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Interaction studies between *Fusarium oxysporum* f. sp. *cubense* and *R. similis* on Banana Var. Ney. Poovan under glass house condition

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Abstract
An investigation was undertaken with fifty mustard genotypes to study the correlation and path coefficient analysis of twelve yield contributing characters. Correlation analysis revealed that seed yield per plant is positively and significantly correlated with harvest index followed by number of secondary branches per plant and number of siliquae per plant at genotypic level. Path coefficient analysis revealed that days to maturity, number of secondary branches per plant, number of siliquae per plant, siliqua length, 1000 seed weight, harvest index and oil content had direct positive effect on seed yield per plant. Whereas, days to 50% flowering, plant height, number of primary branches per plant and number of seed per siliqua had direct negative effects on seed yield per plant both at genotypic and phenotypic levels. Based on the results it has been concluded that harvest index, number of secondary branches per plant and number of siliquae per plant exerted high correlation and direct influence on seed yield per plant. These traits may be considered for selection and to improve the yield of mustard genotypes.

Keywords: Interaction, *Fusarium oxysporum*, *R. similis*, Banana, glass house, wilt index

Introduction

Banana (*Musa* spp.) belongs to family *Musaceae* is the most important fruit crop in the world, serving as a staple food and source of income in many developing countries. Banana is also the world's leading fruit crop and consequently an important export commodity for several agricultural based economies in Asia, America and African continents and represents the fifth most important agricultural crop in world trade (Aurore *et al.*, 2009) [3]. Among the various biotic factors affecting production, Panama wilt complex caused by and by *Fusarium oxysporum* f. sp. *cubense* and *Radopholus similis* is considered as most economically important disease of banana (Gowen, 1995) [6]. In India, the first reports of Panama wilt were in 1911 in West Bengal and 1956 in Tamil Nadu and many reports have been made subsequently. Sundararaju *et al.*, (1996) reported that the burrowing nematode causes severe root rotting, resulting in about 25-35 per cent reduction in yield. When these two pathogens are combined together, the severity of the wilt disease was more, since the nematodes predispose the plants for fungal infection. Therefore, the present study was undertaken to assess the interaction between the wilt fungus, *F. oxysporum* f. sp. *cubense* (Foc) and burrowing nematode, *Radopholus similis*.

Materials and Methods

Interaction between *Foc* and *R. similis* was studied under greenhouse condition. The uniform 90 days old Ney. Poovan Banana plants was potted in 12″ pots with sterilized mixture of soil, sand and farm yard manure (2: 1: 1). This study was conducted under the glasshouse Department of Plant Pathology, College of Agriculture, University of Agricultural and Horticultural science Shivamogga. Two month after planting, treatments involving individual inoculations of *Foc* and *R. similis* as well as simultaneous and sequential inoculation of both these pathogens with appropriate inoculum was made. Nematode inoculum comprised of 1000 juveniles per kg of soil and a fungal inoculum with size of 200 g of giant culture per plant was inoculated. *Fusarium oxysporum* f. sp. *cubense* was cultured on a sorghum seeds. About 200 g of slightly cooked sorghum seeds was taken in 1000 ml autoclavable polythene covers and were sterilized at 121 °C at 15 psi for 20 minutes.

A few discs of *Foc* from actively growing culture was inoculated under aseptic condition and incubated at 27±5 °C for 30 days. The covers were shaken every two day to get uniform growth. The fungus culture maintained on sorghum seeds medium was added around the root system by removing a small quantity of soil and applying soil over it again after inoculation. There were six treatments and each replicated four times as described below.

