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The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2023; 12(5): 3971-3975

www.thepharmajournal.com
Received: 01-02-2023
Accepted: 05-03-2023

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Management of purple blotch of garlic caused by *Alternaria porri*

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Abstract
Among 10 fungicides,10 botanicals and 8 bio-agents were evaluated in *In vitro* condition against *Alternaria porri*, 0.1% Azoxystrobin-23 EC, Tebuconazole-25 EC, Mancozeb-75 WP, *Allium sativum* (15%) and *Trichoderma harzianum* recorded the maximum inhibition of mycelial growth of *Alternaria porri*. The field evaluation of different fungicides and botanicals during *Rabi* 2020-21 indicated that 0.1% Tebuconazole-25 EC was significantly effective in reducing the disease intensity by recording a Percent Disease Index of 20.00 and yield of 86.00 q/ha. 0.1% Azoxystrobin-23 EC, 0.2% Mancozeb-75 WP, 0.2% Propineb-50 WP, 0.1% Hexaconazole-5 EC and *Allium sativum* cloves extract were next best treatments in reducing the disease intensity by recording a PDI of 21.11, 23.33, 24.44, 27.40 and 42.22 and yield of 83.94 q/ha, 82.44 q/ha, 79.37 q/ha, 76.43 q/ha and 66.60 q/ha respectively. Again during *Rabi* 2021-22 among fungicides 0.1% Azoxystrobin-23 EC was significantly effective in reducing the disease intensity by recording a PDI of 20.74 and yield of 84.20 q/ha. 0.1% Tebuconazole-25 EC, 0.2% Mancozeb-75 WP, 0.2% Propineb-50 WP, 0.1% Hexaconazole-5 EC and *Allium sativum* cloves extract were next best treatments found effective in reducing the disease intensity by recording a PDI of 22.22, 23.33, 25.18, 26.54 and 43.33 and yield of 84.50 q/ha, 82.96 q/ha, 79.40 q/ha, 78.67 q/ha and 68.20 q/ha respectively.

Keywords: *Alternaria porri*, fungicides, garlic, management, purple blotch

Introduction
Garlic (*Allium sativum* L.) is an important Spice crop cultivated all over the country during Rabi season except in Ooty hills of Tamil Nadu where it is grown during rainy season. India is the second major producer of Garlic having 2.01 lakh ha. area, 1058 lakh mt production and 5.27 t/ha productivity next after China. India exported 22665.99 mt. Garlic amounting Rs. 3957.75 lakh during 2018-19 (Anon., 2020) [3]. It is widely used in flavouring of food, preparation of chutneys, pickles, curry powder, tomato ketch-up etc. Besides nutritive values, it is included in Indian system of medicines (Ayurvedic, Unani and Siddha) as a carminative and gastric stimulant to help digestion and absorption of food (Sankaracharya, 1974) [16]. It is rich source of carbohydrates, proteins, phosphorus and volatile oil. Garlic crop is affected by various diseases of which, purple blotch caused by *Alternaria porri* (Ellis) Cif. is a major constraint and causes severe yield loss
(Mishra *et al*., 2009) [11]. Spraying of broad-spectrum fungicides like Thiram, Captan and Copper oxy chloride has been recommended for control of purple blotch of garlic. Control achieved by these chemicals is inadequate. Therefore, it is thought worthwhile to test the efficacy of more promising chemicals like Propineb-50 WP, Metiram-50 WP, Chlorothalonil-75 WP, Tebuconazole-25 EC, Hexaconazole-5 EC, Azoxystrobin-23 EC, Fenamidone-10 WP, Myclobutanil-10 WP against fungus. Not much light has been shed on biological control, botanicals which are effective against *Alternaria porri*. Hence, an attempt has been made to test commonly available botanicals and bio agents against the pathogen.

