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Full Length Research Paper

Screening of *Gladiolus* germplasm for agronomic performance and resistance against corm rot disease

Tariq Riaz, Salik Nawaz Khan* and Arshad Javaid

Institute of Plant Pathology, University of the Punjab, Quaid-e-Azam Campus Lahore, Pakistan.

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A field experiment was conducted to evaluate the agronomic performance and resistance of *Gladiolus* germplasm against corm rot disease caused by *Fusarium oxysporum* Schlecht. f. sp. *gladioli* (L. Masey) W.C. Snyder & H.N. Hans. Among the 23 *Gladiolus* varieties tested, Glad Red exhibited the highest spike length of 55 cm followed by Advanced Red (50.2 cm) and White Prosperity (49.5 cm). Highest number of flowers (13 per spike) was recorded in Rose Supreme, Jester Ruffled Yellow, Princess Margaret Rose and Chinon. Glad Red depicted highest field life of flowers (42.5 days), followed by Friendship (42.5 days), Peter Pears (38.7 days) and Chinon (37.3 days). Different varieties showed 6.6 – 56.6% disease incidence and 0 – 33.3% mortality. Advanced Red, White Prosperity, Violetta, San Remo and Yellow Glad were found comparatively more resistant to corm rot disease with disease incidence of 0 – 10%. Indian variety Aarti was found to be the most susceptible to corm rot disease with disease incidence of 56.6%. Disease incidence was significantly and positively correlated with corm size. The present study concludes that Advanced Red and White Prosperity are the most suitable *Gladiolus* varieties for cultivation under agro-climatic conditions of Pakistan, having best floral characteristics and resistance against corm rot disease.

Key words: Corm rot disease, disease resistance, *Fusarium oxysporum* f. sp. *gladioli*, germplasm screening, *Gladiolus*.

INTRODUCTION

Owing to their different sizes, shades and excellent vase life, *Gladiolus* hybrids are among the preferred cut flowers (Bose et al., 2003; Riaz et al., 2007a, b). It is a native of South Africa and has been cultivated globally. Fusarium rot 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). Vascular corm rot is also called "yellows" on infected plants in the field. The causal organism is *Fusarium oxysporum* Schlecht. f.sp. *gladioli* (L. Masey) W.C. Snyder & H.N. Hans., which deteriorates its quality and market value (Armitage, 1993; Remotti et al., 1997; 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.

*Corresponding author. E-mail: salik_nawaz@yahoo.com. Tel: +92 42 99231846. Fax: +92 42 99231187.

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 (Roebroeck and Mes, 1992).

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. In many countries, the use of fumigants such as 1,2-dibromochloropropane and ethylene dibromide has been discontinued or suspended, and a phase-out of methyl bromide, which is the most widely used soil fumigant, is underway (Gamliel et al., 2000; Pavlou and Vakalounakis, 2005). Furthermore, the high cost associated with the use of fungicides is a limiting factor in the profitability of the production (Partridge et al., 2006). Ac-

cordingly, there is an urgent need to work towards the development of safer antifungal agents which are expected to be renewable, non-petrochemical, naturally eco-friendly and easily obtainable (Sharma and Tripathi, 2008). Cultivation of disease resistant varieties is the most suitable practice to manage plant diseases (Li et al., 2008; Rajeswari et al., 2010). The present study was therefore carried out to screen *Gladiolus* germplasm for best agronomic performance and resistance against corm rot disease.

MATERIALS AND METHODS

Soil analysis

Field soil used in the experiment was collected from the experimental station of the Mycology and Plant Pathology Department (MPPL), University of the Punjab, Lahore, Pakistan. The city of Lahore is located on latitude 31.57° N and longitude 74.31° E. Electrical conductivity (EC) of the soil was 0.14 S m^{-1} and its pH was 7.8 (Soil Testing Laboratories. Lahore, Pakistan). The amount of organic matter was 0.69% and quantities of N was 0.05%, and that of P and K were 6.3 and 100 $mgkg^{-1}$, respectively. The concentrations of micronutrients viz. boron, manganese, iron, copper and zinc were 1.06, 22.8, 10.8, 1.9 and 1.3 mg kg^{-1}, res-pectively in the soil sample.