Table 1: Treatments details

Treatments	Abbreviation	Inoculation details
T_1	F	Inoculation with *F. oxysporum* f. sp. *cubense* alone
T_2	N	Inoculation with *R. similis* alone
T_3	N+F	Simultaneous inoculation with *R. similis* and *F. oxysporum* f. sp. *cubense*
T_4	N→F	Inoculation with *R. similis* followed (15 days) by *F. oxysporum* f. sp. *cubense*
T_5	F→N	Inoculation with *F. oxysporum* f. sp. *cubense* followed (15 days) by *R. similis*
T_6	C	Control

Observations

The growth parameters *viz*., Plant height, shoot length, stem girth, number of leaves, leaf area, root length, fresh root weight were recorded with number of lesions per plant, soil and root nematode population was also recoded. The root lesion index was calculated using lesion index rating scale (Ravichandra, 1983) [10]. The wilt incidence at 15 days interval and wilt severity was assessed after 4 months according to Moore *et al*. (1993) [7] as plants were scored for external symptoms on a 1-5 scale.

Results and Discussion

Effect of individual, combined and sequential inoculation of *F. oxysporum* f. sp. *cubense*and *R. similis* on plant height revealed that, there was a significant difference in the plant height within the treatments and data are presented in Table 2. Significant reduction in the plant height was noticed in all the treatments in comparison with uninoculated control. There was significant difference in stem girth of plant inoculated with Foc and *R. similis* compared to uninoculated control. The minimum stem girth was recorded in *R. similis* + Foc (13.50 cm) followed by Foc→ *R. similis* (16.10 cm) compared to uninoculated control plants (17.50 cm). Shoot weight was also reduced either by individual, combined and sequential inoculation with *R. similis* and Foc. Significantly minimum shoot weight was recorded in *R. similis* + Foc (985.00 g) followed by Foc → *R. Similis* (1045.00 g) compared to uninoculated control (1235.00 g). There was significant differences in fresh root weight in inoculated plants with *R. similis* and Foc by individually, combined and sequentially. The treatment *R. similis* + Foc (316.00 g) recorded lowest fresh root weight, followed by *R. similis*→Foc (325.00 g) compared to uninoculated control (505.00 g). The lowest root length was observed in *R. similis* + Foc treatment with root length of 30.15 cm, followed by *R. similis* → Foc treatment with root length (36.50 cm) compared to uninoculated control 49.75cm.

The present findings were in confirmation with Dinesh *et al.* (2014) [5] who found that, significant reduction in plant height, stem girth, shoot weight, fresh root weight and root length was noticed in simultaneous inoculation of *R. similis* and Foc over untreated control. However, Foc inoculated individually caused greater reduction in plant growth than *R. similis* alone. In case of sequential inoculation of *R. similis* and Foc, greatest reduction in plant growth was observed in inoculation of *R. similis* 15 days prior to Foc and also with Foc 15 days prior to *R. similis* over control. Sundararaju and Thangavelu (2009) [12] reported that, maximum reduction of plant growth was observed in plants inoculated with *Pratylenchus coffeae, Meloidogyne incognita* and Foc together. Likewise, Bhabesh *et al.* (2009) [4] recorded greater damage in simultaneous inoculation of fungus and nematode might be attributed to the prior invasion of nematodes into the roots has made the host more favourable for fungal infection with metabolically rich substrate and nematode might also modified the rhizosphere favoring of the fungal growth.

Table 2: Influence of Foc and *R. Similis* interaction on plant growth parameters of banana

Treatments	Plant height (cm)	No. of leaves	Stem girth (cm)	Shoot weight (g)	Root weight (g)	Root length (cm)
F	108.50*	5.50	16.25	1110.00	482.50	40.50
N	108.75	5.25	15.75	1108.50	405.00	42.50
N+F	85.25	5.0	13.50	985.00	316.00	30.15
N→F	87.25	4.25	15.75	1065.00	325.00	36.50
F→N	91.50	5.0	16.10	1045.00	345.00	37.75
C	132.00	6.25	17.50	1235.00	505.00	49.75
S.Em ±	1.08	0.25	0.31	24.83	7.43	0.98
CD @ 5%	3.21	NS	0.93	73.76	22.08	2.90