Materials and Methods
a. In vitro Evaluation of Fungicides
Ten fungicides were evaluated with different modes of action at recommended dose in the laboratory for their efficacy against *Alternaria porri* by the poisoned food technique (Nene and Thapliyal, 1979) [13]. The molten sterilized PDA was used as nutrient medium and required quantity of each fungicide was added separately so as to get a required concentration of that fungicide. The fungicides were thoroughly mixed by stirring and about 15 ml poisoned medium was poured to each of the 90 mm petri dishes and allowed for solidification.

The actively growing periphery of 9 day old culture of *Alternaria porri* was carefully cut by using a gel cutter and transferred aseptically to centre of each petri dish containing the poisoned solid medium. Suitable control was maintained by growing the cultures on PDA without the fungicides (Table-1). The plates were incubated at 27±1 °C for 9 days and the colony diameter was recorded 9 days after growth. Each treatment was replicated 3 times. The percent inhibition of mycelial growth over control was calculated using the formula of Vincent (1927) [25].

$$I = \frac{C-T}{C}$$

I = percent inhibition of mycelial growth
C = radial growth of fungus in control
T = radial growth of fungus in treatment.

b. *In vitro* Evaluation of Botanicals

The fresh leaves and other parts of healthy plants were collected and thoroughly washed with tap water then air dried. Aqueous plant extract was prepared by grinding 100g leaves/other parts with 100ml distilled water (w/v) using a blender and filtrate was collected by passing through double layered muslin cloth. The supernatant was taken as standard plant extract solution (100%). All the extracts obtained were passed through filter paper used for assay. The poisoned food technique (Nene and Thapliyal, 1979) [13] was followed to evaluate the efficacy of botanicals in laboratory against *Alternaria porri* at 15% concentration (Table-2). Each treatment was replicated 3 times. The method followed for conducting the experiment was same as that used for fungicide evaluation.

c. *In vitro* Evaluation of Bio-agents

Interaction of eight antagonists were studied by following dual culture technique (Dennis and Webster, 1971) [7]. The interaction of *Alternaria porri* with antagonistic organisms were evaluated in the laboratory, 20 ml of PDA was poured into 90 mm petri dishes and allowed for solidification. Discs of 5 mm of *Alternaria porri* taken from 9 day old culture was placed at one end of the petri dish and respective antagonistic organisms were inoculated at the opposite side (Table-3). A control was maintained by inoculating only *Alternaria porri* at one end in case of fungal antagonistic. In case of bacterial antagonistic *Alternaria porri* was placed at both ends of petri plates and bacterial culture was inoculated at centre of the petri plate, control was maintained by inoculating *Alternaria porri* at the both the ends of the petri plates. Each treatment was replicated three times and incubated for 6 days at 27 ± 1 °C. The activity of antagonistic organisms were recorded by measuring the colony diameter of *Alternaria porri in* each treatment and compared with control.

d. Management of purple blotch, *Alternaria porri*

The field experiment was laid out in Randomized Complete Block Design with 13 treatments and 3 replications during *Rabi* 2020-21 and 2021-22 at College of Horticulture, Bidar, Karnataka. Healthy Rajalli gadde cultivar seedlings were planted in the field with 15 cm X 10 cm (row to row X plant to plant) spacing in plot size of 3.6 m X 1.8 m. All other cultural practices and pest control practices were followed as recommended in package of practices (Anonymous, 2017) [2]. The first spraying was carried out as soon as first symptom of disease was noticed in the field. Four sequential sprays of fungicides and botanicals were taken at an interval of 15 days (Table-4 and 5). Disease severity was recorded on ten randomly selected plants in each plot, just one day before each spraying and fifteen days after last spraying. Observations on severity of disease on foliage was recorded by using 0 to 5 point scale (Sharma, 1986) [17] and PDI was worked out. The bulb yield in each plot was recorded and computed to hectare basis.

Observations on severity of disease on foliage was recorded by using 0 to 5 point scale

Scale	Severity
0	No disease symptoms
1	A few spots towards tip covering 1 to 10 percent leaf area
2	Several dark purplish brown patch covering 11 to 20 percent leaf area
3	Several patches with paler outer zone covering 21 to 40 percent leaf area
4	Leaf streaks covering 41 to 75 percent leaf area and breaking of the leaves from center
5	Leaf streaks covering more than 76 percent leaf area followed by complete drying and breaking of the leaves from the center.