Procurement of *Gladiolus* germplasm

Twenty two *Gladiolus* hybrids namely Peter pears, Flevo Vision, Glad red, Jester Gold, White Friendship, Wind songs, Mascagni, Jester Ruffled yellow, Rose Supreme, Violetta, Princess Margaret Rose, Pricilla, Friendship, San Remo, Yellow Glad, Advanced Red, White prosperity, Oscar, Fado, Blue Glad, Victor Borgy and Chinon were procured from Sunny View Nurseries and Seed Stores, Lahore, Pakistan, and a local variety Aarti was obtained from a local *Gladiolus* grower.

Isolation of pathogen

Infected corm samples collected from *Gladiolus* growing fields of Lahore, Pakistan were cut into small pieces and surface disinfected by immersing in 1% sodium hypochlorite solution for one minute and then rinsed thrice in sterilized water. The surface sterilized pieces were placed on the malt extract agar (MEA) medium in 9 cm diameter Petri plates and incubated at 25°C for 7 days and maintained on 2% MEA medium. The pathogen associated with corm rot disease of *Gladiolus* was identified as *F. oxysporum* f. sp. *gladioli* based on the descriptions given by Barnett and Hunter (1998).

Koch's postulates were followed for pathogenicity test using *F. oxysporum* f. sp. *gladioli*. The corms of Advanced Red and Aarti (randomly selected) were sown. Experiment was conducted in plastic pots of 9 cm diameter and 15 cm depth, each containing 1.4 kg soil maintained on greenhouse bench. One corm was sown in each pot. Chickpea based *F. oxysporum* f. sp. *gladioli* inoculum was mixed in the soil at 4 g per 100 g of soil three days before plantation and watering was done. Each treatment was replicated.

Inoculum preparation of *F. oxysporum* f. sp. *gladioli*

Mass inoculum of *F. oxysporum* f. sp. *gladioli* was raised on chickpea according to Riaz et al. (2007b). Healthy chickpeas were boiled for 45 min 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 250 g of boiled chickpeas was autoclaved at 121°C under 1.035 × 10^5 Pa pressure for 30 min and cooled at room temperature. A 5 mm disc from periphery of actively growing 7 days old *F. oxysporum* f. sp. *gladioli* culture was introduced into each bag under aseptic conditions. These bags were kept at room temperature in the dark for 8 days. After 8 days, all chickpea bags were completely filled with the fungal growth. These bags were maintained at 4°C until used in further studies.

Field experiment

Twenty three *Gladiolus* hybrids (mentioned above) were cultivated in field plots in November 2006. Experiment was laid down in a split-split plot design. *Gladiolus* cultivars were kept as subplots. In each subplot, there were six ridges (18 cm high and 3 m long). *Gladiolus* corms of uniform size were planted in planting holes on each ridge with inter and intra row spacing of 50 and 60 cm, respectively. There were 6 *Gladiolus* plants on each longitudinal ridge. In each subplot, one row served as control and the rest five rows were experimental. Four grams of chickpea based *F. oxysporum* f. sp. *gladioli* inoculum was mixed in the soil of each planting hole up to the depth of 8 cm, before sowing of corms of *Gladiolus*. Corms were sown at 6 cm depth. Each treatment was replicated.

Plants were harvested 65 days after sowing and data regarding length and dry biomass of both root and shoot were recorded. Data regarding disease incidence and mortality were recorded using:

$$\text{Disease incidence } (\%) = \frac{\text{No. of diseased plants}}{\text{Total No. of plants}} \times 100$$

$$\text{Mortality } (\%) = \frac{\text{No. of plants died due to disease}}{\text{Total No. of plants}} \times 100$$

Statistical analysis

All the data were subjected to one way analysis of variance followed by Duncan's multiple range test to separate the treatment means at 5% level of significance (Steel and Torrie, 1980), using computer software COSTAT.

