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Evaluation of IDM Components for Management of Tomato Powdery Mildew under Protected Cultivation

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A B S T R A C T

Powdery mildew caused by *Oidium neolycopersici* L. Kiss is one of the most important diseases of tomato under polyhouse conditions. During 2014-15, polyhouses of Kangra district (H.P., India) were surveyed and the disease severity was observed between 5.0 to 89.5 per cent affecting both quality and quantity of the harvest. Fourteen hybrids/cultivars of tomato were screened under p house conditions during 2014-15 cropping season, but all were found either susceptible or weakly resistant against powdery mildew. *In vivo* evaluation of bioagents *viz.*, *Trichoderma harzianum*-1 (TH-1), *T. harzianum*-2 (TH-2), *T. viride*-1 (TV-1), *T. viride*-2 (TV-2) and *Pseudomonas fluorescence*-1 (PF-1) @ 10 g/l showed 63.9-75.41 per cent disease control. Among these, both strains of *T. harzianum* (TH-1 and TH-2) were found highly effective in controlling the disease. *In vivo* evaluation of three botanicals *viz.*, *Eupatorium adenophorum*, *Melia azedarach* and *Azadirachta indica* showed that aqueous extract at 100 per cent concentration provided more than 50 per cent disease control being maximum *i.e.* 65.1 per cent was provided by *E. adenophorum*. Three sprays of eight fungicides at 10 days interval were evaluated and hexaconazole 5EC @ 1 ml/l and difenoconazole 25EC @ 0.05 ml/l were found highly effective with 91.0 and 89.2 per cent disease control and 42.0 and 39.0 per cent increase in yield as compared to check, respectively.

Introduction

Tomato (*Solanum lycopersicum* L.) a member of *Solanaceae* family is one of the most popular and widely grown vegetables in the world after potato and stands top in the list of canned vegetables. Tomato plays a significant role in the economy of farmers of Himachal Pradesh. Year round cultivation of tomato can't be done in open fields due to inconsistent weather conditions and biotic factors which influence the production and quality of produce. In Himachal Pradesh, a hill state of India, protected cultivation is gaining importance and tomato as a cash crop is being cultivated throughout the year in polyhouses. Protected cultivation not only provides suitable and congenial microclimate for the crop production but, also for the development of various diseases. Among these, powdery mildew of tomato caused by *Oidium neolycopersici* L. Kiss is one of the most important diseases which reduce production and quality of the produce. The powdery mildew is a dangerous pathogen, which spread through temperate areas of the world and the disease can cause up to 50 per cent yield losses in tomato (Cerkauskas *et al.,* 2011). The host range of the pathogen is broad and it is reported to attack over 60 species in 13 plant families, particularly members of Solanaceae and Curcubitaceae. (Jones *et al.,* 2001). Powdery mildew of tomato caused by *O. neolycopersici* and *L. taurica* has been reported from United States (Kontaxis and Van 1978), Centeral valley (Campbell and Scheuerman 1979), Mexico (Sanchez 1983), Minidoka (Forster 1989), Korea (Woong *et al.,* 1995), Iran (Banihashemi and Zakeri 1996), Florida (Marois *et al.,* 2001), Bolivia (Correll *et al.,* 2005), Venezuella (Montilla *et al.,* 2007), Turkey (Yolageldi *et al.,* 2008), China (Li *et al.,* 2008) and Sebia (Stevanovic *et al.,* 2012). In India, powdery mildew caused by *O. neolycopersici* was first time observed by Baiswar *et al.,* (2009) on *Solanum betaceum*. Singh and Banyal (2015) observed powdery mildew of tomato as one of the most important disease under protected cultivation from Himachal Pradesh. *L. taurica* as a cause of powdery mildew of tomato was reported by Gupta *et al.,* (2013) from Himachal Pradesh. Thomson and Jones (1981) reported 10-90 per cent yield loss in commercial tomato due to powdery mildew. Vallad *et al.,* (2001) reported 50-60 per cent disease incidence and 50 per cent yield loss due to tomato powdery mildew caused by *O. neolycopersici* from Florida. Keeping all these aspects and increasing problem of tomato powdery mildew under protected cultivation in view, a survey was conducted in Kangra district of Himachal Pradesh during 2014-15 to know the status of powdery mildew. Polyhouses from farmer's field in Kangra district were surveyed and high disease severity was recorded from each of the polyhouses. Disease severity varied from 5.0 to 89.0 per cent and highest disease severity of 89 per cent was observed in Kunsal of Kangra district (Himachal Pradesh) with overall average disease severity accounting to 52 per cent. Since, there was no information available on the different aspects of management powdery mildew of tomato under protected cultivation from Himachal Pradesh and even from India, the study was designed for management of powdery mildew of tomato under protected cultivation with the objectives of evaluation of IDM components separately which included the usage of resistant cultivars/hybrids, biological antagonists and chemicals. In the present study, most commonly used cultivars, bioagents and fungicides in the region have been evaluated and it will provide resourceful information on possible management strategies in the region.

