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Fusarium oxysporum f. sp. *cumini* is a serious disease of cumin. Considering its regular occurrence and economic loss the wilt pathogen was selected for present investigation to generate the information's to find out fungicide for controlling wilt. Soil drenching of carbendazim 0.1 per cent (20 g/10 l water) @ 1 l/ sq. meter after one month of sowing reduced Fusarium population in soil up to harvest as well as highest reduction in wilt incidence along with significantly highest seed yield. Seed treatment of carbendazim 12 % + mancozeb 63 % @ 3 g/kg seed was also equally effective in disease reduction and better seed yield except fusarial population reduction in soil as compared to the treatment of carbendazim 0.1 per cent drenching.

Key words: *Fusarium*, carbendazim, copper oxychloride, management

INTRODUCTION

Cumin (*Cuminum cyminum* L.) locally known as 'Jeera' or 'Jiru' belongs to the family Apiaceae. India is the leading producer (70% of world production), consumer and exporter of cumin in the world. Almost 80% of the crop cultivated is consumed in India. (Anon., 2013). Wilt caused by *Fusarium oxysporum* f. sp. *cumini* is a serious disease of cumin (*Cuminum cyminum* L.) in India (Dange, 1995). It is prevalent in all the cumin growing countries. Mathur and Mathur (1956) report wilt of cumin from Rajasthan and identified the causal organism to be *Fusarium oxysporum* (Schl.) Snyder and Hansen. On the basis of host specificity it is finally named as *Fusarium oxysporum* f. sp. *cumini* by Prasad and Patel (1963). Wilt results in yield losses up to 35 per cent in cumin in some districts of Rajasthan (Vyas and Mathur, 2002). Dange *et al.* (1992) report 7.0 to 30.6 per cent losses in Gujarat. Hence, present investigation has been done for finding better fungicide for controlling wilt and its effect on soil microbial population.

MATERIALS AND METHODS

A field experiment was laid out to study the efficacy of conventional fungicides as seed dressing and drenching against cumin wilt. The experiment was carried out during *Rabi* 2011-12, 2012-13 and 2013-14 at the Plant Pathology Department Farm, JAU, Junagadh in Randomized Block Design with eight treatments along with three replications. All the recommended agronomical practices were followed during experimentation. Experiment details are given in Table 1.

The gross and net plot sizes were 5 x 2.5 m and 4 x 2.0 m, respectively. Cumin variety Gujarat cumin-4 was used in the experiment. Broadcasting method was used. All the experimental plots were artificially inoculated with 10 day old culture of *Fusarium oxysporum* f. sp. *cumini* prepared on sorghum grain two week prior to sowing @250g/ plot.

The observation on wilted plants were recorded weekly onward from initiation. After each observation wilted plants were uprooted and destroyed. The disease incidence was calculated using following formula.

$$\text{Per cent wilt incidence} = \frac{\text{Total no. wilted plants recorded throughout the crop season}}{\text{Initial plant stand}} \times 100$$

Quantification of microbial population

To quantify the density of total fungi, total bacteria, *Fusarium* spp., *Trichoderma* spp. and

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Pseudomonas spp. from different treatments the soil samples were assessed. Soil samples (1g/plot) were collected from each replication at three times during crop season: initial, 45 DAS and at harvest. Similarly at 45 day crop age soil samples were also collected from rhizoplane of wilted plant for each replication.

All soil samples were stored in refrigerator. The population of microbes in each soil sample was determined on selective media by dilution technique as mentioned by Benson (2002).

The selective media viz. PDA for total fungi (Atlas, 2010), NA for total bacteria (Atlas, 2010). Komada *for Fusarium* (Komada, 1975), Rose Bangal Agar *Trichoderm*a (Elad and Chet, 1983), and King's B medium for *Pseudomonas* (Atlas, 2010) were used.