RESULTS AND DISCUSSION

Germination and vegetative growth

A marked variation in days to corm sprout was recorded among the various varieties of *Gladiolus*. Corms of different varieties took 15 - 24 days to sprout. Peter Pears, Glad Red and Wind Song were the late sprouting varieties with corm sprouting duration of 22 - 24 days. In contrast to this, Jester Gold, White Friendship, Jester Ruffled Yellow, Rose Supreme, Princess Margaret Rose, San Remo, Chinon and Aarti were found to be the early sprouting varieties with 15 - 18 days sprouting period. Most of the varieties exhibited intermediate sprouting period (19 -21 days) between these two extremes. Corms of Peter Pears took maximum days (24 days), while that

of San Remo took minimum days (15 days) to sprout (Table 1). Corm sprouting duration in different varieties showed variable response to *F. oxysporum* f. sp. *gladioli* inoculation. Corm sprouting duration was signi-ficantly reduced by one day in Glad Red, Jester Gold, Wind Song, Mascangi, Violetta, Pricilla, White Prosperity and Oscar due to *F. oxysporum* f. sp. *gladioli* inoculation. By contrast, fungal inoculation significantly increased sprouting period by one day in Jester Ruffled Yellow, Violetta, Princess Margaret Rose, San Remo, Victor Brogy, Blues and Chinon. In the rest of the varieties, effect of *F. oxysporum* was insignificant on corm sprouting duration (Table 1).

Shoot length in different *Gladiolus* varieties ranged from 56.31 cm in Aarti to 88.2 cm in Victor Brogy. Most of the varieties had shoot length of 70 cm or above, while only few including Pricilla, Jester Gold, Flevo Vision, Jester Ruffled Yellow, Yellow Glad, Mascangiand and Aarti had shoot length of below 70 cm (Table 1). *F. oxysporum* f. sp. *gladioli* inoculation exhibited variable effects on shoot length in different varieties. The fungus significantly reduced shoot length in Flevo Vision and Aarti by 14 and 19.9%, respectively. In all other varieties, effect of *F. oxysporum* f. sp. *gladioli* was insignificant (Tables 1 and 2).

Root length in different *Gladiolus* varieties ranged from 8.1 cm in Glad Red to 16.7 cm in Chinon and Aarti. *F. oxysporum* f. sp. *gladioli* inoculation reduced the root length from 2.8 to 37.7% in different varieties. Adverse effect of *F. oxysporum* f. sp. *gladioli* on root length in Aarti was significant. In Flevo Vision and Friendship, inoculation enhanced root length by 3.7 and 7.9%, respectively (Tables 1 and 2).

Reproductive growth

Maximum number of days to spike emergence (92 days) was recorded in Rose Supreme followed by 91 in Flevo Vision. Most of the varieties took 80 to 90 days for spike emergence. Oscar and Aarti took minimum number of days (70 days) to spike emergence that was significantly lower as compared to all other varieties (Table 1). *F. oxysporum* f. sp. *gladioli* inoculation significantly reduced days to spike emergence in Flevo Vision from 91 to 83% (8.8% reduction). In all other varieties, the effect of *F. oxysporum* f. sp. *gladioli* was insignificant (Tables 1 and 2).

Spike length ranged from 55 cm in Glad red to 36.1 cm in Friendship (Table 1). In Jester Ruffled Yellow and Pricilla, spike length was increased insignificantly by *F. oxysporum* inoculation. In contrast, *F. oxysporum* inoculation significantly reduced spike length in Glad Red, Oscar, Fado and Aarti. Aarti was found to be the most susceptible variety to *F. oxysporum* inoculation. In the rest of the varieties, *F. oxysporum* inoculation reduced spike length insignificantly (Table 1).