Materials and Methods

Host resistance

Fourteen hybrids/cultivars of tomato were screened under net house conditions during 2014-15 cropping season. Ten plants from each of the variety were transplanted to plots and were inoculated with challenge inoculum (<40 conidia per microscopic field at 40X) maintained in specially designed cages. Data on disease severity was recorded using scale 0-4 (Table 1) given by Toyoda (2008).

The data recorded on disease severity of different tomato hybrids/cultivars were further utilized for the calculation of Area Under Disease Progress Curve (AUDPC) and compared with the disease severity. The scale was converted to disease severity by using the formula

The AUDPC was calculated by using formula given by Shaner and Finney (1977).

$$\sum \frac{(y_i + y_{i+1})}{2} t_{i+1} - t_i$$

Where,

y_i = disease severity at time t_i;

y_{i+1} = disease severity at time t_{i+1}

Disease severity index (%) =

$$\frac{\text{Sum of all disease ratings}}{\text{Total no. of plants x maximum disease score}} \text{ X } 100$$

Biological management

In vivo evaluation of botanicals

To study the effect of botanicals as foliar spray for the management of powdery mildew of tomato, aqueous extract of three botanicals *viz., Eupatorium adenophorum, Melia azedarach* and *Azadirachta indica* were prepared and tested against the powdery mildew pathogen under net hose conditions in pots.

Preparation of aqueous extract

The aqueous extract was prepared by soaking 300 g of fine powder of each botanical (leaves) overnight in 600 ml of sterilized distilled water (1:2 W/V) in 1000 ml conical flask. Next day, the extract obtained was filtered through double layer of muslin cloth and twice through Whatman no. 1 filter paper to get clear filtrate. This was considered as standard aqueous extract for further dilutions (Sheo Raj Singh *et al.,* 2007; Aditi, 2015). The plant extract were tested at 10, 25, 50, 75 and 100 per cent concentrations (Aditi, 2015). The aqueous extracts of botanicals were diluted in distilled water to get the desired concentrations. To study the effect of these botanical extract as foliar spray, an experiment was conducted in pots with four treatments replicated four times. In each replication, three pots were taken and each pot having two seedlings of 'Avtar' hybrid. Data on 18 tomato plants were recorded in each treatment. Three sprays of each bioagents were given at 10 days interval. First spray of extract was given on the appearance of disease in month of April and data on powdery mildew severity was recorded at 10 days interval. Plants sprayed with water served as control.

In vivo evaluation of bioagents

To study the efficacy of bioagents against tomato powdery mildew pathogen, five bioagents *viz., Trichoderma harzianum*-1 (TH-1) *T. viride*-1 (TV-I) and *Pseudomonas fluorescence* (PF-I) from AAU, Anand, *T. harzianum*-2 (TH-2) and *T. viride*-2 (TV-2) from CSKHPKV were evaluated against powdery mildew of tomato in pots under net house conditions as foliar sprays at three doses *i.e.* 5, 7.5 and 10 g/l (CFU of 1 X 10^6 to 1 X 10^8) (Aditi, 2015). The experiment was conducted in pots having six treatments replicated thrice. In each replication, three pots were taken and each pot having two seedlings of 'Avtar' hybrid. Data on 18 tomato plants were recorded in each treatment. The first spray of each bioagent was given on the first appearance of disease in the month of April and data on powdery mildew severity were recorded at 10 days interval. Three sprays of each bioagents were given at 10 days interval. Plants sprayed with water served as control.