Note: * Indicated values are the means of replication of respective treatments

F: Fusarium alone; N: *R. similis* alone; N+F: Simultaneous inoculation of Fusarium and *R. similis*; N →F: *R. similis* inoculation followed by Fusarium; F →N: Fusarium inoculation followed by *R. similis*; C: Control

Wilt incidence and severity

There was 100 per cent incidence of wilt in all the treatments except plants received *R. similis* alone and uninoculated control plants (Table 3). The wilt severity was lowest in Foc alone (63.00%) with 3.25 wilt score and it was on par with *R. similis* → Foc (68.00%) with wilt score 3.50 compared to uninoculated control. The maximum wilt severity was observed in plants inoculated with *R. similis* and Foc in combination (78.00%) with wilt score of 4.0 which is significantly superior over other treatments.

Table 3: Influence *Foc* and of *R. similis* interaction on lesion index and wilt severity on banana

Treatments	No. of lesions	Lesion index	Wilt incidence (%)	Wilt score (1-5)	Wilt severity (%)	Wilt score (RDI) (1-8)	Length of stem splitting (cm)	Wilt severity (RDI) (%)
F	0.00	1.00	100.00	3.25	63.00 (52.51)*	4.25	35	47.00 (43.26)
N	36.50	2.00	0.00	1.00	0.00 (0.00)	1.00	00	0.00 (0.00)
N+F	34.50	2.00	100.00	4.00	78.00 (62.00)	6.75	50	80.33 (63.65)
N→F	40.50	2.50	100.00	3.50	68.00 (55.53)	5.50	40	63.67 (52.91)
F→N	32.50	2.00	100.00	3.75	73.00 (58.62)	4.50	42	51.17 (45.60)
C	0.00	1.00	0.00	1.00	0.00 (0.00)	1.00	00	0.00 (0.00)
S.Em ±	1.35	0.20	-	-	2.36	-	-	1.73
CD @ 5%	4.00	0.61	-	-	7.01	-	-	5.15

* Figure in parentheses are angular transformed values

Wilt severity based on rhizome discolouration index

The rhizome discolouration index gave the good indication of wilt severity in different inoculated individually, combination and sequentially with Foc and *R. similis*. The observations on wilt severity differed significantly in all types of inoculation compared to *R. similis* alone and uninoculated control plants (Plate 1). The plants inoculated with Foc alone had lowest wilt severity (37.00%) with wilt score of 4.25. It was on par with Foc → *R. similis* (51.17%) with 4.50 wilt score. Significantly maximum wilt severity was observed in concomitantly inoculated plants with *R. similis* + Foc (80.33%) with wilt score of 6.75. With respect to length of stem splitting (Plate 2) in treatment, *R. similis* + Foc was recorded highest length of stem splitting (50 cm), followed by Foc → *R. similis* (42 cm) and lowest stem splitting was recorded in Foc alone treated plants (35 cm)

The present findings are in confirmation with the findings of authors Somu *et al.* (2014) [11], Abdel Hadi *et al.* (1987) [1] and (Pathak *et al.*, 1999) [8]. The incidence of wilt was highest (65.00%) in inoculation of nematode 15 days prior to *Fusarium oxysporum* f. sp. *cubense* followed by inoculation *F. oxysporum* f. sp. *cubense* 15 days prior to nematode (55.00%) and simultaneous inoculation of *F. oxysporum* f. sp. *cubense* and nematode (50.00%). Least incidence or no incidence was noticed in inoculation of nematode alone (Somu *et al.*, 2014) [11].

Abdel Hadi *et al.* (1987) [1], reported that inoculation of banana roots with Foc and *R. similis* induced lesions after one week. The percentage of rotted roots was 36.50 per cent with the nematode alone, 47.8 per cent with both organisms and 4.0 per cent with the fungus alone. Further, Atkinson (1892) [2] reported the presence of *M. incognita* along with *F. oxysporum* in the rhizosphere of cotton plants increased the severity of wilt caused by the fungus.