Serial dilution method

- One gram soil sample of each plot was suspended in 9 ml sterilized distilled water to prepare dilution of 1:10 or 10^{-1}.
- The tubes were shaked thoroughly.
- One ml suspension from 10^{-1} dilution was transferred to test tube filled with 9 ml sterilized water to prepare dilution of 1:100 or 10^{-2}.
- By this way series of dilutions were made by transferring 1ml of the suspension to the subsequent tubes to get desired dilution for respective microorganism.
- For the enumeration of the fungi (total fungi, *Fusarium* spp. and *Trichoderam* spp.) and bacteria (total bacteria and *Pseudomonas* spp.) the respective dilution were 10^{-3} and 10^{-8}.
- One ml of the desired soil suspension was transferred to Petri plates containing medium and replicated thrice for each plot (replication).
- After rotating gently the plates were incubated at room temperature (27±2°C).

Yield

The seed yield was recorded in kg at the time of harvest. The per cent increase in yield in each treatment over control was worked out by the following formula:

$$\text{Yield increase (\%)} = \frac{\text{Yield in treatment (kg)} - \text{Yield in control (kg)}}{\text{Yield in control (kg)}} \times 100$$

RESULTS AND DISCUSSION

Field trials were conducted during *Rabi* 2011-12, 2012-13 and 2013-14 at the Plant Pathology Department Farm, JAU, Junagadh to study the efficacy of 6 treatment of 2 conventional fungicides as drenching along with one treatment of seed dressing against cumin wilt. All the experimental plots were amended with Junagadh isolate of *Fusarium oxysporum* f. sp. *cumini* grown on sorghum grain 3 day before sowing. Gujarat cumin-4 the major cultivar in the state was used in the experiment. Treatment wise disease incidence, seed yield and microbial population data were compiled and presented in Tables 2,3 and 4 respectively.

Microbial population

Population of *Fusarium* spp., *Trichoderma* spp., *Pseudomonas* spp., total fungal and total bacterial counts were recorded at initial stage, 45 DAS (rhizosphere and rhizoplane) and at harvest using selective media.

Fusarium

Looking to the mean of three seasons (Table2) the fusarial population was reduced up to the harvest in the treatment of carbendazim (0.1 %) drenching. After 45 days of sowing the mean fusarial population reduction on rhizosphere, rhizoplane was 29.87 per cent and 16.88 per cent respectively. The reduction at harvesting time was recorded 0.87 per cent. The fusarial population in all remaining treatments was increased up to the harvest as compared to initial counts. The increase in rhizosphere population ranged between 2.89 per cent (seed treatment of carbendazim + mancozeb) to 63.79 per cent (control) after 45 days of sowingand 26.86 per cent to 107.82 per

Table 1 : Efficacy of conventional fungicides as seed dressing and drenching against cumin wilt

Treatment	Treatment details
T1	Seed treatment with carbendazim + mancozeb 3g/kg seed
T2	Drenching of carbendazim 0.1% 30DAS@1 lit/sq.mt
T3	Drenching of carbendazim 0.05% 30DAS@1 lit/sq.mt
T4	Drenching of carbendazim 0.025% 30DAS@1 lit/sq.mt
T5	Drenching of copper oxychloride 0.3 % 30DAS@1 lit/sq.mt
T6	Drenching of copper oxychloride 0.2% 30DAS@1 lit/sq.mt
T7	Drenching of copper oxychloride 0.1% 30DAS@1 lit/sq.mt
T8	Control (without seed treatment and drenching)

Table 2 : Assessment of soil microbial population in cumin grown field under fungicide drenching treatments (mean of three years)

