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In-vitro Evaluation of Botanicals and Fungicides against Ginger Leaf Spot caused by *Phyllosticta zingiberi* Ramakr

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ABSTRACT: *Phyllosticta zingiberi* Ramakr causing leaf spot of ginger is considered to be destructive, appearing in mild or severe form in all ginger growing tracts of the country. In Karnataka, amongst the various foliar diseases of ginger, occurrence of leaf spot disease caused by *Phyllosticta zingiberi* is significantly increasingwhich destroys the chlorophyllous tissues thereby causing significant reduction in rhizome yield. Therefore, the present study was conducted to know the effective fungicides, botanicals and bioagents for the management of the disease against five isolates of *P. zingiberi* pathogen. The contact fungicides mancozeb 75%WP recorded highest mycelial inhibition of 100 per cent at the least concentration tested (500ppm). In case of systemic fungicides Propiconazole 25%EC, Tebuconazole 25%EC and Difenconazole 25%EC recorded highest mycelial inhibition of 100 per cent at least concentration tested (500ppm). The combination product Carbendazim 12% + mancozeb 63%WP recorded highest per cent mycelial inhibition of 100 per cent at the least concentration tested (500ppm). Among different botanicals tested, 100 per cent mycelial inhibition was recorded by garlic clove extract. Among the bioagents *B. subtilis* recorded 100 per cent mycelial inhibition of all the isolates.

Keywords: Ginger leaf spot, *Phyllosticta zingiberi*, Mycelial Inhibition, Fungicides, Botanicals, Bioagents.

INTRODUCTION

Ginger (*Zingiber officinale* Rosc.) is one of the most important spice crop traded internationally and domestically for spices, medicine, food like salted ginger and beverage. India has a predominant status in the world as one of the largest producer and consumer of ginger. The major ginger producing states are Kerala, Meghalaya, Arunachal Pradesh, Mizoram, Orissa, Sikkim and West Bengal (Potnuru *et al*., 2018).

The production of ginger, however, is largely affected by diseases caused by bacteria, fungi, viruses, mycoplasma and nematodes (Sharma *et al*., 2010). Some of the important diseases includes soft rot (*Pythium* spp.), yellows (*Fusarium* spp.), Rhizome rot complex (fungi, nematode/insect interactions), leaf spot (*Phyllosticta* sp.) and storage rots (*Pythium* spp., *Fusarium* spp.) (Merga, 2021). Among these, leaf spot caused by *Phyllosticta zingiberi* Ramakr. is becoming a serious problem recently due to its severe leaf spotting which destroys the chlorophyllous tissues which leads to reduction in yield and for this reason is considered as a destructive foliar disease of ginger (Singh *et al*., 2000).

The disease was first reported from India (Ramakrishnan, 1942). The disease was common during the months of August, September and October. A higher concentration of inoculum can be built up by growing ginger continuously in the same field. Early plant infection causes a significant decrease in rhizome yield (Merga and Abukiya 2022).

Symptoms are initially observed on leaves as oval to elongated spots or sometimes irregular, white in color, thin and papery at the centre and had a dark brown margin with a yellowish halo. Minute blackish pycnidia could be observed in the centre of the spots in later stages. The pathogen survives through pycnidia even upto 14 months. Continuous cultivation of ginger in the same field helps in build-up of higher concentration of inoculum. Early infection of the plant leads to drastic reduction in rhizome yield (Singh, 2015).

The disease causes severe leaf blight and results in significant reduction in the number and size of rhizomes thereby resulting 13 to 66 percent yield losses (Singh, 2015). Partial shade also reduces epidemics (30–40%), but only for the initial three months, without reducing crop yield (Singh *et al.*, 2000).

Among fungicides, botanicals and bio-agents evaluated in *in vitro* condition, Propiconazole 25 EC (92.30%) followed by Azoxystrobin 25 EC (91.70%), SAAF 75 WP (Mancozeb and Carbendazim) (89.30%), *Allium sativum* (75.70%) and *Trichoderma harzianum* (78.80%) recorded the highest inhibition of mycelial growth of *Phyllosticta zingiberi* (Arunakumara and Satyanarayana 2015).

Further, in recent years there is an increase in ginger leaf spot disease occurrence and severity in Karnataka. The best method of managing the pathogen being use of fungicide however, there are also alternative means like use of botanicals and biocontrol agents to reduce the risk of fungicide resistance. Therefore, the present study is emphasized on findingsuitable fungicide and biologicals for the management of leaf spot of ginger.

MATERIAL AND METHOD

A. Isolation of the pathogen causing leaf spot of ginger

Five isolates*viz*., MND, HSN, RNP, HNP and PYP were isolated from Mandya, Hassan, Ramanathapura, Holenarasipura and Periyapatna respectively and wereobtained from the samples collected from the survey conducted during October 2020. All these isolates were used to evaluate the fungicides, botanicals and biocontrol agents.