The maximum wilt was observed in the presence of *M. incognita* 10 days prior to inoculation of Foc or and *Pseudomonas solanacearum*. Presence of all the three pathogens together had more deleterious effects on banana plants (Pathak *et al*., 1999) [8].

Mechanical wounding or injury by *R. similis* was necessary for *Foc* to cause reddish-brown lesions. The complex infection caused by plant parasitic nematodes and *Foc* gave rise to a necrotic and reduced root system, which in turn, resulted in a reduction in the uptake and transportation of water and nutrients by the plant (Poornima *et al*., 2007) [9].

Plate 1: Influence of Foc and *R. similis* interaction on wilt on Banana

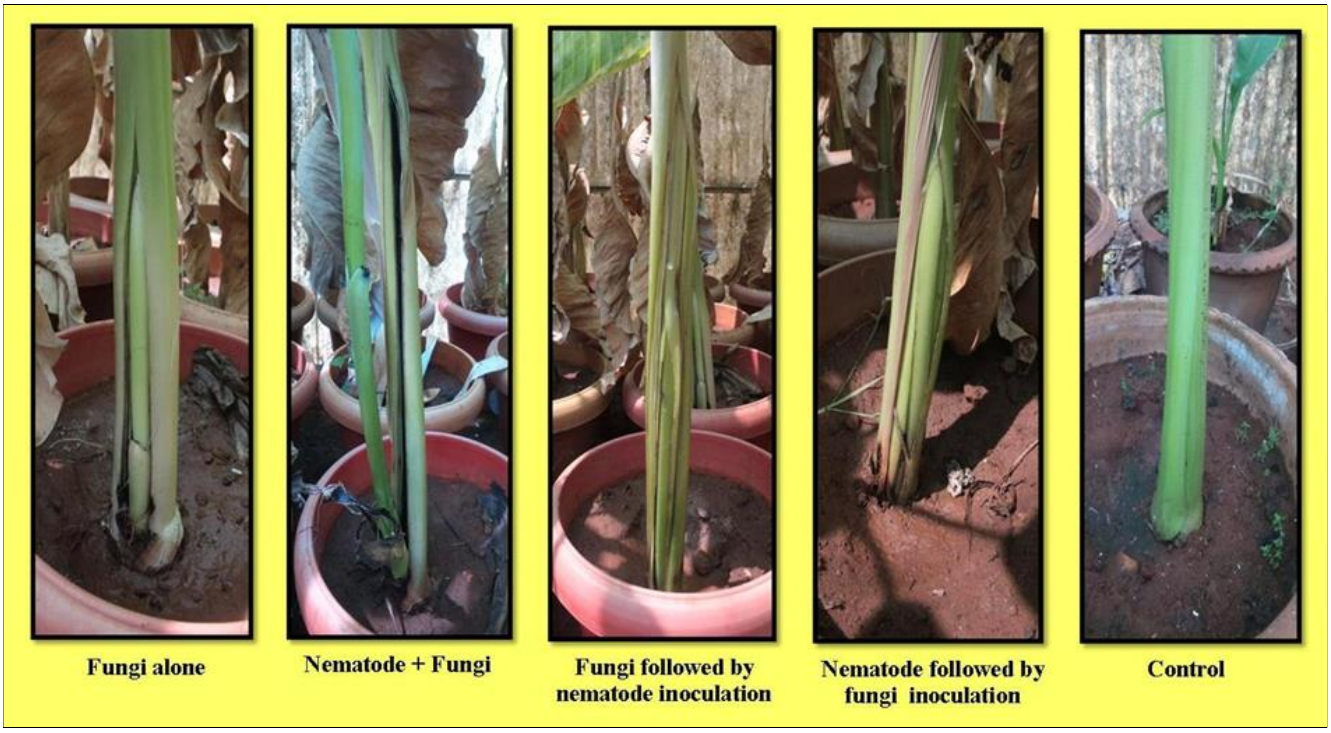

Plate 2: Influence of Foc and *R. similis* interaction on length of stem splitting on Banana

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