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Exploitation of fungicides and plant extracts for ecofriendly management of chilli fruit rot disease

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Abstract
Three promising fungicides, tebuconazole (0.1%), carbendazim + mancozeb (0.1%) and propiconazole (0.1%) and two botanicals extract, NSKE (5%) and neem leaf extract (5%) were for the control of pathogen (*C. capsici*) in the field against fruit rot disease of chilli. These fungicides were applied as seed treatment and plant extracts as foliar spray. Results of the study revealed that maximum reduction in disease (69.30%) with minimum per cent disease (17.24) and maximum fruit yield (8.23 q/ ha) were obtained with the application of propiconazole (0.1%) as seed treatment and foliar spray of neem (NSKE 5%) followed by application of propiconazole (0.1%) as seed treatment and foliar spray with neem leaf extract (5 %) resulted in decreased PDI and increased fruit yield.

Keywords: Chilli, *Colletotrichum capsici*, Percent disease index, NSKE

Introduction
Red pepper (*Capsicum annuum* L.) commonly known as chilli, is a prominent vegetable crop of India belonging to the nightshade family, *Solanaceae*. It has 24 chromosomes (2n) and may be herb or sub-shurb of height up to 2.5 m with extensively branched stem having hairy growth with purplish spots near the nodes. The tap root is strong with numerous lateral roots. Chilli fruits are considered vegetable and are botanically berries (Saxena *et al*., 2016). It is a good source of capsaicin (capsaicinoid), vitamin A, vitamin C, riboflavin and thiamine. It contains about 8.8 g, 5.3 g carbohydrates sugar, 1.9 g protein and 534 micro g beta carotene per 100 g chilli (Panda *et al.*, 2010). In our country, chilli is cultivated on an area of about 986.4 thousand hectares with an annual production of 1404.4 thousand tonnes. Though, in Rajasthan, the area under chilli is about 13.7 thousand hectares with annual production of 18.7 thousand tonnes (Anonymous, 2015-16a). In Jaipur, the area under chilli is about 1296 ha with annual production of 584 MT (Anonymous, 2015-16b). Chilli is a universal spice crop of India grown in almost all the states of the country. The quality of the chilli varies from state to state. For example, chilli of Karnataka is known for its oil content, Gujarat quality is majorly known for its sharp color while that of Rajasthan is well known for making pickles.

Fruit rot or anthracnose or die-back of chilli caused by *Colletotrichum capsici* (Sydow) Butler and Bisby is one of the most destructive diseases of chilli in India. The pathogen causes severe damage to ripened fruits and reduce the quality and quantity of immature and mature fruits. This disease was reported first time in India from Coimbatore of Madras Presidency (Sydow, 1913). Due to this disease, more than 50 per cent crop loss has been reported from different parts of India (Ramchandran *et al*., 2007) [14]. In Thiland, Poonpolgul and Kumphai (2007) [13] noticed anthracnose disease (*Colletotrichum* sp.) as most damaging disease of chilli reducing marketable yield up to 80 per cent. The disease has been reported to cause 8-27 per cent yield loss in Maharashtra, 20-60 per cent in Punjab and Haryana and 30-76 per cent in Tamil Nadu (Bansal and Grover, 1969; Sujathabai, 1992 and Datar, 1995) [5, 6]. In India, a calculated loss of 10-54 per cent has been reported in yield of the crop due to the anthracnose disease (Lakshmesha *et al.* 2005) [11]. The loss is high owing to the post and pre-harvest involvement of the pathogen causing a loss of 10-80 per cent of the marketable yield of chilli fruits (Than *et al.*, 2008). Most of work on management of fruit rot of chilli has been done through fungicide alone. In view of the increasing disease incidence in chilli and prolonged and repeated use of fungicides may also result in environmental pollution and non-acceptability of the produce and also development of resistance in pathogen. Recommended integrated management techniques, as no signal specific management program could eliminate chilli anthracnose. Effective control of *Colletotrichum* diseases usually involves the use of a combination of

cultural control, biological control, chemical control and intrinsic resistance. Therefore, in present study, attempts were made to integrate the use of fungicides and botanicals to manage this disease.