Initial (After inoculation at time of sowing)					After 45 DAS: Rhizosphere					After 45 DAS: Rhizoplane					At Harvest (Rhizosphere)				
*Fusarium**	*Trichoderma**	*Pseudomonas***	Total fungai*	Total Bacteria**	*Fusarium**	*Trichoderma**	*Pseudomonas***	Total fungai*	Total Bacteria**	*Fusarium**	*Trichoderma**	*Pseudomonas***	Total fungai*	Total Bacteria**	*Fusarium**	*Trichoderma**	*Pseudomonas***	Total fungai*	Total Bacteria**
24.2	8.4	8.7	35.0	20.2	24.9	9.2	9.3	36.6	22.2	27.2	9.9	10.3	37.9	23.7	30.7	11.3	11.5	42.5	26.3
23.1	11.0	8.5	41.9	20.1	16.2	8.0	9.7	42.9	23.4	19.2	8.8	10.3	44.1	26.9	22.9	12.3	11.1	45.6	26.4
27.3	11.4	8.6	38.5	23.7	31.7	9.0	9.3	41.5	25.8	34.6	9.6	10.0	42.6	27.7	38.8	13.6	11.2	46.8	30.5
26.5	12.6	8.4	40.2	22.6	32.0	10.8	9.2	42.8	24.0	33.3	11.1	10.2	43.3	24.9	35.9	14.9	11.0	47.2	28.8
29.0	12.7	10.9	44.9	24.4	34.6	8.2	12.8	45.6	27.0	36.4	9.4	13.8	46.6	28.8	42.3	13.9	14.7	54.2	32.8
24.5	15.5	11.8	42.6	24.8	30.4	11.1	12.8	46.7	26.3	33.3	12.2	13.6	49.2	28.0	41.8	17.6	14.7	54.3	29.9
22.9	13.7	10.4	38.5	19.9	28.4	11.6	11.6	43.3	22.6	31.6	12.3	12.3	44.7	24.0	38.8	16.7	13.8	53.8	26.3
24.3	12.2	9.8	37.0	19.8	39.8	13.2	11.2	50.5	23.3	41.5	14.8	12.2	53.7	25.6	50.5	16.5	12.8	61.2	29.2

* CFU (10^{3} g^{-1} soil) ** CFU (10^{8}/g^{-1} soil)

Table 3 : Per cent increase or decrease in microbial population as compared to initial stage in cumin grown field under fungicide drenching treatments (mean of three years)

After 45 DAS*										At Harvest* (Rhizosphere)				
Rhizosphere					Rhizoplane									
Fusarium	*Trichoderma*	*Pseudomonas*	Total fungi	Total Bacteria	*Fusarium*	*Trichoderma*	*Pseudomonas*	Total fungi	Total Bacteria	*Fusarium*	*Trichoderma*	*Pseudomonas*	Total fungi	Total Bacteria
2.89	9.52	6.90	4.57	9.90	12.40	17.86	18.39	8.29	17.33	26.86	34.52	32.18	21.43	30.20
-29.87	-27.27	14.12	2.39	16.42	-16.88	-20.00	21.18	5.25	33.83	-0.87	11.82	30.59	8.83	31.34
16.12	-21.05	8.14	7.79	8.86	26.74	-15.79	16.28	10.65	16.88	42.12	19.30	30.23	21.56	28.69
20.75	-14.29	9.52	6.47	6.19	25.66	-11.90	21.43	7.71	10.18	35.47	18.25	30.95	17.41	27.43
19.31	-35.43	17.43	1.56	10.66	25.52	-25.98	26.61	3.79	18.03	45.86	9.45	34.86	20.71	34.43
24.08	-28.39	8.47	9.62	6.05	35.92	-21.29	15.25	15.49	12.90	70.61	13.55	24.58	27.46	20.56
24.02	-12.78	11.54	12.47	13.57	37.99	-7.52	18.27	16.10	20.60	69.43	25.56	32.69	39.74	32.16
63.79	8.20	14.29	36.49	17.68	70.78	21.31	24.49	45.14	29.29	107.82	35.25	30.61	65.41	47.47

