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INTEGRATION OF SOIL SOLARIZATION WITH FUNGICIDES, BIOLOGICAL CONTROL AGENTS AND SOIL AMENDMENTS FOR THE MANAGEMENT OF *FUSARIUM* WILT DISEASE OF GLADIOLUS (*GLADIOLUS DRACOCIPHALUS* L.)

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Abstract

Soil solarization is a novel technique of controlling soil borne pests including weeds. Hence, the study was carried out on integration of soil solarization with fungicides, biological control agents and soil amendments for the management of *Fusarium* wilt disease of Gladiolus (*Gladiolus dracociphalus* L.). In present study, gladiolus corms were treated with Carbendazim (0.1%), Carbendazim + Iprodionc (0.2%), Carbendazim + Mancozeb (0.2%) or *Trichoderma viride* formulation (0.5%) before sowing both in solarized and un-solarized plots. In un-solarized plots, three fungicide drenches were given at 10 days interval for a month after sowing corms, only where the corms were prior treated with same fungicide.

Soil amendments *viz*., farmyard manaure and Poultry refuse (PR) were applied before solarization while formulation of *Trichoderma viride* was applied after solarization. Soil amendments *viz*., Poultry refuse (PR) with soil solarization was found to be the most effective treatment in disease control (97.5%). Corm dip in a combination product of Carbendazim + Iprodione and solarization was the next best. Soil solarization and Soil amendments *viz*., Poultry refuse (PR) also improved growth the plant and recorded increases in shoot length (48%), spike length (52%), corm size (34%), corm weight (85%) and number of cormels per plant (>100%). Days taken to the first flowering of gladiolus were also reduced by 24 per cent.

Key words : Soil solarization, fungicides, biocontrol agents, soil amendments, *Fusarium oxysporum* f.sp. *gladioli*.

Introduction

The flower of gladiolus (*Gladiolus* sp.) is very popular and grown throughout the world in a wide range of climatic conditions. It has great economic value as a cut-flower and its cultivation is relatively easy. Income from gladiolus flower production is six times higher than that of rice (Momin, 2006). The major obstacle for cultivation of gladiolus in temperate and subtropical regions is the various diseases caused by fungi, bacteria and viruses of which Fusarium wilt disease or yellows caused by *F. oxysporum* f. sp. *gladioli* is a major problem in all over the gladiolus growing areas. Fusarium wilt of gladiolus is considered as a serious and highly devastating disease which can cause 60-70% yield loss (Vlasova and Shitan, 1974) and the damage may reach up to 100% (Pathania and Misra, 2000). It is also a serious problem in India and reduced plant growth and flowering up to 15- 28% in the number of florets/spike (Misra *et al*., 2003).

Fusarium spp. causes yellowing, corm rot, browning of foliage and wilting in gladiolus. It reduces the quality, yield and market value of gladiolus. *F. oxysporum* f. sp. *gladioli* is a soil borne pathogen. As the pathogen is soil-borne in nature, it is difficult to control due to mono-cropping on the pathogen infested land. Soil solarization is an effective method to control soil-bome pathogens in different crops and soil eco-systcms (Katan, 1981). Soil solarization has been found more effective against soil-borne pathogens when integrated with soil amendments, limited use of fungicides and biological control agents (Stevens *et al*., 2003). Hence, an investigation was on the effect of soil solarization in combination with limited use of fungicides, soil amendments and biological control agents, on the incidence of wilt in gladiolus crop and growth characters of the crop.

Materials and Methods

Evaluation of fungicides *in vitro*

Nine fungicides including systemic, *i.e.* Carbendazim 50 WP (Bavistin), Benomyl 50 WP (Benofit), Azoxystrobin 23 SC (Amistar); non-systemic, i.e. Mancozeb 75 WP (Dithane M-45), Thiram 75 WP (Thirox), Chlorothalonil 75 WP (Kavach) and combination fungicides *i.e.* Carbendazim 25% + Iprodionc 25% (Quintal), Carbendazim 12% + Mancozeb 63% (Carmel), Azoxystrobin 18.2% + Difenoconazol 11.4% (Quadris Top) were evaluated by poisoned food technique (Falck, 1907) to find out their efficacy against the test pathogen. Systemic fungicides were tested at 25, 50, 75 and 100 ppm, and the rest were evaluated at 250, 500, 750 and 1000 ppm.

