

Original Research Article

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## Sensitivity of *Phytophthora nicotianae* var. *parasitica* Causing Buckeye Rot of Tomato to Commonly Used Fungicides in Himachal Pradesh

Gurpreet Kaur\* and D.K. Banyal

Department of Plant Pathology, CSK Himachal Pradesh Krishi Vishvavidyalaya,  
Palampur 176 062, Himachal Pradesh, India

\*Corresponding author

### ABSTRACT

Buckeye rot caused by *Phytophthora nicotianae* var. *parasitica* (dastur) Waterhouse is the serious menace to the cultivation of tomato in Himachal Pradesh. Seventeen isolates of *Phytophthora nicotianae* var. *parasitica* causing buckeye rot were collected from different districts of Himachal Pradesh. Sensitivity of these isolates to three commonly used fungicides i.e. mancozeb 75WP (Indofil M-45), copper-oxychloride 50WP (Blitox-50) & metalaxyl-M 4%+ mancozeb 64%WP (Ridomil Gold) in Himachal Pradesh was examined by dual culture technique. On the basis of sensitivity to fungicides the 17 isolates were categorized into three sensitivity classes i.e. highly sensitive, moderately sensitive and less sensitive isolates. Out of seventeen isolates, nine isolates were highly sensitive (Pn-3, Pn-4, Pn-5, Pn-7, Pn-9, Pn-10, Pn-12, Pn-14 & Pn-17), seven isolates (Pn-1, Pn-2, Pn-6, Pn-8, Pn-11, Pn-15 & Pn-16) were moderately sensitive and one isolate (Pn-13) was found less sensitive to mancozeb 75WP. Sensitivity to copper-oxychloride 50WP revealed that seven isolates (Pn-2, Pn-3, Pn-9, Pn-10, Pn-11, Pn-13 & Pn-16) were highly sensitive, nine isolates (Pn-1, Pn-4, Pn-5, Pn-7, Pn-8, Pn-12, Pn-14, Pn-15 & Pn-17) were moderately sensitive and one isolate (Pn-6) was found less sensitive to copper-oxychloride. Whereas, eleven isolates (Pn-2, Pn-3, Pn-4, Pn-5, Pn-6, Pn-10, Pn-11, Pn-12, Pn-13, Pn-15 & Pn-17) were highly sensitive, five isolates were moderately sensitive (Pn-1, Pn-7, Pn-9, Pn-14 & Pn-16) and only one isolate (Pn-8) was found less sensitive to metalaxyl-M 4%+ mancozeb 64%WP. All the isolates were found sensitive to commonly used fungicides but, degree of sensitivity varied significantly. None of the isolate was found resistant to any of the three fungicides i.e. mancozeb 75WP, copper-oxychloride 50WP and metalaxyl-M 4%+ mancozeb 64%WP in Himachal Pradesh.

### Keywords

*Phytophthora nicotianae* var. *parasitica*, Buckeye rot, Tomato, Sensitivity, Fungicides, Management

### Article Info

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### Introduction

Tomato (*Solanum lycopersicum* L.) is one of the most important vegetable crops grown widely all over the world. Tomato is the world's one of largest grown vegetable crop. In the world, the area under tomato is 4783 thousand hectares with production of 177042 thousand metric tonnes (Anonymous, 2016). In India, Tomato is grown over an area of 809 thousand hectares with annual production of

19697 thousand MT. In Himachal Pradesh, it is grown over an area of 18.18 thousand hectares with annual production of 415.41 thousand MT (Anonymous, 2017). Tomato is prone to a number of fungal, bacterial and viral diseases. Among these diseases buckeye rot caused by fungal pathogen *Phytophthora nicotianae* var. *parasitica* (dastur) Waterhouse is the serious menace to the cultivation of tomato in Himachal Pradesh. In India, this disease has been reported for the first time

from Solan area of Himachal Pradesh (Jain *et al.*, 1961). Yield loss up to 40 per cent in tomato fruit has been reported due to buckeye rot in Kashmir (Dar *et al.*, 2004). It causes 30-40 per cent crop loss under favorable weather conditions (Gupta *et al.*, 2005). Buckeye rot incidence may go upto 90 per cent under high humidity and good rainfall (Gupta and Thind 2006). Buckeye rot disease is mainly managed by the chemicals. Some of the fungicides i.e. mancozeb 75WP (Indofil M-45), copper-oxychloride 50WP (Blitox-50) and metalaxyl-M 4%+ mancozeb 64%WP (Ridomil Gold) are widely used for the management of this disease in Himachal Pradesh. However, it is observed that these fungicides were not found equally effective against the disease at different locations, which may be due variation in the pathogen that may lead to loss of sensitivity of the pathogen against these fungicides. It is evident that the fungicides are effective in suppression of buckeye rot, however, no information is available about sensitivity of the pathogen to these fungicides from the state.