Chemical management

To test the bioefficacy of fungicides against the disease, commonly used 8 fungicides were selected *i.e.* four systemic fungicides *viz.,* hexaconazole 5EC (Contaf), triadiemefon 25WP (Bayleton), difenoconazole 25EC (Score) and Azoxysrobin 23EC (Mirador) and four non-systemic fungicides *viz.,* dinocap 48EC (Karathane), mancozeb 75WP (Indofil), propineb 70WP (Antracol) and captan 50WP (Captan) were evaluated as foliar spray for the management of powdery mildew. An experiment was conducted in the polyhouse in Randomized Block Design (RBD) and all the treatments were replicated thrice. Seedlings of tomato hybrid 'Avtar' were transplanted in polyhouse during 2015-2016 with row × plant spacing of 60×30 cm. The first spray of fungicides was given on the first appearance of disease and data on powdery mildew disease severity were recorded before first spray and after 10 days of each spray. Data on 36 tomato plants (12 plants per replication) were recorded in each treatment. For foliar spray, each of the chemicals was evaluated individually by giving three sprays at 10 days interval.

Statistical analysis

The data recorded were subjected to statistical analysis wherever required. The differences exhibited by the treatments in various experiments were tested for their significance by employing CRD and RBD. All the data were analyzed by using CPCS-1 software.

Results and Discussion

The different IDM components *i.e.* evaluation of resistant cultivars, biological and chemical control were studied to manage the powdery mildew of tomato caused by *O. neolycopersici*.

Evaluation of tomato hybrids/cultivars for resistance against tomato powdery mildew

High disease severity *i.e.* 40- 65 per cent were observed in all the 14 tomato varieties /hybrids being minimum *i.e.* 40 per cent in Palam Tomato Hybrid-1 and Naveen and maximum *i.e.* 65 per cent disease severity was observed in Jyoti, Pusa Hybrid-1 and Him Sona.

Among all the hybrids/cultivars, 11 hybrids/cultivars were found susceptible having more than 50 per cent disease severity and three cultivars Palam Pride, Palam Tomato Hybrid-1 and Naveen were having less than 50 per cent disease severity and designated as Weakly Resistant (Table 2). The AUDPC value indicated that varieties having maximum disease severity *i.e.* 65 per cent in Jyoti, Pusa Hybrid-1 and Him Sona were also having maximum *i.e.* 805.0, 910.0 and 735.0 AUDPC value, respectively. The minimum value of AUDPC *i.e.* 409.5 was observed in both Palam Tomato Hybrid-1 and Naveen also having low disease severities. So, none of the evaluated hybrid/cultivar was found resistant against powdery mildew of tomato.

Li *et al.,* (2008) while evaluating different tomato cultivars against powdery mildew found that all *L. esculentum* cultivars were susceptible while *L. peruvianum* LA 2172 and *L. hirsutum* G1.1560 were resistant. Singh *et al.,* (2013) screened 17 varieties of tomato against powdery mildew and found only three varieties *i.e.* Punjab Chuhara, RCMT- 2 and Pant T-8 as completely resistant.

Biological management

In vivo evaluation of bioagents against powdery mildew of tomato

At 5.0 g/l, among all the tested bioagents, *T. harzianum*-1 was most effective and gave 32.0 per cent disease control followed by *T. harzianum*-2 which gave 29.1 per cent disease control over the check. At 7.5 g/l also, *T. harzianum*-1 gave maximum disease control *i.e.* 50.1 per cent followed by *T. harzianum*-2 which gave 46.4 per cent disease control over check. However, at the concentration of 10.0 g/l, *T. harzianum*-1 provided maximum disease control *i.e.* 75.4 per cent followed by *T. harzianum*-2 with non-significant difference and gave 71.1 per cent powdery mildew disease control over check. *P. fluorescence*-1 provided least but, good control of disease (63.9 per cent) among all the bioagents over the control (Table 3). Among all the bioagents, both strains of *T. harzianum* (TH-1 and TH-2) were found highly effective *i.e.* more than 71 per cent disease control @ 10.0 g/l and were statistically at par with each other. Both the strains of *T. viride* (TV-1 and TV-2) were also statistically at par in controlling powdery mildew of tomato and gave 66.7 to 68.3 per cent disease control, respectively. However, both the isolates of *T. harzianum* found to be the best among the tested bio agents against powdery mildew of tomato.

