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Assessment of the performance of different fungicide against *Phytophthora* blight caused by *Phytophthora drechsleri* Tucker F. sp. *cajani*

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Abstract
Pigeonpea (*Cajanus cajan*) is a vital legume crop susceptible to various pests and diseases, with *Phytophthora* blight, caused by *Phytophthora drechsleri* Tucker F. sp. *cajani*, emerging as a significant threat in India alongside other devastating pathogens. In this study, the efficacy of four non-systemic and systemic fungicides against *Phytophthora drechsleri* was evaluated through *in vitro* assays. For the non-systemic fungicides tested at concentrations of 1000 ppm, 1500 ppm, and 2000 ppm, significant inhibition of mycelial growth was observed, with increasing concentrations correlating with higher inhibition rates. Mancozeb exhibited the most pronounced inhibition across all concentrations tested, followed by Captan, Copper oxychloride, and Zineb. Similarly, systemic fungicides displayed notable inhibition of mycelial growth at concentrations of 500 ppm, 1000 ppm, and 1500 ppm. Metalaxyl + Mancozeb showed the highest inhibition, reaching 100% at 1000 ppm, followed by Cymoxanil + Mancozeb, Propineb, and Chlorothalonil.

Keywords: *Phytophthora drechsleri*, propineb, copper oxychloride, chlorothalonil, fungicide

Introduction
Pigeonpea is susceptible to many insects, pests and diseases but only few of them are of economic importance. After Wilt (caused by *Fusarium udum*) and Sterility mosaic (caused by Pigeon pea Sterility Mosaic Virus), *Phytophthora* blight caused by *Phytophthora drechsleri* Tucker F. sp. *cajani* is the third potentially important emerging disease of Pigeon pea in India. Plant diseases caused by *Phytophthora* species will remain an ever-increasing threat to agriculture and natural ecosystems. *Phytophthora* literally means plant destroyer, a name coined in the 19th century by Antony de Bary when he investigated the Potato disease that set the stage for the Great Irish Famine.

The first suspected occurrence of *Phytophthora* blight on Pigeon pea was reported in 1966 by Williams *et al*. (1968). He first isolated a PB-causing pathogen from wilted pigeonpea plants with stem canker symptoms at New Delhi, India. Since that time, the disease has spread to most pigeonpea growing areas in Asia (Pal *et al*., 1970), Africa, America (Kannaiyan *et al*., 1984) [7], Australia, Dominican Republic, Kenya, Panama and Puerto Rico (Nene *et al*., 1996). Recently, the recurrence of *Phytophthora* Blight as a major threat to pigeonpea production and productivity in the Deccan Plateau of India was reported irrespective of cropping system, soil types and cultivars.

Information on worldwide losses caused by PB is not available, but there is no doubt that the disease is of growing importance and has the potential to cause devastation in a susceptible cultivar, particularly in the context of changing pattern in total rainfall in the Semi-Arid tropics where pigeonpea is being cultivated as the primary rainy season pulse crop. Effect of PB on grain yield depends on the onset of the disease in relation to crop growth and disease incidence, both of which largely depend on weather conditions and inoculum levels of the pathogen. Generally, PB incidence was more (11.9-26.5%) on improved cultivars *viz.* BDN-1, BDN-7, ICP 8863 (Maruti) than on local or traditional cultivars (5.0-9.3%).

Characteristic symptoms of disease are water-soaked lesions on the leaves and slightly sunken lesions on stem and petioles. Lesion girdles the stem and the foliage dries up. It is also common to find stems swollen into cankerous structures. Infected stem and branches break easily in wind. Phloem vessels show smoky gray colored discoloration and xylem vessels remain healthy.

It's symptoms have been described as Stem rot, stem blight Amin *et al*., 1978 stem canker (Kaiser and Melendez, 1978) [6] and root rot.