The objective of the present study was to find out the variable response of pathogen to these commonly used fungicides in the isolates of *Phytophthora nicotianae* var. *parasitica* from Himachal Pradesh. Information regarding sensitivity of pathogen to fungicides will facilitate monitoring potential fungicide resistance development and guide development of more effective programs for managing buckeye rot of tomato by applications of alternate fungicides with different modes of action (Qu *et al.*, 2016).

## **Materials and Methods**

### **Collection, Isolation, purification and maintenance of pathogen**

Different tomato growing districts i.e. Kullu, Mandi, Kangra, Bilaspur, Solan and Hamirpur

of Himachal Pradesh were visited during cropping season 2016-17 for the collection of tomato fruits infected by *Phytophthora nicotianae* var. *parasitica*. The fruits showing the symptoms of buckeye rot were collected, placed in paper bags and brought to laboratory for isolation purpose. Pathogen was isolated from naturally infected green fruits of tomato and maintained on potato dextrose agar (PDA) medium. For proper growth of fungal isolate, the culture room temperature was maintained at 25±1°C. Each isolate was purified by using single spore method. Pure cultures of each isolate was multiplied on potato dextrose agar medium and used for further studies. Stock cultures were stored at 10°C and maintained by regular sub culturing at the interval of 15 days.

### ***In vitro* assessment of sensitivity**

Seventeen isolates of *P. nicotianae* var. *parasitica* were evaluated for their sensitivity to commonly used fungicides i.e. copper-oxychloride 50WP (Blitox-50), metalaxyl-M 4%+ mancozeb 64%WP (Ridomil Gold) and mancozeb 75WP (Indofil M-45) under *in vitro*.

These fungicides were evaluated through Poisoned Food Technique (Falck 1907) at concentrations 50, 100, 250, 500 and 750 µg/ml against all the isolates of pathogen. Double strength PDA medium was prepared in distilled water and sterilized in autoclave at 1.05 kg/cm<sup>3</sup> pressure and 121°C for 20 minutes. Simultaneously, double concentration of fungicide was also prepared in sterilized distilled water. Fungicide suspension were added separately to equal quantities of double strength PDA medium aseptically before pouring into Petri plates. These plates were then inoculated with a 5 mm diameter mycelial bit of the each isolate of pathogen taken from the margin of an actively growing colony and placed in the

centre of media plates. A control treatment was also maintained in which only plain sterilized distilled water was added to double strength medium. Each treatment was replicated thrice. The inoculated plates were incubated at  $25\pm 1^{\circ}\text{C}$ . Regular observations were made and finally colony diameter was measured after 7 days when the control plates were completely covered by the growth of pathogen and per cent mycelial inhibition was determined by formula given by McKinney (1923). On the basis of sensitivity of the pathogen towards these fungicides, seventeen isolates were categorised into three classes i.e. highly sensitive, moderately sensitive and less sensitive. The average mycelial growth of the each isolate was calculated. An isolate was designated as highly sensitive (H), when the isolate exhibited average mycelial growth ranging between 0-20.0 mm.

Moderately sensitive isolate (M) exhibited average mycelial growth ranging between 20.1-40.0 mm and less sensitive isolate (L) exhibited average mycelial growth ranging between 40.1 mm and above.

## Results and Discussion

### Collection and isolation of pathogen

More than 25 samples of buckeye rot were collected from six districts (Kullu, Mandi, Kangra, Bilaspur, Solan and Hamirpur) of Himachal Pradesh during 2016-17. From these sample 17 isolates of the pathogen was isolated and purified by using single spore technique. The isolates from different geographical locations were designated as "Pn" and presented in table 1.