Maximum number of flower per spike (16) was recorded in Wind Song. In most of the varieties, there were 10-13 flowers per spike. In few varieties, namely, Pricilla, Oscar, Fado and Aarti, minimum number of flowers per spike (9) was recorded (Table 1). Number of flowers was significantly reduced in Wind Song from 16 to 9 per spike (43.7% reduction) due to *F. oxysporum* inoculation. In Flevo Vision, Glad Red, Jester Gold, White Friendship and Aarti, number of flowers was also markedly reduced from 16.6 – 22.2% due to *F. oxysporum* f. sp. *gladioli* inoculation (Tables 1 and 2). Farmers, smallholders in particular, take into account both quantitative as well as qualitative evaluation of *Gladiolus*. Generally, *Gladiolus* varieties with long floral stalk, greater number of flowers and longer floral life are selected. Based on these characteristics, Glad Red, Wind Song, Jester Ruffled Yellow, Rose Supreme, Princess Margaret Rose, Friendship, White Prosperity and Chinon are the most promising varieties.

Corm diameter ranged from 12.4 – 20 cm in different varieties of *Gladiolus*. Glad Red, Jester Gold, Jester Ruffled Yellow, Princess Margaret Rose, Pricilla, Friendship, Yellow Glad, Advanced Red, Blues and Victor Brogy were found to be the large corm size varieties with corm diameter greater than 16 cm (Table 1). Generally, corm size was reduced in all the tested *Gladiolus* varieties due to *F. oxysporum* f. sp. *gladioli* inoculation. Fungal inoculation significantly reduced corm size by 16 – 33% in Mascangi, Peter Pears, Victor Brogy, Princess Margaret Rose and Aarti. In other varieties, the effect of *F. oxysporum* inoculation on size of corms was insignificant (Tables 1 and 2).

Weight of corms in different *Gladiolus* varieties ranged from 17.9 g in Aarti to 51.6 g in Princess Margaret Rose. Corm weight in Peter Pears, Glad Red, Mascangi, Jester Ruffled Yellow, Violetta, Princess Margaret Rose, Pricilla, Friendship, San Remo and Advanced Red was greater than 40 g. On the other hand, weight of corms was low (below 30 g) in Flevo Vision, White Friendship, Fado, Chinon and Aarti (Table 1). In general, *F. oxysporum* f. sp. *gladioli* inoculation reduced corm weight in different varieties. However, adverse effect of *F. oxysporum* f. sp. *gladioli* inoculation markedly varied in different *Gladiolus* varieties. Peter Pears, Glad Red, Mascangi, Princess Margaret Rose and Aarti were more susceptible to *F. oxysporum* f. sp. *gladioli* inoculation than other *Gladiolus* varieties. There was 16.3–38.5% reduction in corm weight of these varieties due to *F. oxysporum* f. sp. *gladioli* inoculation (Tables 1 and 2).

Disease incidence and mortality

Highest disease incidence of 56.6% was recorded in Aarti which was significantly greater than the disease incidence in all other varieties. Other highly susceptible *Gladiolus* varieties were Princess Margaret Rose, Jester Ruffled Yellow, Glad Red, Flevo Vision and Peter Pears with 43.2, 39.9, 39.9, 36.6 and 33.3% disease incidence, respectively. Five varieties namely, Violetta, San Remo,

Table 1. Screening of *Gladiolus* germplasm for disease resistance against *F. oxysporum* f. sp. *Gladioli*.