Materials and Methods: The following eight fungicides were evaluated (@ 500, 1000 and 1500 ppm for systemic and 1000, 1500, 2000 ppm for non-systemic fungicides.) for testing against *P. drechsleri* F. sp. *cajani* by poisoned food technique.

Sr. No.	Common name	Trade name	Active ingredients	Manufacture
Non-systemic				
1	Captan	Captaf	50 WP	Rallis India Ltd., Mumbai
2	Copper oxychloride	Blitox	50 WP	Rallis India Ltd., Mumbai
3	Mancozeb	Eurofil NT	35 EC	Indofil Chemical Co. Ltd., Mumbai
4	Zineb	Indofil Z	75 WP	Syngenta Ltd., Mumbai
Systemic				
5	Cymoxanil 8% + Mancozeb 64%	Curzate	72 WP	E.I. DuPont India Pvt. Ltd., Gujarat
6	Propineb	Antracol	70 WP	Sarswati Agrochemicals India Pvt. Ltd.,Jammu Kashmir
7	Chlorothalonil	Kavach	75 WP	Syngenta India Ltd., Pune
8	Metalaxyl 8% + Mancozeb 64%	Ridomil M	72 WP	Syngenta Ltd., Mumbai

Efficacy of four systemic fungicides (@ 500, 1000 and 1500 ppm) and four non-systemic fungicides (@ 1000, 1500 and 2000 ppm) was evaluated *in vitro* against *P. drechsleri* F. sp. *cajani* by poisoned food technique. Based on active ingredient, the requisite quantity of each fungicide was calculated and mixed thoroughly with autoclaved and cooled (40°C) Potato Dextrose Agar medium (PDA) in conical flasks to obtain desired concentrations of 500, 1000, 1500 and 1000, 1500, 2000 ppm for systemic and non-systemic fungicides respectively. Fungicide amended PDA medium was then poured (20 ml/plate) aseptically in Petri plates (90 mm dia.) and allowed to solidify at room temperature. For each test fungicide and its test concentration, three plates/ treatment/replication were maintained and replicated thrice. After solidification of the medium, all the plates were inoculated aseptically with a 5 mm culture disc obtained from a week old actively growing isolated pure culture of *P. drechsleri* F. sp. *cajani.* The culture disc was placed on PDA in inverted position in the centre of the Petri plate and plates were incubated at 28 ± 2^0C. Petri plates filled with plain PDA (without any fungicide) and inoculated with the culture disc of the test pathogen were maintained as control (untreated).

Observations on radial mycelial growth/colony diameter of the pathogen were recorded at 24 hours interval and continued till the untreated control plate was fully covered with mycelial growth of the test pathogen. Per cent mycelial growth inhibition of the test pathogen with the test fungicides over untreated control was calculated by applying the formula given by Vincent (1927).

$$\text{Per cent Inhibition (I)} = \frac{C - T}{C} \times 100$$

Where,

C = Growth (mm) of test fungus in untreated control plate

T = Growth (mm) of test fungus in treated plates

Experimental details

Design: CRD

Replication: Three

Treatment: 9

Non-systemic fungicides

T_1 : Captan (Captaf 50 wp)

T_2 : Copper oxychloride (Blitox 50 wp)

T_3 : Mancozeb (Eurofil NT 35 EC)

T_4 : Zineb (Indofil Z-75 WP)

Systemic fungicides

T_5 : Cymoxanil 8% + Mancozeb 64% (Curzate 72 WP)

T_6 : Propineb (Antracol 70 WP)

T_7 : Chlorothalonil (kavach 75 WP)

T_8 : Metalaxyl 8% + Mancozeb 64% (Ridomil IM)

T_9 : Control

Results and Discussion

***1. In vitro* efficacy of fungicides**

A total 8 (4 systemic @ 500, 1000 and 1500 ppm conc. and 4 non-systemic @ 1000, 1500 and 2000 ppm conc.) fungicides evaluated *in vitro* against *Phytophthora drechsleri* F. sp.*cajani* exhibited a wide range of mycelial growth and inhibition of the test pathogen. The results obtained are presented in the Table1 and PLATE I (A, B, C and D).