### Sensitivity to mancozeb 75WP (Indofil M-45)

Sensitivity of *P. nicotianae* var. *parasitica* to mancozeb 75WP (Indofil M-45), the fungicide

was tested at different concentrations (50, 100, 250, 500 & 750  $\mu\text{g/ml}$ ) under *in vitro* and the data on mycelial growth were recorded after 7 days of inoculation (Table 2). The data revealed that there was significant difference among isolates in sensitivity to mancozeb 75WP at different doses. At 50  $\mu\text{g/ml}$ , isolate Pn-13 showed highest mycelial growth i.e. 73.00 mm, followed by isolate Pn-8 which showed 65.17 mm mycelial growth. Isolate Pn-3 showed lowest (17.00 mm) mycelial growth at 50  $\mu\text{g/ml}$  while, other isolates showed mycelial growth ranging from 21.00-60.00 mm. At 100  $\mu\text{g/ml}$ , isolate Pn-13 showed highest mycelial growth i.e. 51.50 mm followed by Pn-8 which showed 50.50 mm mycelial growth, however, Pn-3 showed lowest (13.17 mm) mycelial growth. Other isolates at 100  $\mu\text{g/ml}$  showed mycelial growth ranging between 16.17 to 45.67 mm. Isolate Pn-17 was completely inhibited at 250  $\mu\text{g/ml}$  whereas, remaining isolates showed mycelial growth ranging from 8.50 to 41.33 mm. At 500  $\mu\text{g/ml}$ , isolate Pn-3, Pn-4, Pn-5, Pn-7, Pn-9, Pn-10, Pn-12 and Pn-14 showed complete inhibition of mycelial growth however, in other isolates mycelial growth ranged from 7.33-18.00 mm. At 750  $\mu\text{g/ml}$ , no mycelial growth was observed in any of the isolates.

Seventeen isolates of *P. nicotianae* var. *parasitica* were categorized into three groups of sensitivity i.e. highly, moderately and less sensitive. (Table 3) Out of these three sensitivity groups, PnG1 consisted nine isolates (Pn-3, Pn-4, Pn-5, Pn-7, Pn-9, Pn-10, Pn-12, Pn-14 and Pn-17), which were observed highly sensitive to mancozeb 75WP. The average mycelial growth of isolates of this group ranged between 0-20.0 per cent. In the second group (PnG2) seven isolates (Pn-1, Pn-2, Pn-6, Pn-8, Pn-11, Pn-15 and Pn-16) were placed, which were moderately sensitive to mancozeb 75WP. The average mycelial growth of isolates of this group ranged between 20.1-40.0 per cent. In group PnG3,

the isolates having average mycelial growth 40.1 per cent or above were placed and this group is having only one isolate Pn-13.

### **Sensitivity to copper-oxchloride 50WP (Blitox-50)**

Sensitivity of *P. nicotianae* var. *parasitica* to copper-oxchloride 50WP (Blitox-50), the fungicide was tested at different concentrations (50, 100, 250, 500 and 750 µg/ml) under *in vitro* and the data on mycelial growth were recorded after 7 days of inoculation and presented in table 4. The data revealed that at 50 µg/ml, isolate Pn-6 showed highest mycelial growth i.e. 67.67 mm followed by Pn-8 which gave 64.50 mm mycelial growth. Isolate Pn-9 provided lowest (23.33 mm) mycelial growth at 50 µg/ml while, other isolates showed mycelial growth ranging between 25.17 to 62.33 mm. At 100 µg/ml, isolate Pn-8 gave highest (61.17 mm) mycelial growth followed by Pn-6 which provided 50.33 mm mycelial growth. Isolate Pn-9 provided lowest mycelial growth i.e. 13.67 mm, however other isolates showed mycelial growth ranging from 21.00-43.50 mm at 100 µg/ml. Isolate Pn-2, Pn-3, Pn-9, Pn-10, Pn-11, Pn-13 and Pn-16 provided complete inhibition of mycelial growth at 250 µg/ml. Other isolates at 250 µg/ml showed mycelial growth ranging from 8.17- 40.67 mm. At 500 µg/ml, isolate Pn-1, Pn-5, Pn-7, Pn-8, Pn-12, Pn-14, Pn-15 and Pn-17 also showed complete inhibition of mycelial growth followed by Pn-4 and Pn-6 with 19.17 and 18.85 mm mycelial growth. At 750 µg/ml, no mycelial growth was observed in any of the isolates. Seventeen isolates of *P. nicotianae* var. *parasitica* were categorized into three groups of sensitivity i.e. highly, moderately and less sensitive (Table 5). Out of these three sensitivity groups, PnG1 consisted seven isolates (Pn-2, Pn-3, Pn-9, Pn-10, Pn-11, Pn-13 and Pn-16), which were observed highly sensitive to copper-oxchloride 50WP. The