Gladiolus cultivar	FO	Days to corms sprout	Shoot length (cm)	Root length (cm)	Days to spike emergence	Spike length (cm)	No. of flowers/ spike	Field life of flowers (days)	Corm size (cm)	Wt. of the corms (g)	Disease incidence (%)	Mortaliy (%)
Peter Pears	–	24 a	72.7 e-j	12.3 bc	84 b-h	42.6 e-m	10 e-h	38.7 c	15.2 c-k	41.8 a-e	-	-
	+	24 a	68.7 g-k	11.8 cd	80 f-h	41.9 f-n	9 g-i	13.0 op	10.2 l	32.4 b-i	33.3 a-d	20.0 ab
Flevo Vision	–	20 d	64.0 j-l	10.9 cd	91 a	45.6 b-g	10 e-h	32.7 de	14.2 d-k	29.9 c-i	-	-
	+	20 d	54.7 mn	11.3 cd	83 b-h	38.9 i-o	8 hi	9.3 p-s	12.4 k	23.3 g-i	36.6 a-c	13.3 ab
Glad Red	–	22 b	74.3 d-i	8.1 de	85 a-g	55.0 a	12 b-e	44.6 a	16.7 a-i	43.3 a-d	-	-
	+	21 c	69.8 g-k	6.6 e	85 a-g	50.2 b	10 e-h	14.7 o	16.6 a-k	33.0 b-i	39.9 ab	23.3 ab
Jester Gold	–	18 f	69.2 g-k	11.3 cd	88 a-c	40.5 f-n	11 d-h	33.2 d	16.1 b-k	33.7 b-i	-	-
	+	17 g	66.8 i-k	10.0 cd	87 a-d	38.6 i-o	9 g-i	8.8 q-s	15.5 c-k	30.0 c-i	30.0 a-d	13.3 ab
White Friendship	–	17 g	88.0 a	13.4 a-c	87 a-d	49.5 bc	12 be	20.8 kl	15.5 c-k	29.6 c-i	-	-
	+	17 g	80.3 a-f	11.1 cd	86 a-f	46.0 b-f	10 e-h	8.2 rs	13.8 e-k	24.4 c-i	30.0 a-d	13.3 ab
Wind Song	–	22 b	78.3 b-g	10.7 cd	86 a-f	43.2 d-l	16 a	22.0 jk	14.6 c-k	35.8 a-h	-	-
	+	21 c	77.5 b-h	10.4 cd	85 a-g	41.4 f-n	9 g-i	8.7 q-s	14.1 e-k	36.0 a-h	26.6 b-d	20.0 ab
Mascangi	–	20 d	67.5 h-k	15.8 ab	86 a-f	44.5 c-i	10 e-h	32.0 de	17.1 a-g	42.7 a-d	-	-
	+	19 e	64.0 j-l	13.4 a-c	85 a-g	41.6 f-n	9 g-i	9.4 q-s	12.8 i-k	31.3 b-i	26.6 b-d	20.0 ab
Jester Ruffled Yellow	–	18 f	68.5 g-k	13.4 a-c	89 a-c	38.4 j-o	13 bc	29.0 fg	17.3 a-f	43.7 a-d	-	-
	+	19 e	69.6 g-k	12.0 bd	89 a-c	39.1 j-o	12 b-e	8.2 rs	16.4 b-j	39.1 a-g	39.9 ab	33.3 a
Rose Supreme	–	18 f	86.4 ab	12.4 bc	92 a	45.4 b-h	13 bc	20.6 kl	15.0 c-k	37.1 a-h	-	-
	+	18 f	81.9 a-e	11.0 cd	88 a-c	43.1 d-l	12 b-e	10.5 p-s	13.0 h-k	33.8 b-i	26.6 b-d	10.0 ab
Violetta	–	20 d	69.8 g-k	13.3 a-c	87 a-d	39.3 i-o	10 e-h	17 n	12.4 k	46.7 a-c	-	-
	+	21 c	68.5 g-k	11.7 cd	87 a-d	38.4 j-o	10 e-h	17 n	13.2 g-k	38.9 a-g	10.0 cd	0.0 b
Princess Margaret Rose	–	17 g	78.2 b-g	12.8 bc	84 b-h	43.4 d-l	13 bc	30.1 ef	18.2 ab	51.6 a	-	-
	+	18 f	75.4 c-i	9.8 cd	84 b-h	39.7 h-o	13 bc	7.1 s	15.2 c-k	43.2 a-d	43.2 ab	26.6 ab
Pricilla	–	19 e	51.0 n	13.7 a-c	87 a-d	36.5 m-o	9 g-i	33.8 d	18.1 a-c	40.2a-f	-	-
	+	18 f	78.6 b-g	11.2 cd	81 d-h	41.3 f-n	9 g-i	9.7 p-s	16.9 a-h	45.2 a-d	29.9 a-d	23.3 ab
Friendship	–	19 e	77.5 b-h	11.4 cd	80 e-h	36.1 no	12 b-e	42.5 b	16.9 a-h	47.6 ab	-	-
	+	19 e	74.3 d-i	12.3 bc	82 d-h	34.6 o	12 b-e	10.0 p-s	15.1 c-k	42.4 a-e	20.0 b-d	10.0 ab
San Remo	–	15 i	74.7 d-i	12.0 b-d	86 a-f	40.1 g-o	10 e-h	30.3 ef	13.4 f-k	46.5 a-c	-	-
	+	16 h	74.5 k-m	1 0.1 cd	86 a-f	39.3 i-o	10 e-h	12.8 op	13.0 h-k	45.2 a-d	9.9 cd	3.3 b
Yellow Glad	–	19 e	61.4 l-n	13.3 a-c	79 gh	37.4 l-o	11 d-h	20.0 k-m	16.7 a-i	37.5 a-h	-	-