1.1 Mycelial growth (Non-systemic fungicides)

For 4 non-systemic fungicides, at 1000 ppm [Table1, PLATE I (B)], radial mycelial growth of the test pathogen was ranged from 23.66 mm (Mancozeb) to 52.5 mm (Zineb), as against 90.00 mm in untreated control. However, significantly least mycelial growth was recorded with the fungicide Mancozeb (23.66 mm). This was followed by the fungicide Captan (31.33 mm) and Copper oxychloride (40 mm). Zineb were found comparatively less effective with maximum mycelial growth of 52.5 mm.

Table 1: *In vitro* efficacy of fungicides against mycelial growth and inhibition of *P. drechsleri* F. sp. *Cajani*

Tr. No.	Treatments	Col. dia. *(mm) at Conc.			% Inhibition*		
		1000 ppm	1500 ppm	2000 ppm	1000 ppm	1500 ppm	2000 ppm
Non-systemic fungicides							
T_1	Captan 50WP	31.33	26.00	20.33	65.18 (40.67)	71.11 (45.32)	77.40(50.71)
T_2	Copper oxychloride 50WP	40.00	34.66	30.33	55.55(33.74)	61.48(37.93)	66.29(41.51)
T_3	Mancozeb 75WP	23.66	19.5	15.83	73.70(47.47)	78.32(51.56)	82.40(55.49)
T_4	Zineb 75 WP	52.5	47.33	37.00	41.66(24.61)	47.40(28.29)	58.88(36.07)

		Systemic fungicides					
		500 ppm	1000 ppm	1500 ppm	500 ppm	1000 ppm	1500 ppm
T_5	Cymoxanil 8%+ Mancozeb 64% (72 WP)	11.33	5.66	00.00	87.40(60.92)	93.70(69.56)	100.00(89.98)
T_6	Propineb 75 WP	20.00	16.5	13.66	77.77(51.05)	81.66(54.74)	84.81(58.00)
T_7	Chlorothalonil 75WP	27.66	22.66	18.00	69.25(43.82)	74.81(48.42)	80.00(53.12)
T_8	Metalyxl 8% + Mancozeb 64% (72WP)	6.33	00.00	00.00	92.26(68.37)	100.00(89.98)	100.00(89.98)
T_9	Control (Untreated)	90.00	90.00	90.00	00.00(00.00)	00.00(00.00)	00.00 (00.00)
	S.E.±	0.22	0.20	0.24	0.38	0.37	0.41
	C.D. (P=0.05)	0.68	0.62	0.72	1.15	1.10	1.22

*Mean of three replications, Col= Colony, Dia.= Diameter, Conc. = Concentration, Figures in parenthesis are arc sine transformed values.

At 1500 ppm [Table1 and PLATE I (C)], all the 4 non-systemic fungicides tested exhibited similar trend of inhibition of mycelial growth as that of observed at 1000 ppm, but it was significantly reduced and was ranged from 19.5 mm (Mancozeb) to 47.33 mm (Zineb), as against 90.00 mm in untreated control. However, significantly least mycelial growth was recorded with Mancozeb (19.5 mm), followed by the fungicide Captan (26.00 mm) and Copper oxychloride (34.66 mm). Zineb recorded comparatively maximum mycelial growth of 47.33 mm.

At 2000 ppm [Table1 and PLATE I (D)], all the 4 non-systemic fungicides tested exhibited similar trend of mycelial growth as that of observed at 1000 ppm and 1500 ppm and it was ranged from 15.83 mm (Mancozeb) to 37.00 mm (Zineb), as against 90.00 mm untreated control. However, significantly least mycelial growth was recorded with Mancozeb (15.83 mm), followed by the fungicide Captan (20.33 mm), Copper oxychloride (30.33 mm) and Zineb recorded comparatively maximum mycelial growth of 37.33 mm).