average mycelial growth of isolates of this group ranged between 0-20 per cent. In second group (PnG2) nine isolates (Pn-1, Pn-4, Pn-5, Pn-7, Pn-8, Pn-12, Pn-14, Pn-15 and Pn-17) were placed which were moderately sensitive to copper-oxchloride 50WP. The average mycelial growth of isolates of this group ranged between 20.1-40.0 per cent. In group PnG3, only one isolate Pn-6 was placed because the average mycelial growth was more than 40.1 per cent.

### **Sensitivity to metalaxyl-M 4%+ mancozeb 64%WP (Ridomil Gold)**

Sensitivity of *P. nicotianae* var. *parasitica* to metalaxyl-M 4%+ mancozeb 64%WP (Ridomil Gold), the fungicide was tested at different concentrations (50, 100, 250, 500 & 750 µg/ml) under *in vitro* and the data on mycelial growth was recorded after 7 days of inoculation and presented in table 6. The data revealed that at 50 µg/ml, isolate Pn1 showed highest mycelial growth i.e. 59.50 mm, followed by Pn-8 which provided 58.50 mm mycelial growth. Isolate Pn-5 gave lowest (16.67 mm) mycelial growth at 50 µg/ml while, other isolates showed mycelial growth ranging from 16.83-52.50 mm. At 100 µg/ml, isolate Pn-17 gave complete inhibition of mycelial growth. Minimum mycelial growth was given by Pn-2 (6.67 mm) while, other isolates provided mycelial growth ranging from 10.67-51.83 mm at 100 µg/ml. Isolate Pn-2, Pn-3, Pn-4, Pn-5, Pn-6, Pn-10, Pn-12, Pn-13 and Pn-15 completely inhibited the mycelial growth at 250 µg/ml. Isolate Pn-11 gave minimum mycelial growth i.e. 10.17 mm at 250 µg/ml while, other isolates showed mycelial growth ranging from 13.67-40.24 mm at 250 µg/ml. At 500 µg/ml, isolate Pn-1, Pn-7, Pn-9, Pn-11, Pn-14 and Pn-16 gave complete inhibition of mycelial growth and only one isolate Pn-8 showed 9.50 mm mycelial growth. At 750 µg/ml, all the isolates completely inhibited the mycelial growth.

**Table.1** *Phytophthora nicotianae* var. *parasitica* isolates from different locations of Himachal Pradesh

District	S. No	Isolate Designation	Location
Mandi	1	Pn-1	Jhiri
	2	Pn-3	Nagwain
	3	Pn-14	Takoli
Kangra	4	Pn-13	Jamanabad
	5	Pn-2	Tanda
	6	Pn-9	Harzana
	7	Pn-10	Kohli
	8	Pn-11	Nagrota
	9	Pn-4	Palampur
Bilaspur	10	Pn-5	Namhol
Kullu	11	Pn-6	Bajaura
Solan	12	Pn-7	Badlag
	13	Pn-8	Ochghat
	14	Pn-15	Dharmpur
	15	Pn-16	Saproon
	26	Pn-17	Lohanji
Hamirpur	17	Pn-12	Bara