* per cent values

Table 4 : Efficacy of fungicide drenching against cumin wilt

Treatments	2011-12		2012-13		2013-14		Pooled		Per cent Disease control	Yield increased over control (%)
	Disease Incidence (%)	Seed yield (kg/ha)	Disease Incidence (%)	Seed yield (kg/ha)	Disease Incidence (%)	Seed yield (kg/ha)	Disease Incidence (%)	Seed yield (kg/ha)		
T 1	23.15 (15.46)	679	19.57 (11.21)	612	24.06 (16.62)	556	22.26 (14.35)	662	46.63	26.37
T 2	23.69 (16.15)	816	18.75 (10.33)	762	23.77 (16.24)	610	22.07 (14.12)	780	47.49	37.51
T 3	25.21 (18.14)	689	21.66 (13.62)	525	26.32 (19.66)	420	24.39 (17.06)	579	36.56	15.86
T 4	26.89 (20.45)	692	23.96 (16.49)	550	28.59 (22.90)	440	26.48 (19.88)	597	26.07	18.34
T 5	25.38 (18.36)	671	23.74 (16.21)	520	25.18 (18.10)	413	24.77 (17.55)	569	34.73	14.36
T 6	27.97 (21.99)	681	25.61 (18.69)	541	27.51 (21.33)	433	27.03 (20.65)	588	23.21	17.07
T 7	28.66 (23.01)	631	28.58 (22.89)	475	29.86 (24.79)	380	29.03 (23.55)	527	12.42	7.46
T 8	31.79 (27.75)	462	30.58 (25.88)	338	31.35 (27.06)	270	31.24 (26.89)	487	-	-
							T	Y x T	T	Y x T
SEm ±	1.66	53.38	1.67	59.63	1.43	44.3	0.78	1.35	43.37	46.21
C.D. at 5%	5.03	161	5.07	180	4.28	134	2.24	NS	131	131
C.V. %	10.80	13.88	12.02	19.12	10.26	17.42		9.08		13.36

* The figures in the parentheses are retransformed values

cent at harvest in the same treatments respectively. Almost similar trend was also recorded in rhizosplane population after 45 days of sowing, but little higher i.e. 12.40 per cent and 70.78 per cent in seed treatment and control respectively.

Many farmers in Saurashtra region apply soil drenching of either carbendazim or copper oxychloride for the management of cumin wilt after its initiation (personal feed back of Dr. K. B. Jadeja), although there is no such recommendation. Considering this practice the experiment was framed out to test carbendazim and copper oxychloride with three respective concentrations keeping one higher and one lower concentration of generally recommended dose for their application.

Among two fungicides, none of the concentrations of copper oxychloride has satisfactorily reduced fusarial population in the soil. While highest concentration of carbendazim (0.1 %) which is equivalent to 20 g/ 10 liter water of market product has effectively reduced fusarial population, although the lower concentrations were not effective. Although the fusarial population was lower in all treatments as compared to control. These results indicated that single drenching application of carbendazim 50 % Wp (0.1 %) after 30 DAS checked fusarial population in the soil up to the harvest of crop.

Trichoderma

While assessing mean of three seasons (Tables 2 and 3) Trichoderma population was increased after 45 days of sowing in seed treatment (9.52 % in rhizosphere and 17.86 % in rhizoplane) and in control (8.20 % in rhizosphere and 21.31 % in rhizoplane). All the fungicidal treatments reduced Trichoderma population even after 15 days of their drenching. While at harvest Trichoderma made its deficit and population was increased in all treatments in the range of 9.45 per cent to 35.25 per cent.

Pseudomonas

The mean of three season (Tables 2 and 3) revealed that the Pseudomonas population in all the treatments was increased at both the times of observation. It was observed that increase in population was higher in rhizoplane than in rhizosphere after 45 days of sowing and the population was increased as the crop growth stage increased. Highest population was recorded at harvest. The population difference among the treatment was recorded at first observation but it was not shown at harvesting.

Total fungi

Looking to over all mean of three years total fungal population was increased in all the treatments and comparatively higher population was observed at harvest. Highest fungal population was observed in control treatment in all three years. Total fungal population was increased as the crop growth stage advanced. Population was higher in rhizoplane as compared to rhizosphere. Over all the fungal population was very low in all the fungicidal treatments as compared to control at both the times. This shows the fungicidal effect in the soil on fungal population.

Total bacteria

The mean of three seasons (Tables 2 and 3) revealed that the total bacterial population in all the treatments was increased at both the time of observation. It was observed that increase in population was higher in rhizoplane than in rhizoplane after 45 days of sowing and the population was increased as the crop growth stage advancd. Highest population was recorded at harvest. The increase in bacterial population was higher than fungal population as compared to control.

