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Effect of physical, chemical and biological corm treatments on vegetative growth, flowering, corm character and corm rot in gladiolus

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Abstract
Gladiolus is an important commercial bulbous crop. The major concern in commercial production is the *Fusarium* yellows or *Fusarium* wilt or corm rot caused by *Fusarium oxysporum* f. sp. *gladioli*. The fungus can survive for a very long period as mycelium, chlamydospores, microconidia and macroconidia in infected corms and soil. *Fusarium* invades the vascular system of the plant. Therefore, chemical treatment with contact fungicides is not very effective against pathogen which is inside deep lesion and express in next season resulting in huge losses. Therefore, to manage the disease integrated approach should be followed by combining sanitation, systemic fungicides, physical and bio-control methods for corm and soil treatment. The carbendazim, hot water and *Trichoderma harzianum* were reported effective to control the soil-borne pathogen under chemical, physical and biological class respectively. Therefore, these treatments and their combinations were tested for management of *Fusarium* corm rot in gladiolus cv. 'Arka Amar' under Bengaluru conditions. The corm treatments significantly reduced the disease during storage. The integrated corm treatments were found effective against corm rot without adverse effect on plant growth and flowering. It also significantly increased the number of daughter corms.

Keywords: Gladiolus, corm rot, carbendazim, hot water treatment, *Trichoderma harzianum*, integrated disease management

Introduction
Gladiolus is commercially grown as cut flower crop. It belongs to the family Iridaceae and native to South Africa. It was first introduced in India during the 20th Century in hilly areas (Misra *et al*. 1998) [14]. It is cultivated in most of the agro-climatic regions during winters and under mild climatic conditions throughout the year. It is commercially propagated by corms and cormels. Most of the diseases in gladiolus are spread by infected soil, corms and cormels. The most devastating disease is *Fusarium* corm rot caused by *F. oxysporum* f. sp. *gladioli*. Pryal (1909) [16] reported it from California, and though the first report of symptoms was reported in 1912, it took 14 years when Massey (1926) [12] identified disease and pathogen from other gladiolus growing areas of the USA. In India, *F. oxysporum* f. sp. *gladioli* was first reported in Uttar Pradesh (Singh, 1969) [20]. Once the *Fusarium* establishes in the stock of corms, it is difficult to eradicate (Buxton, 1955; Chandel and Deepika, 2010) [2, 3]. The fungus enters corms through wounds and infects the corms. The corm may rot at any stage, but maximum rotting occurs after harvest during drying, curing and storage. Dormancy period of three months provides enough time for fungus to spread in stock. Therefore, corms and cormels are usually treated twice before planting and after harvesting, to reduce the pathogen load.

Fusarium invades the vascular system of the plant which transfers the disease from the mother corm to daughter corms and cormels. Therefore, chemical treatment with contact fungicides is not very effective against pathogen which is inside deep lesion and prevails in next season causing huge losses. The corm rot disease causes 60-70% plant mortality in Russia (Vlasova and Shitan, 1974). Kulkarni (2006) [10] reported that the disease incidence in Dharward, Belgaum and Bengaluru District was 42.81%, 27.46% and 22.41%, respectively. In Himachal Pradesh, disease incidence ranged between 7.12 and 64.23% (Chandel and Deepika, 2010) [3]. *Fusarium* corm rot can be effectively managed by hot water treatment above 50°C to 57°C for

5 to 30 minutes (Bald *et al*., 1956; Vigodsky, 1970; Cohen *et al.*, 1990; Ramos-Garcia et al., 2009) [1, 5, 18]. It has been found that *Fusarium* fungus is killed at 53°C and above temperature, but above 57°C adversely affects the corms sprouting and growth in field (Ramos-Garcia *et al*., 2009) [18]. *Trichoderma harzianum* is found effective against *F. oxysporum* f. sp. *gladioli*. It can be applied as both corm dip and soil treatment. The *T. harzianum* prevents fusaric acid secretion in infected corms (Nosir *et al*., 2010) [15]. The bio-control species must have resistance to fungicide for efficient integrated disease management. Sriram *et al*. (2011) [21] reported carbendazim tolerance in *T. harzianum* isolate GJ16B. The integrated methods are used to control the disease and to reduce environmental hazards. The carbendazim, hot water and *T. harzianum* were reported effective to control the soil-borne pathogen. Therefore, the experiment was designed to study the response of gladiolus cv. 'Arka Amar' to corm treatments for producing quality spikes, healthy corms and cormels, under Bengaluru conditions.

Materials and Methods

The experiment was carried out at ICAR-Indian Institute of Horticultural Research, Hesarghatta Bengaluru, India (Latitude: 13º7'48" N, Longitude: 77º 29' 24" E, Altitude: 890m above mean sea level). Hesarghatta has a mild tropical climate.