Kamal *et al.,* (2007) reported *Pseudomonas fluorescence* as a good biocontrol agent in reducing powdery mildew of tomato. Velandia and Cotes (2007) found that formulated and unformulated prototype of *Trichoderma koningii* reduced tomato powdery mildew incidence and disease severity by 25- 28 per cent and 28- 66 per cent, respectively. Abdel-Kader *et al.,* (2012) evaluated five bioagents against tomato powdery mildew and found that *Trichoderma harzianum* and *Bacillus subtilis* showed significant reduction in disease incidence of tomato powdery mildew as compared to other bioagents. Bucio villalabos and Martinez (2016) observed that C4 strain of *T. harzianum* among tested isolates gave better results when the formulation was sprayed on foliage in combination with drench to stem base against powdery mildew of tomato.

So, three sprays at 10 days of interval of all the tested bioagents at 10 g/l found effective against powdery mildew of tomato.

In vivo evaluation of botanicals against tomato powdery mildew

Evaluation of botanicals against powdery mildew of tomato revealed that *E. adenophorum* was found to be highly effective under net house conditions. At 10 per cent concentration, *E. adenophorum* gave 6.3 per cent disease control among evaluated botanicals followed by *A. indica* and *M. azedarach* which gave 4.4 and 2.9 per cent disease control, respectively as compared to check (Table 4).

At 25, 50 and 75 per cent concentrations, against tomato powdery mildew *E. adenophorum* gave high disease control *i.e.* 18.5, 53.5 and 58.8 per cent followed by *A. indica* which gave 9.7, 45.3 and 51.9 per cent over the check, respectively.

At 100 per cent concentration, *E. adenophorum* provided maximum *i.e.* 65 per cent disease control followed by *A. indica* with 57.0 per cent and minimum disease control *i.e*. 53.0 per cent was provided by *M. azedarach* as compared to check. However, all the three tested botanicals at 100 percent concentrations as 3 foliar sprays at 10 days interval gave more than 50 per cent tomato powdery mildew control and can be used in the disease management strategies. *E. adenophorum* at 100 per cent found to be the best among tested botanicals.

Naturally occurring biologically active compounds from plants are less hazardous than synthetic compounds. Szczech *et al.,* (2000) found that brewery refuse extract was effective against tomato powdery mildew at 30, 60 and 100 per cent concentrations. Ko *et al.,* (2003) evaluated seven oils and found high level of antifungal activity of sunflower oil against *O. neolycopersici* causing powdery mildew of tomato.

Sudha and Lakshman (2009) reported that leaf extract of *Azadirachta indica* (10 per cent) and bulb extract of *Allium sativum* and *A. cepa* (eight per cent) were highly effective against chili powdery mildew.

Table.1 0-4 scale used for screening of tomato cultivars (Toyoda, 2008)

Score	Visual observation	Response
0	No visible pustule	Completely resistant
1	Pustule with less than 10% leaf surface area	Moderately resistant
2	Pustule with less than 50% leaf surface area	Weakly resistant
3	Pustule with less than 75% leaf surface	Moderately Susceptible
4	Pustule with more than 76% leaf surface area	Susceptible

Table.2 Evaluation of tomato hybrids/cultivars against *Oidium neolycopersici*

Hybrid/Cultivar	Per cent Severity	Rating	Reaction Type	AUDPC
Jyoti	65	3	S	805.0
Pusa Hybrid-1	65	3	S	910.0
Him Sona	65	3	S	735.0
K-21	62	3	S	686.0
R-21	62	3	S	661.5
P-21	60	3	S	679.0
S-22	60	3	S	707.0
Arshit	60	3	S	672.0
Rakshita	50	2	S	535.5
Palam Pink	50	2	MS	518.0
Palam Pride	48	2	WR	490.0
Palam Tomato Hybrid 1	40	2	WR	409.5
Naveen	40	2	WR	409.5
Avtar	60	3	S	731.5

*WR- Weakly Resistant; MS- Moderately Susceptible; S-Susceptible.