The pathogen was grown on Potato dextrose agar medium prior to the setting of the experiment. The fungicide suspension was made by adding required quantity of fungicides to the melted Potato dextrose agar medium to obtain the desired concentration on the basis of active ingredient present in the chemical. Thirty ml of poisoned medium was poured in each sterilized Petriplate and suitable checks were maintained without addition of fungicides. five mm of ten days old fungal disc was taken from the periphery of the culture and was placed in the centre of the poisoned medium asceptically and incubated at 26±1°C for seven days. Three replications were maintained for each treatment and the diameter of the colony was measured in 2 directions and the average was recorded after incubation for seven days. Per cent inhibition of the fungus was calculated by using the following formula (Vincent, 1947):

$$I = C - T / C \times 100$$

Where, I = Percentage of growth inhibition of pathogen.

C = Radial growth of the pathogen in control.

T = Radial growth of the pathogen in treatment

Antagonistic activity/evaluation of *Trichoderma* spp. *in vitro*

Five species of *Trichoderma*, *viz*., *T. viride*, *T. hamatum*, *T. pofysporum*, *T. harzianum* and *T. virens* were isolated from different gladiolus growing areas were evaluated under *in vitro* conditions for the antagonistic activity against the wilt pathogen by dual culture technique (Huang and Hoes, 1976). Mycelial discs (5 mm), each of bioagents and the pathogen were taken from the margins of their actively growing cultures and transferred to potato dextrose agar medium in the Petri plates on the opposite sides. The Petri plates were subsequently incubated at 28±1^{0}C. Colony diameter of the test fungus up to the zone of inhibition was recorded in case of each bioagents and per cent growth inhibition of the test pathogen was calculated over control by using the following formula.

$$I = C - T / C \times 100$$

Where, I = Percentage of growth inhibition of pathogen.

C = Radial growth of the pathogen in control.

T = Radial growth of the pathogen in treatment

Evaluation of soil amendments *in vitro*

Soil amendments as poultry manure, farmyard manure, bonemeal and soymeal significantly reduced population of soil borne plant pathogens (Lazarovits, 2001). Five soil amendments *viz*., 6 Farmyard manure (FYM), Poultry refuse (PR), Mustard oil cake (MOC), Saw dust burning (SD) and Municipal waste compost (MWC) were evaluated under in vitro conditions. 5% of each above soil amendments were taken and mixed in the soil in the lower lid of Petri plate and on the upper lid of the same size, culture of the pathogens was inoculated on the, double strength potato dextrose medium, The Petri plates were then sealed and nit under solarized and un-solarized conditions below 5 cm in soil and inhibitory effect was observed on the mycelial growth.

Integration of soil solarization with fungicides, biological control agents and soil amendments

Based on the *in vitro* and *in vivo* studies on efficacy of fungicides, bioagents and soil amendments against the pathogen, the best treatments were then integrated with soil Solarization to find out their individual and combined effect on the incidence of *Fusarium* wilt and different growth parameters of the crop. A field experiment was laid out in factorial randomized block design in during crop season in a field where gladiolus was being cultivated for the last five year. Among different soil amendments, Poultry refuse (PR) were found the best. Soil amendments farmyard manure (FYM) and Poultry refuse (PR) were applied before solarization of the field at the rate of 10 t/ha in 1 m x 1 m plots. Bioagent *T. viride* that was found best in efficacy among five bioagents evaluated earlier was applied as corm dresser at the rate of 0.5 per cent before sowing of the corms. The treated corms were sown in the plots where formulation of *T. viride* was applied at the rate of 50 g per plot before sowing. Fungicides namely Carbendazim + Iprodionc (Quintal), Carbendazim (Bavistin) and Carbendazim + Mancozeb (Carmel), which proved effective *in vitro*

Table 1 : Integrated effect of soil solarization with use of fungicides, biocontrol agents and soil amendments on disease incidence, crop growth and quality of gladiolus.

Treatment		Disease incidence (%)	Shoot length(cm)	Spike length (cm)	Corn size (mm)	Corm wt (g)	Cormels/ plant	Flowering (d)
Carbendazim +iprodione (Quintal)(0.20%)	S US	1.5 17.4	97.1 87.1	85.7 68.7	56.0 51.3	59.0 40.6	18.0 11.5	95.2 105.0
Carbendazim (Bavistin) (0.10%)	S US	6.4 19.3	91.1 83.1	80.1 65.2	56.1 49.0	53.8 42.3	17.5 10.5	97.5 102.0
Carbendazim+ mancozeb (Carmel)(0.20%)	S US	8.3 24.1	89.2 83.1	77.1 64.1	54.0 46.2	50.0 34.2	17.5 12.2	105.0 107.0
T. viride (0.50%)	S US	5.1 19.3	99.5 82.2	86.2 70.1	62.0 55.6	61.6 52.2	20.2 10.1	93.0 99.5
FYM (10 t./ha)	S US	3.5 21.1	96.3 82.3	81.5 68.5	55.6 46.6	55.0 39.2	19.4 10.2	95.0 99.0
Poultry refuse (PR) (10 t./ha)	S US	0.6 18.3	103.0 82.1	90.1 69.1	56.1 54.0	64.5 45.0	20.1 12.1	91.0 97.0
Control (unamended)	S US	15.1 40.4	86.2 70.1	69.4 59.5	46.0 41.1	43.5 33.6	14.0 9.5	110.0 119.0
CD (f= 0.05)		0.54	3.22	3.70	4.01	6.22	3.24	3.32