The gladiolus variery 'Arka Amar' corms with 4-5 cm diamter were selected for planting. The corms were planted in pots. The potting media was prepared in 1:1:1 ratio of soil, sand and coco-peat. The media was autoclaved for one hour at 121ºC to remove all the microorganism. The experiment was laid out in completely randomised design with four treatments and five replications.

The selected corms were divided into four sets. The scales were removed and corm treatments were applied before planting. One set of corms was kept as control (T_0). The second set corms were dipped in 0.2% carbendazim solution for 2 minutes (T_1 treatment). The third set of corms were treated with T_2 treatment (hotwater+carbendazim treatment). The corms were dipped in hot water (54°C $\pm$ 2°C) for 25 minutes then corms were air dried for 20-30 minutes. After air dring the corms were diped in 0.2% carbendazim solution for 2 minutes. The fourth set of corm was treated same as set three corms (T_2 treatment) followed by *Trichoderma* treatment (T_3 treatment= hotwater+carbedazim+*Trichoderma* treatments). The 50 gram of sporulated *Trichoderma harzianum* isolate GJ 16B was dispersed in 500 ml of water and stired till the spores get mixed in the water then the volume was made up to 5 L. The corms were dipped in the solution for 3 minutes.

After the treatments, the corms were air dried for two days at room temperature. The corms were planted in pots. The pots were kept under polyhouse. After sprouting of corms, irrigation was done twice or thrice a week depending upon environmental condition. At 15 days interval, 19:19:19 fertilizer was applied 2 g per pot. The observations were recorded on per cent wilted plants in field, per cent corm rot in storage, vegetative, floral and corms parameters such as days to sprouting, average number of sprouts, average number of leaves per sprouts, days to spike emergence, days to bud colour appearence, days to first floret opening, average number of florets per spike, spike length and plant height. After harvesting of corms, observations were recorded on average number(s) of corms, average corm diameter and corm weight. The corm treatments were repeated on harvested daughter corms. The corms were kept in cold storage (4°C$\pm$ 2°C). After 100 days of storage, per cent corm rot was observed. The observed data were analysed using SAS GLM procedure (SAS, 2012) [19] and the significance of treatment effects for various traits was compared ($P<0.01$) using Least Significant Difference Post-hoc test (Gomez, 1984) [8].

Results

The effect of different corms treatments on growth, flowering and corm parameters is depicted in Tables 1, 2 and 3. The data presented in Table 1 indicated that the corm treatments (T_1, T_2 and T_3) significantly differed from the control (T_0). Early sprouting was recorded in control (T_0) plants, which is significantly different from the T_1, T_2 and T_3 corm treatments. Maximum average number of sprouts were observed in T_2 and T_3 corm treatments followed by T_1. However, T_1, T_2 and T_3 corm treatments were at par but significantly different from control (T_0). No significant effect was observed on average number of leaves per sprout. Early spike emergence was observed in control plants, which is statistically different from T_1, T_2 and T_3 plants.

Table 1: Effect of different corm treatments on days to sprouting, number of sprouts, average number of leaves per sprout and days to spike emergence

Treatments	Days to sprouting	Average number of sprout	Average number of leaves/ sprout	Days to spike emergence
T_0: Control	14.000b	1.000b	8.000	80.500b
T_1: Carbendazim	22.833a	1.833a	7.667	97.333a
T_2: Carbendazim+HWT	22.667a	2.167a	7.333	100.500a
T_3: Carbendazim+HWT+*Trichoderma*	22.500a	2.167a	7.333	101.667a
CV (%)	10.780	19.733	7.223	4.845
LSD (P=0.01)	3.630	0.581	NS	7.560

Note: 'a' indicates statistically at par treatments, 'b' indicates the statistically at par treatments, and 'a' and 'b' are statistically different treatment; HWT= hot water treatment; *Tirchoderma*= *T. harzianum* GJ 16B strain; NS=not significant

The effect of different corm treatments on days to bud colour appearance, opening of first floret, spike length and plant height are presented in Table 2. The effect of corm treatments was statistically significant on days to bud colour appearance and first floret opening but no significant difference was observed on spike length and plant height. Minimum days to bud colour appearance and first floret opening were observed in control (T_0) plants which were significantly differ from T_1, T_2 and T_3. No significant effect was observed on average number of florets per spike due to corm treatments (Table 3).