Disease incidence and yield

The result presented in Table 4 showed that in the first year (2011-12) lowest disease incidence was recorded in T-1 i.e. seed treatment (15.46 %) and it was statistically at par with T-2 (16.15 %), T-3 (18.14 %), T-4 (20.45 %) and T-5 (18.36 %). Highest disease incidence was recorded in control (27.75 %). In all the treatment the seed yield was higher as compared to control. Highest seed yield of 816 kg/ha was obtained in the treatment of T-2 (carbendazim 0.1 %) and was statistically at par with T-1 (679 kg/ha), T-3 (689 kg/ha), T-4 (692 kg/ ha), T-5 (671 kg/ha) and T-6 (681 kg/ha). The seed yield in control treatment was only 462 kg/ha.

In the second season (2012-13) lowest disease incidence was recorded in T-2 (10.33 %) and it was statistically at par with T-1 (11.21 %) and T-3 (13.62 %). While highest disease incidence was recorded in control (25.88 %). Highest seed yield of 762 kg/ha was obtained in the treatment T-2 (carbendazim 0.1 %) and it was at par with seed treatment (612 kg/ha). The seed yield in control treatment was only 338 kg/ha.

In third season 2013-14 lowest disease incidence was recorded in the treatment of carbendazim 0.1 per cent (16.24 %). It was statistically at par with seed treatment (16.62 %), T-3 (19.66 %) and T-5 (18.10 %). Highest seed yield of 610.00 kg/ha was obtained in the treatment T-2 and it was at par with T-1 (556.67 kg/ha). The seed yield in control treatment was only 270.67 kg/ha. .

Looking to the pooled data of three years lowest disease incidence was recorded in the drenching treatment of carbendazim 0.1 per cent (14.12 %) which was at par with seed treatment of carbendazim + mancozeb (14.35 %). In these treatments 47.49 per cent and 46.63 per cent disease control was recorded along with 37.15 per cent and 26.51 per cent higher seed yield as compared to control respectively. In the remaining treatments except drenching of copper oxychloride 0.1 per cent (T-7) significant disease reduction was observed. The disease incidence and respective disease control as shown in parentheses are 17.06 per cent (36.56 %), 17.55 per cent (34.73 %), 19.88 per cent (26.07 %) and 20.65 per cent (23.21 %) in T-3, T-5, T-4 and T-6 respectively. Highest seed yield of 780 kg/ha was recorded in carbendazim 0.1 per cent drenching and it was at par with seed treatment of carbendazim + mancozeb with 662 kg/ ha. The yield in other treatments was at par with control.

It is concluded from these results that soil drenching of carbendazim 0.1 per cent (20 g/10 l water) @ 1 l/ sq. meter after one month of sowing reduced Fusarium population in soil up to harvest as well as highest reduction in wilt incidence along with significantly highest seed yield. Seed treatment of carbendazim 12 % + mancozeb 63 % (Company product viz. Saaf 75 wp) @ 3 g/kg seed was also equally effective in disease reduction and better seed yield except fusarial population reduction in soil as compared to the treatment of carbendazim 0.1 per cent drenching.

The negative effect of fungicidal drenching was recorded on Trichoderma population after 45 DAS, although the biocontrol agent subsequently build up in the soil. Seed treatment did not harmed

Trichoderma population in the soil. The total fungal count was also less after 45 days of sowing as against control.

In the present finding the effective disease control with higher grain yield recorded in the treatments of carbendazim 0.1 per cent drenching attributes to important factors i.e. reduction of Fusarium population. While better disease control along with higher seed yield in the treatment of seed treatment only seems to be combine effect i.e. reduction of Fusarium and maintaining Trichoderma population. In the present findings the fungicide carbendazim effectively controled cumin wilt when applied as seed treatment or soil drenching.

There are number of findings on cumin wilt control with seed treatment of carbendazim and other fungicides (Deepak and Lal, 2009 ; Raheja and Patel, 2011). These findings support the results of the research work carried out. This is because of reduction of fusarial population in rhizosphere/ rhizoplane as reflected in the present experiment. Population of wilt pathogen and disease incidence relationship had been reported by Marwar and Lodha (2002) They recorded initial population of *Fusarium oxysporum* f. sp. *cumini* and subsequent years its population in the field increases with increase in wilt incidence and this increase is correlated with a rise in wilt incidence.

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