Treatment x solarization x disease incidence	0.77
Treatment x solarization x corm weight	8.73
Treatment x solarization x shoot length	4.51
Treatment x solarization x no. of cormels	4.61
Treatment x solarization x spike length	5.22
Treatment x solarization x days to 1st flowering	4.75
Treatment x solarization x size of corm	5.54

Figures were aresine transformed before analysis, S = Solarized, US = Un-solarized.

studies were used for 30 min corm dip before sowing followed by three drenching of the same fungicide one month after sowing of the corms at 10 days interval. All the treatments mentioned above were applied both in solarized and un-solarized conditions and each treatment was replicated thrice. Soil solarization was done by first irrigating all the 42 cultivated plots to saturation level and then covering half of the plots (21 no.) with transparent polyethylene mulch (25 urn) for 40 d in each year. After 40 d of solarization, the mulch was removed and immediately planting of corms of variety Peter Pears was done at a spacing of 20 cm × 20 cm. Incidence of the wilt along with shoot and spike length was recorded 120 d after sowing of the corms. The size and weight of corms and numbers of cormels per corm were recorded 210 day after sowing of the corms. In addition, days to first flowering were also recorded. All the observations were recorded by selecting five plants randomly from each treatment in solarized and non-solarized plots.

Results and Discussion

Combination product Carbendazim 25% + Iprodionc 25% was the most effective inhibiting the pathogen (86%). Carbendazim 12% + Mancozeb 63% and Carbendazim 50 WP, with mycelial inhibition are 80 and 84% were repectvely. Carbendazim 50 WP and Carbendazim 12% + Mancozeb 63% were found statistically at par for their efficacy against the pathogen. Azoxystrobin 23 SC was the least effective fungicide. Combination fungicide *i.e.* Carbendazim and Mancozeb have been reported to be effective against the wilt pathogen (Kaur *et al*., 1989). All the five species of *Trichoderma* tested against the pathogen were found effective with growth inhibition ranging from 46 to 62 per cent. Among different species of *Trichoderma*, *T. viride* was the most effective (62% inhibition of the pathogen). *T. harzianum* showed a growth inhibition of 60 per cent. *T. virens* was the least effective (46%). Different species of *Trichoderma* have been reported to be effective against *Fusarium oxysporum* causing wilt in different crops (Angarita, 1997). Soil solarization with transparent polyethylene mulch has been reported to increase soil p, which has an adverse effect on viability and potential of different soil-borne pathogens (Katan, 1981). Soil amendments *viz*., Poultry refuse (PR) with soil solarization was found to be the most effective treatment in disease control (97.5%). The next best disease control ((96%) was in treatment with corm dip in Carbendazim 25% + Iprodionc 25% (Quintal) (table 1). Integration of soil solarization with fungicides, formulation of *Trichoderma viride*, Soil amendments proved effective in reducing the incidence of *Fusarium* wilt of gladiolus accompanied with increases in different growth parameters. Soil solarization in combination with farmyard manure amended plots was found next in efficacy with 91 per cent control in incidence of the wilt in comparison to un-amended and un-solarizcd control. Treatment of corms in Carbendazim 12% + Mancozeb 63% (Carmel) followed by plantation in solarized plots was the least effective. However, treatment of soil solarization alone was found more effective than many treatments like corm dip in fungicides, corm dressing with *T. viride* formulation, soil amendment of Poultry refuse (PR) and soil amendment of farmyard manure in un-solarized plots.

Integration of soil solarization with other methods of disease management was also found effective in improving different growth parameters of gladiolus. Soil amendment of in Poultry refuse (PR) in solarized soil resulted in increases 48.5, 51.0, 33.0, 85.8 and 105.0 per cent in shoot length (48%), spike length (52%), size of corms (34%), weight of corms (85%) and number of cormels per plant (103%) and also resulted in the reduction in days required for first flowering (by 24%) as compared to un-amended and un-solarized control (table 1). Other treatments like corm pressing with fprmulation of *T. viride* and corm dip in Carbendazim 25% + Iprodionc 25% (Quintal) followed by plantation in solarized plots were also found equally effective with no significant difference in the growth parameters.

Thus, integration of soil amendment with Poultry refuse (PR) followed by soil solarization for 40 days resulted in effective control of wilt of gladiolus along with enhanced growth in different growth parameters of the crop.

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