Table 2: Effect of different corm treatments on days to bud colour appearance, first floret opening, spike length (cm) and plant height (cm)

Treatments	Days to bud colour appearance	Days to 1st floret opening	Spike length (cm)	Plant height (cm)
T_0: Control	87.000b	92.833b	76.833	98.583
T_1: Carbendazim	104.833a	108.667a	77.833	90.833
T_2: Carbendazim+HWT	104.833a	107.500a	77.667	90.667
T_3: Carbendazim+HWT+*Trichoderma*	107.000a	110.667a	71.167	89.500
CV (%)	4.306	4.027	8.821	7.203
LSD (P=0.01)	7.138	6.940	NS	NS

Note: 'a' indicates statistically at par treatments, 'b' indicates the statistically at par treatments, and 'a' and 'b' are statistically different treatment; HWT= hot water treatment; *Tirchoderma= T. harzianum* GJ 16B strain; NS=not significant

Table 3: Effect of different corm treatments on average number of florets per spike, average number of corms, average corm diameter and corm weight.

Treatments	Average number of florets/ spike	Average number of corms	Average corm diameter (cm)	Average corm weight (g)
T_0: Control	13.000	1.000b	6.417a	55.167a
T_1: Carbendazim	11.667	2.000a	4.725b	32.000b
T_2: Carbendazim+HWT	10.833	2.167a	4.017c	26.333bc
T_3: Carbendazim+HWT+*Trichoderma*	11.333	2.167a	4.250bc	22.833c
CV (%)	12.596	15.746	8.347	17.469
LSD (P=0.01)	NS	0.474	0.665	9.780

Note: 'a' indicates statistically at par treatments, 'b' indicates the satistically at par treatments, 'c' indicates the statistically at par treatment and 'a', 'b' and 'c'are statistically different treatment; HWT= hot water treatment; *Tirchoderma= T. harzianum* GJ 16B strain; NS=not significant

The treatment significantly influenced the number of corms, corm diameter and corm weight (Table 3). Maximum average corms were harvested from T_2 and T_3 plants and minimum from control (T_0) plants. The corm treatment significantly influenced the average corm diameter and corm weight. Minimum corm diameter was observed in T_2 plants followed by T_3 both are at par but significantly differ with T_1 and control. Minimum average corm weight was recorded in T_3 treatment which is at par with T_2 treatment.

The disease incidence data is depicted in Figure 1. The media was sterilized and pots were kept in polyhouse. The objective was to get per cent disease due to pathogen present in/on corms. In control 14.28% of disease incidence was observed whereas no diseased plants were observed in T_1, T_2 and T_3 treatments. The harvested corms were kept in storage after repeating the same treatments given to mother corms. The harvested corms were kept in storage, and after 100 days of storage, disease incidence was recorded 66.67%, 13.33%, 6.25% and 6.67% in control, T_1, T_2 and T_3, respectively.