Table 1. Contd.

Gladiolus cultivars	FO	Days to corms sprout	Shoot length (cm)	Root length (cm)	Days to spike emergence	Spike length (cm)	No. of flowers/ spike	Field life of flowers (days)	Corm size (cm)	Wt. of the corms (g)	Disease incidence (%)	Mortaliy (%)
	+	19 e	56.8 l-n	11.9 b-d	79 gh	38.7 i-o	11 d-h	10.0 p-s	14.6 c-k	35.4 a-h	6.6 d	3.3 b
Advanced Red	–	20 d	77.5 b-h	12.8 bc	82 d-h	50.2 b	11 d-h	25.8 hi	16.6 a-i	44.2 a-d	-	-
	+	20 d	76.6 b-i	11.8 cd	80 e-h	50.7 b	11 d-h	9.1 q-s	17.6 a-e	40.0 a-g	6.6 d	3.3 b
White Prosperity	–	21 c	73.5 ef	13.7 a-c	83 c-h	49.5 bc	13 bc	21.8 jk	15.0 c-k	36.1 a-h	-	-
	+	20 d	72.3 e-j	11.2 cd	85 a-g	45.9 b-g	14 b	12.0 pq	13.6 f-k	33.0 b-i	6.6 d	0.0 b
Oscar	–	21 c	72.3 e-j	12.1b-d	70 i	47.7 b-e	9 g-i	21.6 jk	15.1 c-k	32.8 b-i	-	-
	+	20 d	70.4 f-k	11.1cd	71 i	41.9 f-n	9 g-i	7.3 s	13.8 e-k	28.2 d-i	23.3 b-d	13.3 ab
Fado	–	19 e	84.6 ab	13.1 a-c	86 a-f	45.9 b-h	9 g-i	24.3 ij	17.7 a-e	28.3 d-i	-	-
	+	19 e	84.8 a-c	12.2 b-d	86 a-f	38.0 k-o	9 g-i	8.3 rs	13.4 f-k	23.5f-i	26.6 b-d	26.6 ab
Blues	–	20 d	83.9 a-d	12.5 bc	89 a-c	41.4 f-n	11 d-h	18.5 l-n	20.0 a	34.0 b-i	-	-
	+	21 c	80.2 a-f	11.9 b-d	90 ab	43.6 d-k	11 d-h	7.3 s	16.9 a-h	29.2 d-i	30.0 a-d	20.0 ab
Victor Brogy	–	19 e	88.2 a	13.5 a-c	87 a-d	41.8 f-n	11 d-h	27.5 gh	19.6 ab	33.2 b-i	-	-
	+	20 d	85.1 ab	10.3 cd	85 a-g	39.1 i-o	10 e-h	9.8 p-s	15.7 ck	24.4 f-i	29.6 a-d	23.3 ab
Chinon	–	18 f	70.7 f-k	16.7a	83 c-h	48.4 b-d	13 bc	37.3 c	14.9 c-k	25.7e-i	-	-
	+	19 e	70.4 f-k	13.9 a-c	83 c-h	44.3 c-j	13 bc	10.6 p-r	13.5 f-k	22.1 hi	16.6 b-d	6.6 ab
Aarti	–	17 g	56.3 l-n	16.7a	70 i	41.4 f-n	9 g-i	17.9 mn	12.6 jk	17.9 ij	-	-
	+	17 g	45.1 o	10.4 cd	70 i	28.0 p	7 i	6.9 s	9.6 l	11.0j	56.6 a	10.0 ab