**Table.2** Sensitivity of *Phytophthora nicotianae* var. *parasitica* isolates to mancozeb 75WP (Indofil M-45)

Isolates	Mycelial growth (mm) at different concentrations (µg/ml)						Mancozeb 75WP sensitivity
	50	100	250	500	750*	Average	
<b>Pn-1</b>	50.67	44.00	29.33 (5.50)	16.33 (4.16)	0.00 (1.00)	35.08	M
<b>Pn-2</b>	40.17	36.00	28.67 (5.44)	8.83 (3.13)	0.00 (1.00)	28.42	M
<b>Pn-3</b>	17.00	13.17	8.50 (3.08)	0.00 (1.00)	0.00 (1.00)	9.67	H
<b>Pn-4</b>	26.83	22.17	19.17 (4.48)	0.00 (1.00)	0.00 (1.00)	17.04	H
<b>Pn-5</b>	31.33	22.00	16.00 (4.12)	0.00 (1.00)	0.00 (1.00)	17.33	H
<b>Pn-6</b>	40.83	34.50	27.17 (5.30)	10.00 (3.31)	0.00 (1.00)	28.13	M
<b>Pn-7</b>	24.50	20.33	11.00 (4.06)	0.00 (1.00)	0.00 (1.00)	15.08	H
<b>Pn-8</b>	65.17	50.50	27.17 (5.30)	13.17 (3.76)	0.00 (1.00)	39.00	M
<b>Pn-9</b>	25.67	21.00	11.00 (3.46)	0.00 (1.00)	0.00 (1.00)	14.42	H
<b>Pn-10</b>	21.00	16.17	12.50 (3.67)	0.00 (1.00)	0.00 (1.00)	12.42	H
<b>Pn-11</b>	41.17	30.83	22.00 (4.79)	8.57 (3.09)	0.00 (1.00)	25.64	M
<b>Pn-12</b>	33.00	27.50	19.00 (4.47)	0.00 (1.00)	0.00 (1.00)	19.88	H
<b>Pn-13</b>	73.00	51.50	41.33 (6.50)	18.00 (4.35)	0.00 (1.00)	45.96	L
<b>Pn-14</b>	31.67	22.67	14.33 (3.91)	0.00 (1.00)	0.00 (1.00)	17.17	H
<b>Pn-15</b>	60.00	45.67	30.67 (5.62)	15.00 (3.99)	0.00 (1.00)	37.84	M
<b>Pn-16</b>	56.50	41.50	20.83 (4.67)	7.33 (2.88)	0.00 (1.00)	31.54	M
<b>Pn-17</b>	39.17	20.67	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	14.96	H
<b>Control</b>	90	90	90 (9.53)	90 (9.53)	90 (9.53)	-	-
<b>CD (p=0.05)</b>	1.82	1.44	0.16	0.14	0.00		

**L= less sensitive, M= moderately sensitive, H= highly sensitive, \* not included for calculating average**

**Table.3** Grouping of *Phytophthora nicotianae* var. *parasitica* isolates on the basis of sensitivity to mancozeb 75WP (Indofil M-45)

Group no.	Isolates	Sensitivity to Mancozeb 75WP
<b>PnG1</b>	Pn-3, Pn-4, Pn-5, Pn-7, Pn-9, Pn-10, Pn-12, Pn-14 and Pn-17	Highly sensitive
<b>PnG2</b>	Pn-1, Pn-2, Pn-6, Pn-8, Pn-11, Pn-15 and Pn-16	Moderately sensitive
<b>PnG3</b>	Pn- 13	Less sensitive

**Table.4** Sensitivity of *Phytophthora nicotianae* var. *parasitica* isolates to copper-oxchloride 50WP (Blitox-50)

Isolates	Mycelial growth (mm) at different concentrations (µg/ml)						Copper-oxchloride 50WP sensitivity
	50	100	250	500	750*	Average	
<b>Pn-1</b>	49.00	43.50	8.17 (3.02)	0.00 (1.00)	0.00 (1.00)	25.17	M
<b>Pn-2</b>	32.00	22.83	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	13.71	H
<b>Pn-3</b>	25.50	21.50	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	11.75	H
<b>Pn-4</b>	43.00	37.00	24.00 (4.99)	19.17 (4.49)	0.00 (1.00)	30.79	M
<b>Pn-5</b>	51.67	41.33	14.00 (3.87)	0.00 (1.00)	0.00 (1.00)	26.75	M
<b>Pn-6</b>	67.67	50.33	40.67 (6.45)	18.85 (4.45)	0.00 (1.00)	44.38	L
<b>Pn-7</b>	62.33	41.33	37.77 (6.22)	0.00 (1.00)	0.00 (1.00)	35.36	M
<b>Pn-8</b>	64.50	61.17	22.83 (4.88)	0.00 (1.00)	0.00 (1.00)	37.13	M
<b>Pn-9</b>	23.33	13.67	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	9.25	H
<b>Pn-10</b>	32.67	25.17	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	14.46	H
<b>Pn-11</b>	34.17	27.33	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	15.38	H
<b>Pn-12</b>	50.33	41.17	20.83 (4.67)	0.00 (1.00)	0.00 (1.00)	28.08	M
<b>Pn-13</b>	25.17	21.00	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	11.54	H
<b>Pn-14</b>	41.67	22.83	16.50 (4.18)	0.00 (1.00)	0.00 (1.00)	20.25	M
<b>Pn-15</b>	55.00	34.50	24.00 (5.00)	0.00 (1.00)	0.00 (1.00)	28.38	M
<b>Pn-16</b>	31.33	23.83	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	13.79	H
<b>Pn-17</b>	58.00	30.67	15.00 (3.99)	0.00 (1.00)	0.00 (1.00)	25.92	M
<b>Control</b>	90.00	90.00	90.00 (9.53)	90.00 (9.53)	90.00 (9.53)	-	-
<b>CD (p=0.05)</b>	1.63	1.56	0.12	0.04	0.00		