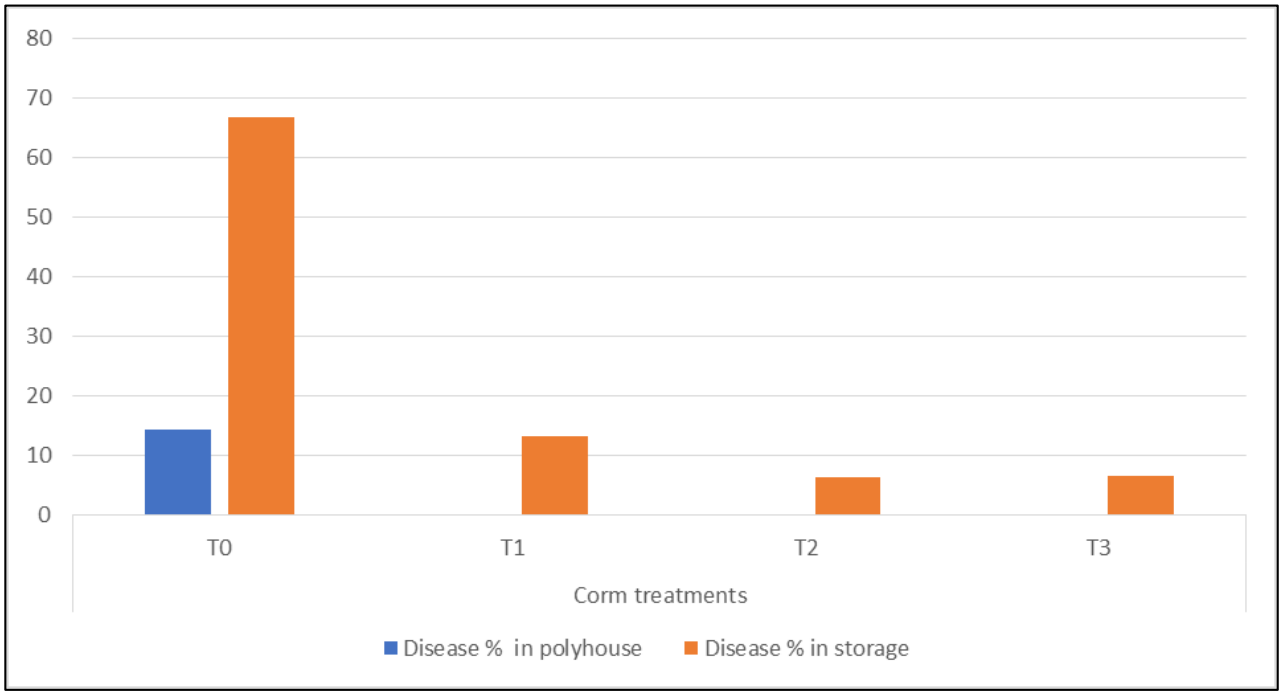

Fig 1: Effect of corm treatments on disease incidence in cropping period and in storage.

Discussion

The result of the experiment indicates that the corm treatments had a significant effect on the gladiolus cv. 'Arka Amar'. In T_1, T_2 and T_3 treatments, the sprouting was delayed in comparison to control plants. Bald *et al.* (1956) [1] and Ramos-García *et al.* (2009) [18] also reported a similar effect on sprouting by chemicals and hot water treatments on corms before planting. However, the effect of hot water treatment depends on the temperature, variety, harvest period and size of the corm (Vigodsky, 1970; Cohen *et al.*, 1990) [5]. Hot

water treatment with a combination of reduced dosages of fungicides was found effective on gladiolus, iris and tulip (Magie, 1985; Garibaldi and Migheli, 1988; Migheli and Garibaldi, 1990; Elmer, 2006) [11, 7, 13, 6]. Magie (1985) [11] reported that the hot water temperature might vary depending upon a host; for small gladiolus corms 52°C hot water temperature and for cormels 55°C. Whereas, Cohen *et al*. (1990) [5] reported hot water treatment at 57°C for 30 minutes, for eradication of *F. oxysporum* f. sp. *gladioli* propagules. The late sprouting in T_1, T_2 and T_3 treatment resulted in late spike emergence, bud colour appearance and first floret opening. The corm treatments increased the number of sprouts and corms. The maximum sprouts and corms were recorded from single mother corm was four in T_3 treatment. However, the average is 2.16 sprouts and 2.16 corms per corm. The treatment suppressed the apical bud and promoted sprouting of side buds. Therefore, the treated corms produced more than one corm in comparison to control. Most of the corm treatment study confined to improved floral traits and effective disease management, not on effect of corm treatments on harvested corm yield, diameter and weight. We observed a significant effect of corm treatments on corm weight and diameter. The control plants produce heavy single corm per corm, but the treated plants yielded more than one corm of acceptable corm diameter and weight for planting. The big corms are usually divided into 2 to 4 pieces for planting. The division of corm increases the disease incidence, thus not preferred for commercial planting. Ultimately the quality yield of cut spike decreases. The infection passed through mother corms to daughter corms, from corm to corm and due to a cut and injured planting material (Gullino *et al*., 2015) [9]. The fungus invades the healthy roots and corms from cut or injured parts. The fungus infects vascular tissue and gets transmitted to daughter corms and cormels. The planting material should be free from the pathogen(s) for quality cut flower and less disease incidence. The small to medium sized corms are suitable for planting and management of corm rot disease.

The systemic fungicide treatments help to reduce surface disease. The hot water treatment causes softening of the corm surface and allow systemic fungicide to penetrate deep into tissue (Gullino *et al*., 2015) [9] and *T. harzianum* strain fights with further development of mycelium in soil and corm (Ram *et al*., 2004; Chandel and Tomer, 2007; Chandel and Deepika, 2010) [17, 4, 3]. However, all the three treatments were found at par on the observed parameter. The harvested daughter corms were kept in storage, and after 100 days of storage, the disease incidence was 66.67%, 13.33%, 6.25% and 6.67% in control, T_1, T_2 and T_3, respectively. The media was sterilized and pots were kept in polyhouse which suggest that the disease incidence observed in field was due to pathogen present in mother corms which increased in daughter corms during 100 days storage. This observation indicates that the treatment combination of carbendazim with hot water (T_2) and carbendazim, hot water followed by *Trichoderma* (T_3) were more effective in controlling the disease than carbendazim treatment.

Conclusion

The corm treatments before planting and after harvest reduce the disease incidence. The single chemical treatment is not enough to control the *Fusarium* corm rot. The integrated approach of carbendazim, hot water treatment and *Trichoderma harzianum* GJ 16B can be a good strategy in management of *Fusarium* wilt disease in gladiolus.

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