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Suresh Meena
Department of Plant Pathology, Sri Karan Narendra Agriculture University, Jobner, Jaipur, Rajasthan, India

RP Ghasolia
Department of Plant Pathology, Sri Karan Narendra Agriculture University, Jobner, Jaipur, Rajasthan, India

Jitendra Sharma
Department of Plant Pathology, Sri Karan Narendra Agriculture University, Jobner, Jaipur, Rajasthan, India

Corresponding Author:
Suresh Meena
Department of Plant Pathology, Sri Karan Narendra Agriculture University, Jobner, Jaipur, Rajasthan, India

Efficacy of fungicides against *Alternaria alternata* causing alternaria blight of fennel

Suresh Meena, RP Ghasolia and Jitendra Sharma

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Abstract
Fennel **(***Foeniculum vulgare* Mill.) is a major seed spice crop, belongs to family *Apiaceae* (*Umbelliferae*). Fennel crop suffers from various diseases caused by fungi and other microorganisms. Amongst the major fungal diseases of fennel, the Alternaria blight caused by *Alternaria alternata*, is becoming a measure threat to the fennel cultivation. During present investigations six fungicides were evaluated against *Alternaria alternata* under *in vitro* and *in vivo* conditions. Among these fungicides, mancozeb + carbendazim (300 ppm) was found most effective in inhibition of mycelial growth (96.90%) and while in field, two spray of mancozeb + carbendazim (0.2%) was recorded highly effective in reducing disease intensity (71.53%) by increasing 73.07 per cent seed yield followed by mancozeb over unprotected control. The benefit cost ratio value was highest (1.95) with two sprays of mancozeb + carbendazim at 15 days interval followed by mancozeb (1.84).

Keywords: Fennel, alternaria blight, *Alternaria alternata*, fungicides

Introduction
India is rightly known as the land of spices. Seed spices are very important in human health and have a crucial role in Indian cuisine. Fennel **(***Foeniculum vulgare* Mill**.)** is a major seed spice crop, belongs to family *Apiaceae* (*Umbelliferae*). Fennel oil and fennel oleoresins are used in pizza sauces, toppings, non-alcoholic beverages, liquors, ice creams and in seasoning of processed meats. In India, Gujarat stands first in fennel production. Fennel crop suffers from various diseases viz., Ramularia blight (*Ramularia foeniculi*), root rot (*Rhizoctonia solani*), wilt (*Fusarium oxysporum* f. sp. *funiculi*), powdery mildew (*Leveillula taurica* var. *languinosa*), Alternaria blight (*Alternaria alternata*) and stem rot (*Sclerotinia sclerotiorum*). Amongst the major diseases of fennel, the Alternaria blight disease is becoming a measure threat to the fennel cultivation. The disease manifests itself on all above ground plant parts in the form of angular, black depressed lesions on the basal leaves. Infantino *et al.*, (2009) [2] reported 30-100 per cent disease incidence on fennel. Therefore, the present investigations aimed to test six fungicides against Alternaria blight under *in vitro* and *in vivo* conditions.

Material and methods
Collection, isolation and identification of the pathogen
Infected plants of fennel were collected from farmer's field and isolations were made from the infected plants showing typical symptoms of Alternaria blight on potato dextrose agar (PDA) medium and culture purified by single spore technique. For further confirmation or identity of the fungus, the culture was sent to ITCC, Division of Plant Pathology, IARI, New Delhi and identified as *Alternaria alternata* with I. D. No. 9256.13.

In vitro efficacy of fungicides
Laboratory experiment was carried out to find out the efficacy of six fungicides [mancozeb (Indofil M-45); carbendazim (Bavistin); hexaconazole (Sitara); propiconazole (Tilt); mancozeb + carbendazim (Saaf); difenoconazole (Score)] with three (100, 300 and 150 ppm) concentrations against *A. alternata* on growth inhibition of the pathogen by poisoned food technique (Schmitz, 1930). Desired quantity of chemical was mixed thoroughly in 100 ml of PDA, just before pouring in sterilized Petri plates and allowed to solidity. A mycelial disc of 2 mm diameter of the pathogen taken from a 10 day old culture with the help of sterilized cork

borer was then placed at the center of the Petri plate. The inoculated Petri dishes were incubated at 25 ± 1 ˚C temperature in BOD. The experiment was conducted in Completely Randomized Design (CRD). Four plates were used for each treatment serving as four replications. Colony diameter was measured after 7 days of inoculation. Per cent growth inhibition was calculated by using Bliss (1934) [1] formula-

$$I = \frac{(C-T)}{C} \times 100$$

Where,
I = Per cent mycelial inhibition
C = Mycelial growth in control (mm)
T = Mycelial growth in treatment (mm)