Percent Disease Index was worked out as follows.

$$\text{Percent Disease Index (PDI)} = \frac{\text{Sum of individual ratings}}{\text{Number of plants or leaves examined X maximum disease grade}} \text{ X } 100$$

Results and Discussion

a. *In vitro* Evaluation of Fungicides

The results indicated that significant difference among fungicides in inhibiting the growth of the *Alternaria porri.* Among ten fungicides were evaluated with different mode of action Azoxystrobin-23 EC (93.60%) recorded maximum inhibition of mycelia growth of pathogen followed by Tebuconazole-25 EC (90.40%), Mancozeb-75 WP (82.34%), Propineb-50 WP (80.46%), Hexaconazole-5EC (76.57%), Fenamidone-10 WP (73.67%) and least inhibition was observed in Chlorothalonil-75 WP (47.44%) (Table-1). The results on the efficacy of Mancozeb-75 WP are in conformity with Chethana *et al.* (2011) [5]. The results are in agreement with Arunakumara (2006) [4] who reported propineb-50 WP as effective fungicide against *A. solani* causing early blight of tomato. Chethana *et al.*, 2012 [6] reported that Chlorothalonil-75 WP as less effective against *A. porri* in onion crop

Table 1: *In vitro* evaluation of fungicides against *Alternaria porri*

Treatments	Fungicides	Concentration (%)	Percent inhibition of mycelia growth
T1	Propineb -50WP	0.2	80.46[d]
T2	Metiram-50WP	0.2	58.43[h]
T3	Mancozeb-75WP	0.2	82.34[c]
T4	Chlorothalonil-75WP	0.2	47.44[i]
T5	Copper oxy chloride-50WP	0.3	72.04[g]
T6	Hexaconazole-5EC	0.1	76.57[e]
T7	Azoxystrobin-23EC	0.1	93.60[a]
T8	Fenamidone-10WP	0.1	73.67[f]
T9	Tebuconazole-25EC	0.1	90.40[b]
T10	Myclobutanil-10WP	0.1	72.74[fg]

Note: In the vertical columns means followed by same letters are not different statistically by Duncan Multiple Range Test (DMRT) (P=0.01).

b. *In vitro* Evaluation of Botanicals

The results revealed that effect of plant extracts on the fungal growth was significant. The *Allium sativum* cloves extract was found effective in inhibiting the mycelia growth (64.64%) followed by *Clerodendron inerme* (57.10%), *Aloe vera* (55.14%), *Eucalyptus globes* (48.30%) and least inhibition was observed in *Glyricidia maculata* (26.04%) (Table-2). The results are in conformity with Prasad and Naik (2003) [15] and Mesta *et al.* (2011) [10] where garlic clove extract was found effective in inhibiting the mycelial growth of *Alternaria solani* and *Alternaria helianthi* respectively. The effectiveness of garlic clove extract as a pesticide is due to volatile oil which contains dialyl disulphide, diallyl trisulphide and sulphodoxides derived from allicin (Vijayalakshmi *et al.*, 1999) [19]. Pramodkumar (2007) [14] reported *Clerodendron* leaf extract as one of the best plant extract in inhibiting the mycelial growth of *Alternaria porri.*

Table 2: *In vitro* evaluation of botanicals against *Alternaria porri*

Treatments	Botanicals	Plant Parts used	Concentration (%)	Percent inhibition of mycelia growth
T1	*Allium cepa*	Bulbs	15	28.47[i]
T2	*Allium sativum*	Cloves	15	64.64[a]
T3	*Clerodendron inerme*	Leaves	15	57.10[b]
T4	*Azadirachta indica*	Leaves	15	39.20[e]
T5	*Lantana camera*	Leaves	15	35.40[f]
T6	*Aloe vera*	Leaves	15	55.14[c]
T7	*Ocimum sanctum*	Leaves	15	33.87[g]
T8	*Glyricidia maculata*	Leaves	15	26.04[j]
T9	*Eucalyptus globes*	Leaves	15	48.30[d]
T10	*Durantha repens*	Leaves	15	31.40[h]