1.2 Mycelial growth inhibition (Non-systemic fungicides)

Results [Table 1 and PLATE I (B, C and D)], revealed that all the 4 non-systemic fungicides tested (@ 1000 ppm, 1500 ppm and 2000 ppm each) significantly inhibited mycelial growth of *Phytophthora drechsleri* F. sp. *cajani* over untreated control. Further, the percentage mycelial growth inhibition was increased with increase in concentrations of the fungicides tested.

At 1000 ppm [Table 1 and PLATE I (B)], percent mycelial growth inhibition of the test pathogen was ranged from 41.66% (Zineb) to 73.70% (Mancozeb). However, significantly highest mycelial inhibition was recorded with the fungicide Mancozeb (73.70%). The second best fungicide found was Captan (65.18%), followed by Copper oxychloride (55.55%) and Zineb (41.66%) was found least effective.

At 1500 ppm [Table1 and PLATE I (C)], mycelial growth inhibition was increased compared to 1000 ppm and it was ranged from 47.40 (Zineb) to 78.32 (Mancozeb) per cent. However, significantly highest mycelial inhibition was recorded with the fungicides Mancozeb (78.32%). This was followed by the fungicides, Captan (71.11%), Copper oxychloride (61.48%). Zineb (47.40%) was recorded very less inhibition.

At 2000 ppm [Table1 and PLATE I (D)], all the 4 non-systemic fungicides tested exhibited comparatively increased mycelial growth inhibition than that of at 1000 and 1500 ppm and it was ranged from 58.88 (Zineb) to 82.40 (Mancozeb) per cent inhibition of mycelial growth of the test pathogen. However, significantly highest mycelial inhibition was recorded with the fungicides Mancozeb (82.40%). This was followed by the fungicides, *viz*., Captan (77.40%) and Copper oxychloride (66.29%). Zineb (58.88%) was found least effective.

1.3 Mycelial growth (Systemic fungicides)

For 4 systemic fungicides, at 500 ppm [Table 1 and Plate-I (A)], radial mycelial growth of the test pathogen was ranged from 6.33 mm (Metalaxyl + Mancozeb) to 27.66 mm (Chlorothalonil), as against 90.00 mm in untreated control. However, significantly least mycelial growth was recorded with the fungicide Metalaxyl + Mancozeb (6.33 mm). This was followed by the fungicides *viz*., Cymoxanil + Mancozeb (11.33 mm), Propineb (20 mm) and Chlorothalonil (27.66 mm).

At 1000 ppm [Table1 and PLATE I (B)], all the 4 systemic fungicides tested exhibited similar trend of inhibition of mycelial growth as that of observed at 500 ppm, but it was significantly reduced and was ranged from 00.00 mm (Metalaxyl + Mancozeb) to Chlorothalonil (22.66 mm), as against 90.00 mm in untreated control. However, with the fungicide Metalaxyl + Mancozeb there was no any growth observed. This was followed by the fungicides *viz*., Cymoxanil + Mancozeb (5.66 mm) and Propineb (16.5 mm). Chlorothalonil (22.66 mm) was recorded maximum mycelial growth.

At 1500 ppm [Table 1 and PLATE I (C)], all the 4 systemic fungicides tested exhibited similar trend of mycelial growth as that of observed at 500 ppm and 1000 ppm and it was ranged from 00.00 mm (Metalaxyl + Mancozeb) to 18.00 (Chlorothalonil), as against 90.00 mm untreated control. However, with the fungicide Metalaxyl + Mancozeb and Cymoxanil + Mancozeb there was no any growth observed. This was followed by the fungicides *viz*., Propineb (13.66 mm) and Chlorothalonil (18.00 mm).