In each column, values with different letters show significant difference (P ≤ 0.05) as determined by Duncan's multiple range test; – without *F. oxysporum* inoculation;+ with *F. oxysporum* inoculation.

Yellow Glad, Advanced Red and White Prosperity were comparatively resistant to the disease with disease incidence of 10% or below. The rest of the *Gladiolus* varieties showed moderate susceptibility to corm rot disease with disease incidence of 20 – 30% (Table 1).

Highest mortality of 33.3% was recorded in Jester Ruffled Yellow followed by 26.6% in Fado and Princess Margaret Rose. Other varieties with comparatively high mortality of 20% or above were Peter Pears, Glad Red, Wind Song, Mascangi, Pricilla, Blues and Victor Brogy. Varieties Chinon, San Remo, Yellow Glad and Advanced Red showed very low mortality of less than 10%, while no mortality was recorded in White Prosperity and Violetta. The rest of the *Gladiolus* varieties showed 10-19% mortality rate (Table 1).

Correlation studies

Data regarding the correlation coefficient among different vegetative, reproductive and disease parameters is summarized in Table 3. Disease incidence showed significant negative correlation with size and weight of corms. In contrast, the correlation between corm size and plant mortality was significant and positive. Although all other correlations were insignificant, correlation coefficient values for some correlated parameters were comparatively high and can be considered. For example, shoot length was positively correlated with days to spike emergence, spike length, number of flowers and corm size, and negatively correlated with disease incidence. Similarly, days to spike emergence was positively correlated with number of flowers per spike, corm size and corm weight, and negatively correlated with disease incidence.

Table 2. Percentage decrease in vegetative and reproductive growth parameters of different *Gladiolus* varieties due to *Fusarium oxysporum* f. p.*gladioli* inoculation.

