50	1.33	2.12				
4 and 8	4.39	2.42	2.24	0.64	3.76	3.83	0.28	0.76	0.24	0.50	1.33	2.12				
5 and 6	4.71	2.59	2.40	0.69	4.03	4.11	0.30	0.82	0.25	0.53	1.43	2.27				
5 and 7	4.59	2.53	2.34	0.67	3.94	4.01	0.30	0.80	0.25	0.52	1.39	2.21				
5 and 8	4.59	2.53	2.34	0.67	3.94	4.01	0.30	0.80	0.25	0.52	1.39	2.21				
6 and 7	4.23	2.33	2.16	0.62	3.63	3.69	0.27	0.73	0.23	0.48	1.28	2.04				
6 and 8	4.23	2.33	2.16	0.62	3.63	3.69	0.27	0.73	0.23	0.48	1.28	2.04				
7 and 8	4.11	2.26	2.09	0.60	3.52	3.58	0.26	0.71	0.22	0.46	1.25	1.98				

plants inoculated with diverse cultures of *Fusarium*. Arka Gold and Arka Amar exhibited maximum rachis length in plants inoculated with culture 1 and culture 2, respectively (Table 3, 4 and 5). The results are in accordance with the findings of Gupta *et al.* (2001) and Kamble (2001).

Along with the spike characters, number of florets/spike, floret diameter and number of florets remaining open at a time are important for a cut flower variety as it decide the attractiveness of the spike and vase life. In general, the genotype with more number of florets/spike produced longer vase life. The genotypes under study have shown highly significant differences with respect to number of florets per spike in control and in plants inoculated with culture 2, whereas, there was no significant difference in plants inoculated with culture 1. The maximum number of florets was produced by Pink Friendship followed by Arka Aayush, Arka Amar, Arka Naveen, IIHRG-12 and Arka Kesar in control plants and Arka Amar, Arka Kesar, Arka Naveen and Arka Aayush in plants inoculated with culture 2 and minimum number of florets was produced by Arka Gold (Table 3, 4 and 5). Similar results were reported by Jagdish *et al.* (2003), Punam *et al.* (2009), Ankit *et al.* (2015) and Shaukat *et al.* (2012).

For the good appearance of a spike, the florets should be attractive, big and arranged in a compact manner, with more number of florets opening at a time on one side of the rachis. Highly significant variation recorded for flower size among the different genotypes of gladiolus studied in the control pots, culture 1 and culture 2. In control pots, the genotype Arka Gold recorded significantly largest flowers (8.77 cm) followed by IIHRG-12 (8.66 cm), Arka Amar (8.50 cm), and was statistically on par with each other, while *Psittacinus* hybrid produced smaller sized flowers (7.11 cm) compared to other genotypes. In culture 1, maximum floret diameter (8.60 cm) was recorded in IIHRG-12 and was statistically on par with Arka Gold (8.50 cm), Arka Amar (8.25 cm), Arka Kesar (8.16 cm), whereas Pink Friendship and Arka Aayush registered minimum floret diameter (7.00 cm). This parameter differed with higher significance among the genotypes inoculated with culture 2. The maximum floret diameter was recorded in genotype IIHRG-12 (9.37 cm) followed by Arka Amar (9.28 cm), Arka Naveen (8.78 cm), Arka Kesar (8.57 cm) and was statistically on par with each other, whereas minimum diameter (7.16 cm) was recorded in Pink Friendship (Table 3, 4 and 5).

Similarly, there was highly significant difference with respect to number of florets remain open at a time in control and in pathogen challenged plants. In control pots, maximum number of florets remain open at a time was recorded in *Psittacinus* hybrid, followed by Arka Aayush, Arka Amar and Arka Naveen, however, minimum recorded in Arka Gold. Whereas, in plants inoculated with *Fusarium*, maximum number of florets remain open at a time was recorded in Arka Amar and minimum in Pink Friendship. However, it is the inherent character of the genotypes (Table 3, 4 and 5). The above results are supported by Gupta *et al.*

(2001), Kamble (2001) and Ankit *et al.* (2015).

Along with all these growth and flower characters, a good cut flower genotype should also produce bigger size daughter corms and good number of cormels. In the present study, the genotypes have shown varied response with respect to the weight, number of corms and cormels produced. Number of daughter corms per corm differed with higher significance in control and pathogen challenged plants. The maximum number of daughter corms produced by *Psittacinus* hybrid and Pink Friendship in control plants and in plants inoculated with culture 2 and culture 1, respectively. The genotype Arka Kesar produced minimum number of corms in control and in plants inoculated with culture 2. However, there was no significant difference in total weight of corms in control plants and in the plants inoculated with culture 2. Plants challenged with culture 1 differ with higher significance, whereas Pink Friendship, Arka Gold and Arka Amar recorded maximum total weight of corms and it was minimum in *Psittacinus* hybrid. Highly significant differences were recorded with respect to mean weight of the corms in control plants. Maximum corm weight was recorded in Arka Gold followed by Arka Amar, IIHRG-12, Arka Kesar, Arka Aayush and it was minimum in *Psittacinus* hybrid. The production of daughter corms of more weight may be attributed to the good vegetative growth of the plants in the initial stages, which supplies good amount of photosynthates for storage in the corms which are also the storage organs (Table 3, 4 and 5). This is in line with the finding of Poon *et al.* (2010) and Shaukat *et al.* (2012) in gladiolus.

There should be good production of cormels to have the good amount of planting material for the next generations. There was no significant difference for number of cormels per corm in control plants, whereas there was highly significant difference for this character in the pathogen challenged plants. The highest number of cormels were produced by Arka Gold and Arka Kesar did not produce any cormels in plants inoculated with culture-1, whereas, the maximum number of cormels were recorded in Arka Amar followed by IIHRG-12, Arka Aayush and minimum in Arka Naveen in plants inoculated with culture 2. Though, *Psittacinus* hybrid has got least weight of daughter corms. It had good production of big sized cormels though less in number comparatively (Table 3, 4 and 5).

The results of the present study clearly indicated that among eight genotypes screened for *Fusarium* resistance and agronomic performance, four genotypes, viz. *Psittacinus* hybrid, Arka Amar, IIHRG-12 and Arka Gold were found to be promising and resistance against *Fusarium* wilt.

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