Materials and Methods

Three promising fungicides, tebuconazole (0.1%), carbendazim + mancozeb (0.1%) and propiconazole (0.1%) and two botanicals extract, NSKE (5%) and neem leaf extract (5%) were selected for the control of pathogen (*C. capsici*) in the field against fruit rot disease of chilli. These fungicides were applied as seed treatment (Jadon *et al*., 2015) [8], and plant extracts as foliar spray. The seeds of chilli cultivar 'Pusa Jwala' were treated with required dose of fungicide and were rolled on pure culture of *C. capsici* and sown in nursery bed.

The field experiment was laid down in 2.25 m x 1.50 m sized plots having three replications in randomized block design. Thirty day-old seedlings were transplanted in plots from the nursery beds. Twenty five plants in each replication were maintained at distance of 45cm x 30cm plant spacing. The plants were raised by following the normal agronomical practices including irrigation and fertilizers as per requirements.

Chilli plants of 60 days age were inoculated by spraying the spore suspension of *C. capsici* ($3x10^4$ conidia/ml) thoroughly on the plant canopy in the afternoon for creating disease on plants. Foliar sprays of each plant extract was applied after 5 days of inoculation with pathogen and second spray at 15 days interval (as per below schematic representation). Control plots were maintained with spray of water.

The schematic presentation of the treatment is as follows:

T_1 = Seed treatment with tebuconazole (0.1%) and spray of NSKE (5%)

T_2 = Seed treatment with tebuconazole (0.1%) and spray of NLE (5%)

T_3 = Seed treatment with carbendazim + mancozeb (0.1%) and spray of NSKE (5%)

T_4 = Seed treatment with carbendazim + mancozeb (0.1%) and spray of NLE (5%)

T_5 = Seed treatment with propiconazole (0.1%) and spray of NSKE (5%)

T_6 = Seed treatment with propiconazole (0.1%) and spray of NLE (5%)

T_7 = Check

Disease severity was recorded 90 DAS as standard disease rating scale (0-5) described as follow

Fruit area affected	Disease grade	Disease reaction
Healthy	0	Immune (I)
1-5.0 %	1	Resistant (R)
5.1-10.0%	2	Moderately resistant (MR)
10.1-25.0%	3	Moderately susceptible (MS)
25.1-50.0%	4	Susceptible (S)
>50.1%	5	Highly susceptible (HS)

The per cent disease intensity was calculated using the formula of Wheeler (1969) [18].

$$\text{Per cent Disease Intensity} = \frac{\text{Sum of individual ratings}}{\text{Total no. of observations x Maximum disease rating}} \times 100$$

Results and Discussion

Integration of fungicides and botanicals

The integrated use (Table 1) of propiconazole (0.1%) as seed treatment and NSKE (5%) as spray resulted in lowest (17.24%) disease intensity and maximum disease control (69.30%) over check along with highest yield (8.23 q/ha) followed by seed treatment with propiconazole and foliar application of NLE (22.22 PDI, 60.44 per cent disease control and 8.10 q/ha yield). Application of tebuconazole (0.1%) as seed treatment and NSKE (5%) as spray gave 25.55 per cent disease intensity and 54.51 per cent disease control and 7.58 q/ha yield with 122.47 % increased yield. The foliar application of carbendazim + mancozeb (0.1%) as seed treatment and NLE (5%) as foliar spray was showed 34.64 per cent disease intensity that accounted for 38.33 per cent efficacy of disease control and its showed the lowest 6.86 q/ha yield and 101.32 per cent increase yield over control (48.54 PDI and 3.41 q/ha yield).