Table.3 *In vivo* evaluation of bioagents against *O. neolycopersici* causing powdery mildew of tomato

Bioagent	Per cent disease severity at different doses (g/l)*			Per cent disease control at different doses (g/l)		
	5.0	**7.5**	**10.0**	**5.0**	**7.5**	**10.0**
***Trichoderma harzianum -1* (TH-1)**	31.3 (34.0)	23.3 (28.8)	11.3 (19.6)	32.0	50.1	75.4
***Trichoderma harzianum* – 2 (TH-2)**	32.6 (34.8)	25.0 (29.9)	13.0 (21.1)	29.1	46.4	71.7
***Trichoderma viride -1* (TV-1)**	37.0 (37.0)	28.6 (31.9)	15.3 (23.0)	19.5	38.7	66.7
***Trichoderma viride*– 2 (TV-2)**	34.6 (36.0)	28.0 (32.3)	14.6 (22.5)	24.7	40.0	68.3
***Pseudomonas fluorescence* (PF-1)**	38.7 (38.4)	30.0 (33.2)	16.6 (24.1)	15.9	35.7	63.9
Control	46.0 (42.7)	46.7 (43.1)	46.0 (42.7)	-	-	-
CD (p=0.05)	1.99	2.16	2.38	-	-	-

*Figures within parentheses are arc sine transformed values

Table.4 *In vivo* evaluation of botanical against *Oidium neolycopersici* causing powdery mildew of tomato

Botanical	Per cent disease severity at different concentration*					Per cent disease control at different concentration				
	10	**25**	**50**	**75**	**100**	**10**	**25**	**50**	**75**	**100**
Eupatorium adenophorum	41.7 (40.2)	35.2 (36.4)	20.0 (26.5)	18.0 (25.1)	15.0 (22.7)	6.3	18.5	53.5	58.8	65.1
Melia azedarach	43.2 (41.1)	40.0 (39.2)	24.7 (29.8)	23.0 (28.6)	20.2 (26.7)	2.9	7.4	42.5	47.3	53.0
Azadirachta indica	42.5 (40.7)	39.0 (38.6)	23.5 (29.0)	21.0 (27.2)	18.5 (27.2)	4.4	9.7	45.3	51.9	57.0
Control	44.5 (41.8)	43.2 (41.2)	43.0 (40.9)	43.7 (41.4)	43.0 (40.9)	-	-	-	-	-
CD (p=0.05)	0.83	0.88	1.89	1.37	1.49	-	-	-	-	-

*Figures within parentheses are arc sine transformed values

Table.5 Fungicidal management of powdery mildew of tomato under protected cultivation

Fungicide	Dose (%)	% disease severity after 10 days*			% Disease control after 3rd spray	Yield	
		1st spray	**2nd spray**	**3rd spray**		**Yield (q/100 m²)**	**% Yield increase**
Hexaconazole 5 EC	0.10	23.3 (28.8)	17.6 (24.8)	7.4 (15.8)	91.0	13.8 (21.8)	42.0
Triadimefon 25 WP	0.05	28.3 (32.1)	22.8 (28.5)	11.1 (19.5)	86.0	13.0 (21.4)	34.0
Difenoconazole 25 EC	0.05	25.3 (30.2)	19.2 (25.9)	8.5 (16.9)	89.2	13.5 (21.5)	39.2
Azoxystrobin 23 EC	0.10	31.7 (34.2)	33.4 (35.3)	48.4 (44.1)	39.0	11.5 (19.8)	17.9
Dinocap 48EC	0.10	28.4 (32.2)	23.1 (28.7)	11.3 (19.6)	85.7	12.8 (20.9)	32.1
Mancozeb 75WP	0.25	32.2 (34.6)	34.7 (36.0)	49.5 (44.7)	37.5	11.3 (19.6)	16.0
Propinenb 70WP	0.25	32.5 (34.6)	37.2 (37.6)	60.9 (51.3)	23.1	10.4 (18.8)	6.8
Captan 50WP	0.30	32.8 (34.9)	38.8 (38.5)	63.9 (53.0)	19.3	9.9 (18.4)	1.8
Control	-	37.4 (37.7)	49.4 (44.6)	79.2 (62.9)	-	9.7 (18.1)	-
CD (p=0.05)	-	1.83	2.05	2.23	-	0.36	-