1.4 Mycelial growth inhibition (Systemic fungicides)

Results [Table 1 and PLATE I (A, B and C)], revealed that all the 4 systemic fungicides tested (@ 500 ppm, 1000 ppm and 1500 ppm each) significantly inhibited mycelial growth of *Phytophthora drechsleri* F. sp. *cajani* over untreated control. Further, the percentage mycelial growth inhibition was increased with increase in concentrations of the fungicides tested (PLATE I).

500 ppm [Table 1 and Plate-I (A)], percent mycelial growth inhibition of the test pathogen was ranged from 69.25% (Chlorothalonil) to 92.26% (Metalaxyl + Mancozeb). However, significantly highest mycelial inhibition was recorded with the fungicide Metalaxyl + Mancozeb (92.26%). The second-best fungicide found was Cymoxanil + Mancozeb (87.40%). These were followed by the fungicides *viz*., Propineb (77.77%) and Chlorothalonil (69.25%).

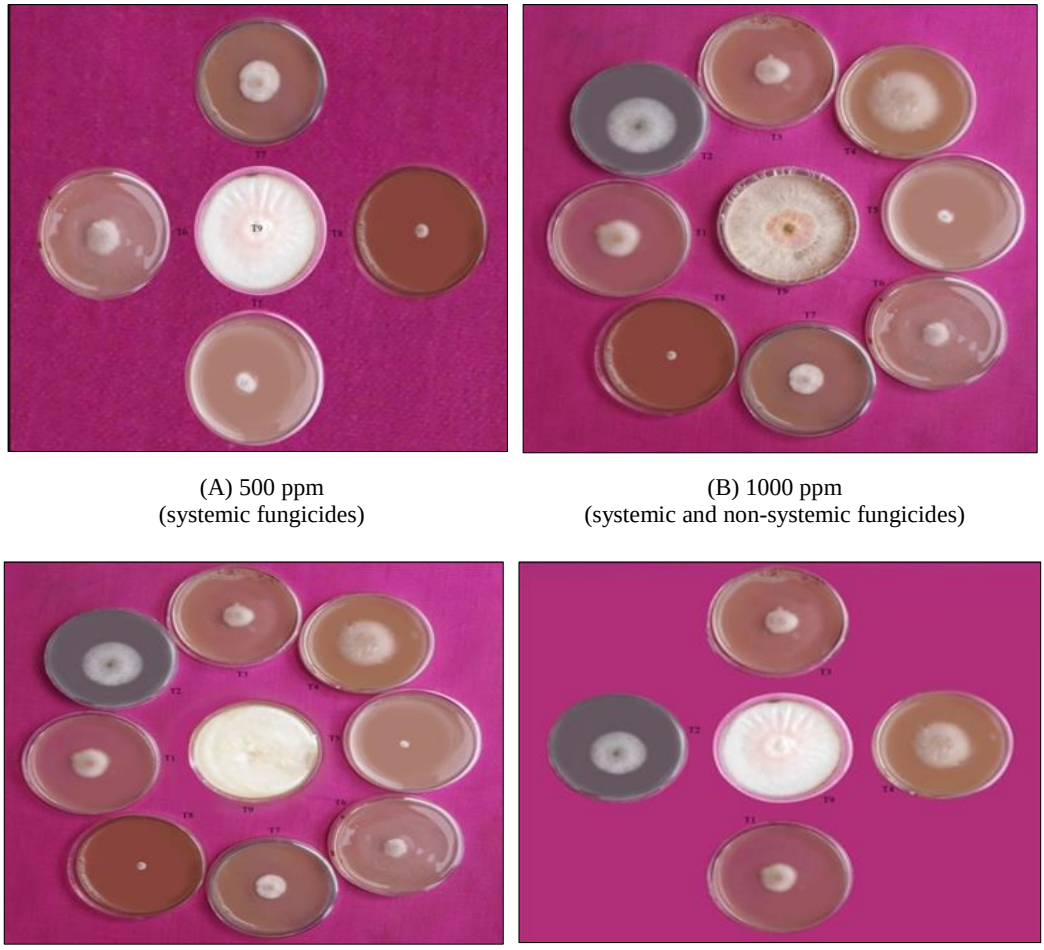
At 1000 ppm [Table 1 and Plate-I (B)], mycelial growth inhibition was increased compared to 500 ppm and it was ranged from 74.81 (Chlorothalonil) to 100 (Metalaxyl + Mancozeb) per cent. However, fungicide Metalaxyl + Mancozeb caused cent per cent (100%) mycelial inhibition. This was followed by the fungicides, Cymoxanil + Mancozeb