***In vivo* efficacy of fungicides**

A field experiment was conducted for two consecutive years during *rabi*
2013-14 and 2014-15. Sowing was done in last week of October in both the years using local susceptible cultivar of fennel in RBD with seven treatments including control in three replications. To manage the disease by two foliar applications of fungicides [mancozeb (0.25%); carbendazim (0.1%); hexaconazole (0.1%); propiconazole (0.1%); mancozeb + carbendazim (0.2%); difenoconazole (0.1%)] were sprayed at an interval of 15 days starting from the initial appearance of the disease. One untreated control was also maintained. The disease intensity was recorded as per 0-5 rating scale given by Jaiman *et al*. (2013) [3] with slight modifications as follows after 15 days of last spray of fungicides. Randomly selected five plants from each field were rated as per following description and per cent disease intensity (PDI) was calculated as per following formula of Wheeler (1969) [6]. The seed yield was recorded in q/ha. The results were analysed statistically.

Disease rating scale for blight of fennel

S. No	Description	Grade
1	No incidence/ Healthy	0
2	Symptoms on leaf tip and leaves only	1
3	Symptoms on leaves and petiole	2
4	Symptoms on leaves, petiole and stem	3
5	Symptoms on leaves, petiole stem and inflorescence	4
6	Symptoms on leaves, stem, inflorescence including	5
	Seed	
	PDI = Sum of numerical disease rating	x 100
	No. of plants assessed x Maximum disease rating	

Results and discussions

***In vitro* efficacy of fungicides**

The efficacy of fungicides was evaluated against *A. alternata* on PDA by poisoned food technique. The data presented in Table 1 showed that all the fungicides caused significant reduction in mycelial growth as compared to control. Irrespective of concentrations, mancozeb + carbendazim proved to be the most effective in reducing (96.90%) the mycelial growth of *A. alternata* followed by mancozeb (92.73%), hexaconazole (90.30%). difenaconazole and carbendazim were observed statistically at par with each other. Minimum mycelial growth inhibition (80.87%) was noted with propiconazole. Interactions between fungicides and concentrations were also found significant.

***In vivo* efficacy of fungicides**

Six fungicides were evaluated for management of Alternaria blight of fennel by spraying twice at 15 days interval under natural field conditions. Two years pooled results on per cent disease intensity (Table 2) revealed that all the fungicides were significantly effective in reducing the Alternaria blight disease intensity over control. The minimum disease intensity (23.13%) was recorded with the application of mancozeb + carbendazim with 71.53 per cent decreased intensity. However, mancozeb was observed to be second best with 27.33 per cent disease intensity. Hexaconazole and carbendazim were observed statistically at par to each other. Propiconazole was found least effective in controlling the disease.

Pooled analysis of two years seed yield data of fennel was found statistically significant over control. Results (Table 2) showed that maximum seed yield (16.20 q/ha) was recorded in mancozeb + carbendazim with 73.07 per cent increased seed yield followed by mancozeb (15.54 q/ha). Hexaconazole, carbendazim and difenoconazole recorded 15.01 q/ha, 13.48 q/ha and 12.64 q/ha seed yield, respectively. Least seed yield was obtained with propiconazole (10.86 q/ha).

Based on the cost of different treatment and net profit, benefit cost ratio was worked out. The highest net profit of Rs. 85428 and benefit cost ratio 1.95 was obtained with the application of mancozeb + carbendazim followed mancozeb (1.84). Spray of hexaconazole also gave good net profit with B:C ratio 1.80 (Table 3).