* Figures within parentheses are arc sine transformed values

Chemical management

Data recorded from the evaluation of chemicals (Table 5) indicated that out of eight fungicides tested, three sprays of hexaconazole 5 EC @ 1 ml/l was most effective and gave 91.0 percent disease control with 42.0 per cent increase in yield, followed by difenoconazole 25EC @ 0.5 ml/l which gave 89.2 per cent disease control with 39.2 per cent increase in yield over the check and statistically at par with hexaconazole 5EC. Triadimefon 25WP @ 0.5 g/l and dinocap 48EC @ 1 ml/l were also found effective for the management of powdery mildew of tomato and provided 86.0 and 85.7 per cent disease control with 34.0 and 32.1 per cent increase in yield over control, respectively, under protected cultivation. Statistically, dinocap 48EC was at par with triadimefon 25WP.

Among systemic fungicides, azoxystrobin 23EC @ 1 ml/l was found to be least effective with 39.0 per cent disease control and 17.9 per cent increase in yield and statistically at par with non systemic fungicide *i.e.* mancozeb 75WP @ 2.5 g/l which provided 37.5 per cent disease control and 16.0 per cent increase in yield as compared to check. propineb 70WP @ 2.5 g/l was found also found less effective with 23 per cent disease control and 68 per cent increase in yield as compare to control.

Among all the fungicides, captan 50WP @ 3 g/l was least effective in controlling powdery mildew of tomato under protected cultivation provided only 19.3 per cent disease control with 1.8 per cent increase in yield as compared to check. During the study, it was also observed that the disease severity gradually decreased from initial disease severity with sprays of hexaconazole 5EC (23.3-7.4 per cent), triadimefon 25WP (28.3-11.1 per cent), difenoconazole 25EC (25.3-8.4 per cent) and dinocap 48EC (28.4-11.3 per cent), however, it was increased in other fungicide *i.e.* azoxystrobin 23EC (31.7-48.4 per cent), mancozeb 75WP (32.2-63.9 per cent), propineb 70WP (32.5-60.9 per cent) and captan 50WP (32.8-63.9 per cent) but, less as compared to check.

Hence, it was observed that three sprays at 10 days interval of hexaconazole 5EC @ 1 ml/l or difenconazole 25EC @ 0.5 ml/l were highly effective for the management of tomato powdery mildew. Triadimefon 25WP @ 0.5 g/l and dinocap 48EC @ 1 ml/l were also found effective and can be used in the management of disease. However, hexaconazole EC was found best. Maximum tomato powdery mildew control and increase in the fruit yield was obtained with three sprays of Score (difenoconazole), followed by Tilt (propiconazole), Contaf (hexaconazole) and Folicur (tebuconazole) (Anonymous 2013).

Hooda *et al.*, (2011) found that out of IPM, Chemical and organic modules, there was significant yield enhancement in chemical and IPM modules compared to purely organic module against major pests and diseases of tomato. Cerkauskas and Brown (2015) reported Acibenzolar-5-methyl, trifloxystrobin, azoxystrobin, sulfur and JMS-stylet oil were effective in controlling powdery mildew of tomato.

In conclusion, none of the evaluated 14 tomato hybrid/cultivar was found resistant against the powdery mildew disease. Foliar sprays of tested bioagents (10 g/l) and botanicals (100%) were found very effective in the management of the disease. Both the strains of *T. harzianum* (TH-1 and TH-2) were highly effective and gave 75.4 and 71.7 per cent disease control at 10 g/l, respectively. *E. adenophorum* was highly effective and gave 65.1 per cent disease control at 100 per cent concentration followed by *A. indica* which gave 57.0 per cent disease control among the tested botanicals. However, least but good disease control (53.0%) was also provided by *M. azedarach*. Three sprays at 10 days interval of hexaconazole 5EC @ 1 ml/l or difenoconazole 25EC @ 0.5 ml/l were highly effective for the management of powdery mildew of tomato.

Overall, three sprays of bioagents at 10 g/l and botanicals at100 per cent concentration from the onset of first appearance of symptom or spray of hexaconazole 5EC @ 1 ml/l found to be the best suggested for effectively managing the tomato powdery mildew.

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