L= less sensitive, M= moderately sensitive, H= highly sensitive, \* not included for calculating average

**Table.5** Grouping of *Phytophthora nicotianae* var. *parasitica* isolates on the basis of sensitivity to copper-oxychloride 50WP (Blitox-50)

Group no.	Isolates	Sensitivity to Copper-oxychloride 50WP
<b>PnG1</b>	Pn-2, Pn-3, Pn- 9, Pn-10, Pn-11, Pn-13 and Pn-16	Highly sensitive
<b>PnG2</b>	Pn-1, Pn-4, Pn-5, Pn-7, Pn-8, Pn-12, Pn-14, Pn-15 and Pn-17	Moderately sensitive
<b>PnG3</b>	Pn- 6	Less sensitive

**Table.6** Sensitivity of *Phytophthora nicotianae* var. *parasitica* isolates to metalaxyl-M 4%+ mancozeb 64%WP (Ridomil Gold)

Isolates	Mycelial growth (mm) at different concentrations (µg/ml)						Metalaxyl-M 4%+mancozeb 64%WP Sensitivity
	50	100	250	500	750*	Average	
<b>Pn-1</b>	59.50	34.50 (5.95)	19.50 (4.52)	0.00 (1.00)	0.00 (1.00)	28.38	M
<b>Pn-2</b>	21.00	6.67 (2.76)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	6.92	H
<b>Pn-3</b>	21.33	16.33 (4.16)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	9.42	H
<b>Pn-4</b>	34.50	16.67 (4.20)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	12.79	H
<b>Pn-5</b>	16.67	12.50 (3.67)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	7.29	H
<b>Pn-6</b>	22.83	18.00 (4.35)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	10.21	H
<b>Pn-7</b>	50.00	31.67 (5.71)	14.22 (3.90)	0.00 (1.00)	0.00 (1.00)	23.97	M
<b>Pn-8</b>	58.50	51.83 (7.26)	40.24 (6.42)	9.50 (3.23)	0.00 (1.00)	40.02	L
<b>Pn-9</b>	41.67	30.67 (5.62)	13.67 (3.82)	0.00 (1.00)	0.00 (1.00)	21.50	M
<b>Pn-10</b>	31.00	13.67 (3.82)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	11.17	H
<b>Pn-11</b>	22.83	16.00 (4.12)	10.17 (3.33)	0.00 (1.00)	0.00 (1.00)	12.25	H
<b>Pn-12</b>	20.67	15.33 (4.04)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	9.00	H
<b>Pn-13</b>	16.83	10.67 (3.41)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	6.88	H
<b>Pn-14</b>	52.50	25.50 (5.14)	18.17 (4.37)	0.00 (1.00)	0.00 (1.00)	24.04	M
<b>Pn-15</b>	20.33	14.00 (3.87)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	8.58	H
<b>Pn-16</b>	47.00	30.67 (5.62)	21.15 (4.70)	0.00 (1.00)	0.00 (1.00)	24.70	M
<b>Pn-17</b>	21.67	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	5.42	H
<b>Control</b>	90.00	90.00 (9.53)	90.00 (9.53)	90.00 (9.53)	90.00 (9.53)	-	-
<b>CD (p=0.05)</b>	1.28	0.14	0.10	0.06	0.00		

L= less sensitive, M= moderately sensitive, H= highly sensitive

\* not included for calculating average

**Table.7** Grouping of *Phytophthora nicotianae* var. *parasitica* isolates on the basis of sensitivity to metalaxyl-M 4%+ mancozeb 64% WP (Ridomil Gold)

Group no.	Isolates	Sensitivity to metalaxyl-M 4%+ mancozeb 64%WP
<b>PnG1</b>	Pn-2, Pn-3, Pn-4, Pn-5, Pn-6, Pn-10, Pn-11, Pn-12, Pn-13, Pn-15 and Pn-17	Highly sensitive
<b>PnG2</b>	Pn-1, Pn-7, Pn-9, Pn-14 and Pn-16	Moderately sensitive
<b>PnG3</b>	Pn- 8	Less sensitive