Note: In the vertical columns means followed by same letters are not different statistically by Duncan Multiple Range Test (DMRT) (P=0.01).

c. *In vitro* Evaluation of Bio-agents

All the *Trichoderma* sp inhibited the growth of *Alternaria porri* effectively. Among these antagonists *Trichoderma harzianum* showed highest inhibition (56.00%) followed by *Trichoderma viride* (53.00%) (Table-3). Imtiaz and Lee (2008) [9] reported *Trichoderma harzianum* and *Trichoderma virens* as most effective in inhibiting the growth of *Alternaria porri.* The next best antagonist was *Chaetomium globosum* with 42.00% inhibition of the pathogen. Vannacci and Harman (1987) [18] have reported *Chaetomium globosum* as one of the effective antagonist of *Alternaria brassicola*. The entamopathogenic fungi *viz., Beauveria bassiana,Verticillium lecanii and Metarhizium anisopliae* were less effective and could inhibit the pathogen up to 23.00%, 21.00% and 17.00% respectively. Ineffectiveness of *B. bassiana* and other entomopathogenic fungi against *A. solani* maybe due to entomopathogenic nature (Anju Sharma *et al.*, 2010) [1].

Table 3: Effect of different antagonists on growth of *Alternaria porri*

Treatments	Antagonists	Percent inhibition of mycelia growth
T1	*Trichoderma harzianum*	56.00[a]
T2	*Trichoderma viride*	53.00[b]
T3	*Chaetomium globosum*	42.00[c]
T4	*Beauveria bassiana*	23.00[e]
T5	*Verticillium lecanii*	21.00[e]
T6	*Metarhizium anisopliae*	17.00[f]
T7	*Pseudomonas fluorescence*	21.00[e]
T8	*Bacillus subtilis*	31.67[d]

Note: In the vertical columns means followed by same letters are not different statistically by Duncan Multiple Range Test (DMRT) (P=0.01).

d. Management of purple blotch, *Alternaria porri*

In subsequent sprays all the fungicides and botanicals treated plots recorded significantly less percent disease index over control. During *Rabi* 2020-21 among fungicides 0.1% Tebuconazole-25 EC was significantly effective in reducing the disease intensity by recording a PDI of 20.00 and yield of 86.00 q/ha (Table-4). 0.1% Azoxystrobin-23 EC, 0.2% Mancozeb-75 WP, 0.2% Propineb-50 WP, 0.1% Hexaconazole-5 EC and 0.1% Fenamidone-10 WP were next best treatments found effective in reducing the disease intensity by recording a PDI of 21.11, 23.33,24.44, 27.40 and 28.51 and yield of 83.94 q/ha, 82.44 q/ha, 79.37 q/ha, 76.43 q/ha and 78.44 q/ha respectively. Among botanicals tested, PDI of 42.22 and yield of 66.60 q/hq was recorded in *Allium sativum* cloves extract at 15% concentration. In the control plot highest PDI of 50.00 and yield of 62.00 q/ha was recorded.

Table 4: Effect of different fungicides and botanicals on purple blotch of Garlic caused by *Alternaria porri* during – *Rabi*, 2020-21

Details of treatments	Mean PDI	Bulb yield (q/ha)	Percent yield increase over control
T1- 0.3% Copper oxy chloride-50WP	31.11^{d}	74.50^{f}	20.16
T2-0.2% Metiram-50WP	32.22^{d}	72.57^{g}	17.04
T3-0.2% Mancozeb-75WP	23.33^{e}	82.44^{c}	32.96
T4- 0.2%Propineb -50WP	24.44^{e}	79.37^{d}	28.01
T5-0.1%Hexaconazole-5EC	27.40^{d}	76.43^{e}	23.27
T6- 0.1%Azoxystrobin-25EC	21.11^{ef}	83.94^{b}	35.38
T7-0.1% Fenamidone-10WP	28.51^{d}	78.44^{d}	26.51
T8-0.1% Myclobutanil-10WP	30.00^{d}	72.20^{g}	16.45
T9-0.1%Tebuconazole-25EC	20.00^{f}	86.00^{a}	38.70
T10-15%*Allium sativum*	42.22^{c}	66.60^{i}	7.41
T11-15% *Aloe vera*	45.55^{b}	68.30^{h}	10.16
T12- 15% *Clerodendron inerme*	46.66^{b}	64.70^{j}	4.35
T13-Control	50.00^{a}	62.00^{k}	-