(93.70%), Propineb (81.66%) and Chlorothalonil (74.81%).

At 1500 ppm [Table 1 and Plate-I (C)], all the 4 systemic fungicides tested exhibited comparatively increased mycelial growth inhibition than that of at 500 and 1000 ppm and it was ranged from 80.00 (Chlorothalonil) to 100 (Metalaxyl + Mancozeb and Cymoxanil + Mancozeb each) per cent inhibition of mycelial growth of the test pathogen. However, fungicide Metalaxyl + Mancozeb and Cymoxanil + Mancozeb caused cent per cent (100%) mycelial inhibition. These were followed by the fungicides, *viz*., Propineb (84.81%) and Chlorothalonil (80.00%).

Results of the present study on effect of fugicides on mycelial growth and sporulation of *P. drechsleri* F. sp. *cajani* are in consonance with those reported earlier by several workers (Lal Singh *et al*. 2010, Jagtap *et al*. 2012 [5], Rekanovic *et al*. 2012 [10], Chaudhari & Banyal 2013 [1], Nath *et al*. 2013 [8]). Simillar study was conducted by Elliott *et al*. (2015) [2] on nine isolates of *Phytophthora ramorum* Werres, de Cock & Man isn't Veld. They were screened *in vitro* variations of systemic and contact fungicides for mycelial growth inhibition and zoospore germination inhibition, and *in planta* for suppression of lesion expansion on rhododendron foliage. Three isolates from each of the major clonal lineages, NA1, NA2, and EU1 were used. Systemic fungicides were the most effective at preventing mycelial growth and zoospore germination of *P. ramorum*.

Plate-I



(A) 500 ppm
(systemic fungicides)

(B) 1000 ppm
(systemic and non-systemic fungicides)

(C) 1500 ppm
(systemic and non-systemic fungicides)

(D) 2000 ppm
(non-systemic fungicides) Cymoxanil+ Mancozeb

T_1 : Captan
T_2 : Copper oxychloride
T_3 : Mancozeb
T_4 : Zineb
T_5 : Cymoxanil 8% + Mancozeb 64% (Curzate 72 WP)
T_6 : Propineb (Antracol 70 WP)
T_7 : Chlorothalonil (kavach 75 WP)
T_8 : Metalaxyl 8% + Mancozeb 64% (Ridomil IM)
T_9 : Control

In vitro efficacy of fungicides (systemic and non -systemic) at different concentrations on radial mycelial growth and inhibition of P. *drechsleri* F. sp. *cajani*

Conclusions

Phytophthora blight, caused by *Phytophthora* Drechsleri F. sp. cajani, is an emerging threat to pigeonpea, following wilt and sterility mosaic diseases. This pathogen, first reported in India in 1966, has since spread globally. Its impact on grain yield depends on disease onset and weather conditions. Non-systemic fungicides like Mancozeb and Captan, and systemic fungicides like Metalaxyl + Mancozeb, were evaluated for their efficacy in inhibiting mycelial growth. Mancozeb was the most effective non-systemic fungicide, while Metalaxyl +

Mancozeb showed complete inhibition among systemic fungicides, highlighting the need for effective management strategies against *Phytophthora* blight.

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