Most of work on management of fruit rot of chilli has been done through fungicide alone. In view of the increasing disease incidence in chilli and prolonged and repeated use of fungicides may also result in environmental pollution and non-acceptability of the produce and also development of resistance in pathogen. Bailey (1987) [4] and Agrios (2005) [1] recommended integrated management techniques, as no signle specific management program could eliminate chilli anthracnose. Effective control of *Colletotrichum* diseases usually involves the use of a combination of cultural control, biological control, chemical control and intrinsic resistance (Wharton and Dieguez-Uribeondo, 2004). Therefore, in present study, attempts were made to integrate the use of fungicides and botanicals to manage this disease. Results of the study revealed that maximum reduction in disease (69.30%) with minimum per cent disease (17.24) and maximum fruit yield (8.23 q/ ha) were obtained with the application of propiconazole (0.1%) as seed treatment and foliar spray of neem (NSKE 5%). This was followed by application of propiconazole (0.1%) as seed treatment and foliar spray with neem leaf extract (5 %) resulted in decreased PDI and increased fruit yield. Our findings are in agreement with results of Hegde *et al*, (2001) [7] who tested the efficacy of the plant extracts (chilli, ocimum, neem, onion, *Clerodendron*) and fungicides (0.05% carbendazim, 0.2% mancozeb) in controlling *C. capsici* causing fruit rot of chilli and reported that all the plant extracts and fungicides tested exhibited inhibitory activity against the pathogen. Similarly, Krishnam and Reddy (2007) [10] have also been tested differential in sensitivity of carbendazim and thiophanate methyl at different concentrations against different isolates of *C. capsici* and reported that the some isolates are highly sensitive to carbendazim and other were highly sensitive to thiophanate methyl and all the isolates was varied greatly in their per cent inhibition values at all the seven concentrations tested. However, use of botanicals and vermivash was less effective as compared to chemicals. But they are safer in application for vegetables and fruit crops in terms of toxic residues and also eco-friendly for maintaining in the ecological biodiversity in the environment.

Jadon *et al.* (2015) [8] have also been tested various fungicides (hexaconazole, tebuconazole, propiconazole, difenoconazole, vitavax, carbendazim with captan and mancozeb) as seed

treatment against groundnut diseases and found effective in managing soil borne diseases along with yield advantage.

Table 1: Efficacy of fungicides and botanicals against fruit rot of chilli (*C. capsici)* and dry fruit yield (*In vivo*)

Fungicides	Disease severity (%)*			Disease control (%)			Dry fruit yield (q/ha)			Yield increase (%)		
	2015-16	2016-17	Pooled	2015-16	2016-17	Mean	2015-16	2016-17	Pooled	2015-16	2016-17	Mean
T_1	24.44	26.66	25.55	55.56	53.50	54.51	8.05	7.10	7.58	111.29	136.67	122.47
	(29.63)	(31.09)	(30.36)									
T_2	25.00	28.61	26.81	54.55	50.10	52.27	7.95	6.90	7.43	108.66	130.00	118.06
	(30.00)	(32.34)	(31.18)									
T_3	28.88	32.22	30.55	47.49	43.80	45.61	7.65	6.80	7.23	100.79	126.67	112.19
	(32.51)	(34.58)	(33.55)									
T_4	31.72	37.55	34.64	42.33	34.50	38.33	7.05	6.66	6.86	85.04	122.00	101.32
	(34.28)	(37.79)	(36.05)									
T_5	15.31	19.17	17.24	72.16	66.56	69.30	8.75	7.70	8.23	129.66	156.67	141.56
	(23.03)	(25.97)	(24.53)									
T_6	21.11	23.33	22.22	61.62	59.31	60.44	8.65	7.55	8.10	127.03	151.67	137.89
	(27.35)	(28.88)	(28.12)									
T_7	55.00	57.33	56.17	-	-	-	3.81	3.00	3.41	-	-	-
	(47.87)	(49.21)	(48.54)									
Sem $\pm$	0.52	0.60	0.42	-	-	-	0.18	0.17	0.20	-	-	-
CD (p=0.05)	1.56	1.78	1.24	-	-	-	0.54	0.49	0.60	-	-	-

* Average of three replications

** Values in parenthesis are angular transformed

T_1= ST with Tebuconazole & NSKE Spray, T_2=ST with Tebuconazole & NLE spray, T_3=ST with Carbendazim + mancozeb & NSKE spray,

T_4=ST with Carbendazim + mancozeb & NLE spray, T_5=ST with Propiconazole & NSKE spray, T_6= ST with Propiconazole & NLE spray, T_7 = Control

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