Note: In the vertical columns means followed by same letters are not different statistically by Duncan Multiple Range Test (DMRT) (P=0.05).

During *Rabi* 2021-22 among fungicides 0.1% Azoxystrobin-23 EC was significantly effective in reducing the disease intensity by recording a PDI of 20.74 and yield of 84.20 q/ha (Table-5).0.1% Tebuconazole-25 EC, 0.2% Mancozeb-75 WP, 0.2% Propineb-50 WP, 0.1% Hexaconazole-5 EC and 0.1% Myclobutanil-10 WP were next best treatments found effective in reducing the disease intensity by recording a PDI of 22.22, 23.33, 25.18, 26.54 and 27.77 and yield of 84.50 q/ha, 82.96 q/ha, 79.40 q/ha, 78.67 q/ha and 71.44 q/ha, respectively. Among botanicals tested, PDI of 43.33.00 and yield of 68.20 q/ha was recorded in *Allium sativum* cloves extract at 15% concentration. In the control plot highest PDI of 51.10 and yield of 61.00 q/ha was recorded. Studies conducted by Wangikar *et al*., (2012) [21] on management of purple blotch of onion in Marathawada region of Maharashtra revealed that lowest disease severity of purple blotch with spray of Mancozeb-75 WP at 0.25%, Hexaconazole-5 EC at 0.1% and Difenconazole-25 EC at 0.05%. Gupta *et al*., (2012) reported that systemic fungicides Tebuconazole-25 EC at 0.1% and Azoxystrobin-23 EC at 0.1% effectively controlled purple blotch disease of garlic. The results on the effectiveness of foliar application of *Allium sativum* cloves extract in the management of *Alternaria* blight are in conformity with Nashwa and Abo-Elyousr (2012) [12].

Table 5: Effect of different fungicides and botanicals on purple blotch of Garlic caused by *Alternaria porri* during – *Rabi*, 2021-22

Details of treatments	Mean PDI	Bulb yield (q/ha)	Percent yield increase over control
T1- 0.3% Copper oxy chloride-50WP	35.55^{d}	73.83^{e}	21.03
T2-0.2% Metiram-50WP	32.22^{e}	70.36^{f}	15.34
T3-0.2% Mancozeb-75WP	23.33^{gh}	82.96^{b}	36.00
T4- 0.2%Propineb -50WP	25.18^{g}	79.40^{c}	30.16
T5-0.1%Hexaconazole-5EC	26.54^{g}	78.67^{c}	28.96
T6- 0.1%Azoxystrobin-25EC	20.74^{gh}	84.20^{ab}	38.03
T7-0.1% Fenamidone-10WP	29.63^{f}	76.23^{d}	24.96
T8-0.1% Myclobutanil-10WP	27.77^{fg}	71.44^{f}	17.11
T9-0.1%Tebuconazole-25EC	22.22^{gh}	84.50^{a}	38.52
T10-15%*Allium sativum*	43.33^{c}	68.20^{g}	11.80
T11-15% *Aloe vera*	45.55^{b}	65.83^{h}	7.91
T12- 15% *Clerodendron inerme*	46.29^{b}	64.53^{h}	5.78
T13-Control	51.10^{a}	61.00^{i}	-

Note: In the vertical columns means followed by same letters are not different statistically by Duncan Multiple Range Test (DMRT) (P=0.05).

Acknowledgement

We thank College of Horticulture, Bidar and University of Horticultural Sciences, Bagalkot, Karnataka, India for their provisions to this study.

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