Gladiolus cultivar	Increase/decrease over control (%)								
	Days to corms sprout	Shoot length	Root length	Days to spike emergence	Spike length	No. of flowers/ spike	Field Life of flowers	Corm Size	Wt. of the corms
Peter Pears	+4.0	-5.5	-4.1	-4.8	-1.6	-10.0	-69	-33.0	-22.0
Flevo Vision	0.0	-14	+3.7	-8.8	-14.7	-20.0	-71	-12.7	-22.1
Glad Red	-4.0	-6.0	-18.5	0.0	-8.7	-16.6	-67	-0.6	-23.8
Jester Gold	-5.0	-3.4	-11.5	-1.1	-4.7	-18.2	-73	-3.7	-10.9
White Friendship	0.0	-8.7	-17.2	-1.1	-7.1	-16.7	-60	-10.9	-17.6
Wind Song	-4.5	-1.0	-2.8	-1.2	-4.1	-43.7	-60	-3.4	+0.5
Mascangi	-5.0	-5.1	-15.2	-1.2	-6.5	-10.0	-71	-25.1	-26.7
Jester Ruffled Yellow	+5.5	+1.6	-10.4	0.0	+1.8	-7.7	-72	-5.2	-10.5
Rose Supreme	0.0	-5.2	-13.7	-4.3	-5.1	-7.6	-49	-13.3	-8.9
Violetta	+5.0	-1.8	-12.0	0.0	-2.3	0.0	-0	+6.4	-16.7
Princess Margaret Rose	+5.8	-3.6	-23.4	0.0	-8.5	0.0	-76	-16.0	-16.3
Pricilla	-5.2	+54	-18.2	-6.9	+13.2	0.0	-71	-6.6	+12.4
Friendship	0.0	-4.1	+7.9	+2.5	-4.2	0.0	-76	-10.6	-10.9
San Remo	-6.7	-0.2	-15.8	0.0	-2.0	0.0	-58	-3.1	-2.8
Yellow Glad	0.0	-7.5	-9.8	0.0	+3.5	0.0	-50	-12.6	-5
Advanced Red	0.0	-1.2	-7.8	-2.4	+1.0	0.0	-65	+6.0	-4.5
White Prosperity	-4.7	-1.6	-18.2	+2.4	-7.2	+7.7	-45	-9.3	-8.6
Oscar	-4.7	-2.6	-8.2	+1.4	-21.2	0.0	-66	-8.6	-14.1
Fado	0.0	+0.2	-6.9	0.0	-17.2	0.0	-65	-24.3	-17.0
Blues	+5.0	-4.4	-4.8	+1.1	+5.3	0.0	-61	-15.5	-14.1
Victor Brogy	+5.2	-3.5	-23.7	-2.3	-6.4	-9.0	-64	-19.9	-26.5
Chinon	+5.5	-0.4	-16.8	0.0	-8.4	0.0	-72	-9.3	-14.0
Aarti	0.0	-19.9	-37.7	0.0	-32.3	-22.2	-61	-23.8	-38.5

+, Increase over control; –, Decrease over control.

Table 3. Correlation among various vegetative, reproductive and disease parameters in 23 varieties of *Gladiolus.*

Parameter	Days to corms sprout	Shoot length	Root length	Days to spike emergence	Spike length	No. of flowers	Corm Size	Wt. of the corms	Disease incidence
Shoot length	-0.01	-							
Root length	-0.37	-0.27	-						
Days to spike emergence	-0.04	0.32	-0.28	-					
Spike length	0.29	0.36	-0.17	-0.04	-				
No. of flowers	0.08	0.38	-0.21	0.29	0.18	-			
Corm Size	0.07	0.29	-0.09	0.26	-0.10	0.04	-		
Weight of the corms	0.08	0.07	-0.38	0.26	-0.22	0.18	0.11	-	
Disease incidence	-0.08	-0.14	-0..02	-0.00	-0.01	-0.06	0.06	-0.28	-
Mortality	0.11	0.12	-0.17	0.27	-0.07	0.06	0.47*	0.07	0.68*

*Significant at $P \leq 0.05$.

Conclusion

The present study concludes that Advanced Red and White Prosperity are the most suitable *Gladiolus* varieties for cultivation under agro-climatic conditions of Pakistan, having best floral characteristics and resistance against corm rot disease. The varieties Glad Red, Rose Supreme, Jester Ruffled Yellow, Princess Margaret Rose and Chinon are among the best in floral characteristics but susceptible to corm rot disease. The varieties can be cultivated in areas with no corm rot threat. Indian variety Aarti was found to be the least suitable for cultivation due to least agronomic performance and highest susceptibility for corm rot disease. The other unsuitable varieties for cultivation in the area are Oscar, Fado, Blues, Victor Brogy and Flevo Vision, either due to their less agronomic performance or high susceptibility to corm rot disease.

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