Seventeen isolates of *P. nicotianae* var. *parasitica* were categorized into three groups of sensitivity i.e. highly, moderately and less sensitive (Table 7). Group PnG1 accommodated eleven isolates (Pn-2, Pn-3, Pn-4, Pn-5, Pn-6, Pn-10, Pn-11, Pn-12, Pn-13, Pn-15 and Pn-17), which were highly sensitive to metalaxyl-M 4%+ mancozeb 64%WP. The average mycelial growth of isolates of this group ranged between 0-20.0 per cent. Five isolates (Pn-1, Pn-7, Pn-9, Pn-14 and Pn-16), which were moderately sensitive to metalaxyl-M 4%+ mancozeb 64%WP were placed in group PnG2. The average mycelial growth of isolates of this group ranged between 20.1-40.0 per cent. In group PnG3, only one isolate Pn-8 was placed having average mycelial growth more than 40.1 per cent.

From the above data it was concluded that all the isolates were sensitive to commonly used fungicides but, degree of sensitivity varied significantly. Out of seventeen isolates, nine isolates (Pn -3, Pn-4, Pn-5, Pn-7, Pn- 9, Pn-10, Pn-12, Pn-14 and Pn-17) were highly sensitive, seven isolates (Pn-1, Pn-2, Pn-6, Pn-8, Pn-11, Pn-15 and Pn-16) were moderately sensitive and one isolate Pn-13 was less sensitive. Out of seventeen isolates, seven isolates (Pn -2, Pn-3, Pn- 9, Pn-10, Pn-11, Pn-13 and Pn-16) were highly sensitive, nine isolates (Pn-1, Pn-4, Pn-5, Pn-7, Pn-8, Pn-12, Pn-14, Pn-15 and Pn-17) were moderately sensitive and one isolate Pn-6 was less sensitive. Out of seventeen isolates, eleven isolates (Pn -2, Pn-3, Pn-4, Pn- 5, Pn-6, Pn-10, Pn-11, Pn-12, Pn-13, Pn-15 and Pn-17) were highly sensitive, five isolates (Pn-1, Pn-7, Pn-9, Pn-14 and Pn-16) were moderately

sensitive and only one isolate Pn-8 was less sensitive.

However, none of the isolate was found resistant to any of the three fungicides i.e. mancozeb 75WP, copper-oxchloride 50WP and metalaxyl-M 4%+ mancozeb 64%WP. The variation in effectiveness of these fungicides at different locations may be due to the differences in the sensitivity among the different isolates of the pathogens.

The variation in sensitivity may be due to the continuous and long term use of these fungicides by the farmers against the pathogen in particular areas. The sensitivity of the *Phytophthora* spp. against the different fungicides has been reported by different workers. Sujkowaski *et al.*, (1995) reported that the sensitivity of *P. infestans* isolates was lowest for cymoxanil, low for chlorothalonil and higher for metalaxyl. Kato *et al.*, (1997) reported that there were significant differences among isolates of *P. infestans* for degree of sensitivity to one fungicide individually, but there were no significant difference among the isolates for degree of sensitivity to mancozeb and chlorothalonil. Jaarsveld *et al.*, (2002) screened one hundred and thirty-two isolates of *P. nicotianae* for sensitivity to metalaxyl and found that growth of most isolates was inhibited completely at 1.0 a.i µg/ml. Hu *et al.*, (2008) screened 95 isolates of *P. nicotianae* for their sensitivity to mfenoxam at 100 a.i. µg/ml. Twenty- five isolates were highly resistant, four were intermediately resistant and sixty- six isolates were observed sensitive. Wang *et al.*, (2013) studied the mfenoxam sensitivity in the

*P. parasitica* var. *nicotianae* and found that 41.9 per cent isolates were intermediately resistant and 58.1 per cent were sensitive to mefenoxam, however, no isolate was found resistant. Qu *et al.*, (2016) studied twenty isolates of *P. nicotianae* from tobacco to determine their sensitivity to fluopicolide, mandipropamid and oxathiapiprolin. Results indicated that *P. nicotianae* isolates were sensitive to the fungicides, with lower EC<sub>50</sub> for oxathiapiprolin than for fluopicolide and mandipropamid.

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