In the present investigation, as far as disease control and yield are concerned all the fungicides performed better in reducing per cent disease intensity and increasing seed yield. The results are in agreement with several workers. They reported that mancozeb + carbendazim and mancozeb was found to be effective in reducing Alternaria blight disease in different crops. Patel and Patel (2008) [4] also reported that Ramularia blight of fennel caused minimum disease intensity with mancozeb and mancozeb + carbendazim. Vihol *et al.* (2009) [5] observed that field sprayed with mancozeb + carbendazim and mancozeb were highly effective and economic against *A. burnsii*, causing blight of cumin.

Table 1: Effect of fungicides on mycelial growth of *Alternaria alternata* after 7 days of incubation at 25 + 1 ^{0}C

Fungicides	Per cent inhibition of mycelial growth*			
	concentration (ppm)			
	100ppm	300ppm	500ppm	Mean
Mancozeb	78.20	100.00	100.00	92.73
	(62.17)	(90.00)	(90.00)	
Carbendazim	66.30	100.00	100.00	88.77
	(54.51)	(90.00)	(90.00)	
Hexaconazole	70.90	100.00	100.00	90.30
	(57.35)	(90.00)	(90.00)	
Propiconazole	60.00	82.60	100.00	80.87
	(50.77)	(65.35)	(90.00)	
Mancozeb +	90.70	100.00	100.00	96.90
Carbendazim	(72.24)	(90.00)	(90.00)	
Difenoconazole	62.80	100.00	100.00	87.60
	(52.42)	(90.00)	(90.00)	
Control	0.00	0.00	0.00	0.00
	(0.00)	(0.00)	(0.00)	
		SEm+		CD (p= 0.05)
Fungicide (F)		0.72	1.98	
Concentration (C)		1.09	3.03	
F X C		1.89	5.25	

*Average of three replications in parentheses are angular transformed values

Table 2: Effect of fungicides on Alternaria blight of fennel and seed yield

Fungicides	Concentration	Per cent disease intensity*			Decrease in PDI over control (%)	Yield (q/ha)*			Increase in yield over control (%)
	(%)	2013-14	2014-15	Pooled		2013-14	2014-15	Pooled	
Mancozeb	0.25	26.43	28.22	27.33	66.37	16.12	14.95	15.54	66.02
		(30.94)	(32.09)	(31.51)					
Carbendzim	0.1	32.00	34.02	33.01	59.38	14.00	12.95	13.48	44.02
		(34.45)	(35.68)	(35.07)					
Hexaconazole	0.1	29.54	31.35	30.45	62.53	15.82	14.20	15.01	60.36
		(32.92)	(34.05)	(33.49)					
Propiconazole	0.1	40.21	42.80	41.51	48.92	11.21	10.50	10.86	16.05
		(39.35)	(40.86)	(40.11)					
Mancozeb +	0.2	22.08	24.18	23.13	71.53	17.15	15.25	16.20	73.07
Carbendazim		(28.03)	(29.45)	(28.74)					
Difenoconazole	0.1	37.22	39.87	38.55	52.56	13.43	11.85	12.64	35.04
		(37.60)	(39.16)	(38.38)					
Control	-	78.69	83.85	81.27	-	10.05	8.68	9.36	-
		(62.51)	(66.30)	(64.41)					
SEm+		1.60	1.30	1.45		0.34	0.37	0.36	
CD (p=0.05)		4.91	4.01	4.46		1.05	1.15	1.10	
*Average of four replications									

Figures in parentheses are angular transformed values

Table 3: Economic benefit cost ratio of various treatments used to control Alternaria blight of fennel

Fungicides	Concentration	Cost of cultivation	Price of fungicides	Labour Rs./ha	Total cost	Seed Yield kg/ha	Gross income	Net profit	B:C ratio
Mancozeb	0.25	40800	1350	1500	43650	1554	124320	80670	1.84
Carbendzim	0.1	40800	924	1500	43224	1348	107840	64616	1.50
Hexaconazole	0.1	40800	672	1500	42972	1501	120080	77108	1.80
Propiconazole	0.1	40800	1740	1500	44040	1086	86880	42840	0.97
Mancozeb + Carbendazim	0.2	40800	1872	1500	44172	1620	129600	85428	1.95
Difenoconazole	0.1	40800	4272	1500	46572	1264	101120	54548	1.17

Selling price Rs/kg = 80
Labour Rs/ spray = 250 (6 labour for 2 spray)
Price of fungicides Rs/kg for 2 spray

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