B. Evaluation of fungicides against the pathogen

The efficacy of six contact fungicides, seven systemic fungicides and six combination products at different concentrations were tested against the pathogen. These fungicides were evaluated by "Poison Food Technique" as given by Grover and Moore (1982) under laboratory conditions. The efficacy of the fungicides was expressed as per cent inhibition of mycelial growth, which was calculated by using the formula given by Vincent (1947).

$I = C - T / CX100$

where; I = Per cent inhibition,

C = Radial growth of fungus in control,

T = Radial growth of fungus in treatment.

C. Evaluation of plant extracts against the pathogen

Different parts of 12 plant species *viz.*, onion bulb, garlic clove, capsicum, turmeric rhizome and leaves of Neem, Datura, Ocimum, Eucalyptus, Calotropis, Ipomoea, Plectranthus and Parthenium respectively were used in this study.

The plant extracts were tested at 5 concentrations (1, 5, 10, 15 and 20%) on potato dextrose agar medium. Poison food technique was followed to evaluate the antifungal activity of the plant extracts. Radial growth of the fungus was measured and per cent inhibition of mycelial growth was calculated using the formula given by Vincent (1947).

D. Evaluation of bioagents against the pathogen

Evaluation of six bioagents against *P. zingiberi* Ramkr. isolates was carried out using dual culture technique. The per cent inhibition of growth of the pathogen was calculated by using the formula suggested by Vincent (1947).

RESULTS AND DISCUSSION

A. Evaluation of fungicides against the pathogen

Highest mycelial inhibition of 100 per cent was recorded by mancozeb at 500ppm (Table 1and Plate 1) followed by COC (94.37%) and Bordeaux mixture (87.33 %). Least mycelial inhibition was recorded by Chlorothalonil (75.85 %) followed by Carbendazim (83.56 %) and Captan (85.85 per cent). These results obtained from present investigation are in line with Ravikumara *et al*. (2015), where they reported that among contact fungicides, Mancozeb recorded to be most effective in inhibiting the mycelial growth of both the fungus *P. musarum* and *Helminthosporium torulosum* causing leaf spot diseases in Banana. Mancozeb is a multisite activity fungicide impacting metabolism in target cells. The effectiveness of the mancozeb is because it interferes with enzymes containing sulphydryl groups disrupting several biochemical processes within the fungal cell cytoplasm and mitochondria (Yang *et al*., 2019).

Among seven systemic fungicides tested highest mycelial inhibition of 100 per cent was recorded by Propiconazole, Tebuconazole, and Difenconazole at 500ppm (Table 2 and Plate 2) followed by Tricyclazole at 1000ppm. It was observed that the triazole group fungicides tested showed 100 per cent mycelial inhibition even at the least concentration tested (500ppm).The effectiveness of the triazole fungicides may be attributed to their interference with the biosynthesis of fungal sterols and inhibition of ergosterol biosynthesis wherein ergosterol, a sterol is an essential component of fungal cell membrane (Yang *et al*., 2019).These results are in accordance with Bandyopadhyay *et al*. (2015) wherein they reported that Propiconazole is effective against *P. zingiberi* at 0.1 % at field conditions. Similarly, Ravikumara *et al*. (2015), observed that systemic fungicides like Propiconazole, Difenconazole and Triadimefon to be most effective in inhibiting the growth of *P. musarum* at all concentrations compared to other fungicides tested.

Among six combination products tested highest mycelial inhibition of 100 per cent was recorded by Carbendazim 12 % + Mancozeb 63 % WP at all six concentrations in all isolates (Table 3). The lowest per cent mycelial inhibition of 84.29 per cent was recorded by Tebuconazole 50 % + Trifloxystrobin 25 % WG at 500 ppm. The above results are in line with Ravikumara *et al*. (2015), where they reported that among the combination products tested against *H. torulosaum*, Carbendazim 12 % + Mancozeb 63 % WP gave the 100 per cent inhibition at all the concentrations tested (100, 250, 500 and 750 ppm).This indicates that these two fungicides have synergistic effect and hence exhibited a high degree of inhibiton against the pathogen *in-vitro* even at low concentration and it is due inhibition of mitosis and cell division (Mathivanan and Prabavathy 2007).

Table 1: *In vitro* evaluation of contact fungicides against *P. zingiberi* isolates.

Contact fungicides	Conc. (ppm)	MND		HSN		RNP		HNP		PYP	
		Mean mycelial growth (mm)	Per cent growth inhibition (%)	Mean mycelial growth (mm)	Per cent growth inhibition (%)	Mean mycelial growth (mm)	Per cent growth inhibition (%)	Mean mycelial growth (mm)	Per cent growth inhibition (%)	Mean mycelial growth (mm)	Per cent growth inhibition (%)
Captan	**500**	23.30	74.04 (59.40)	27.70	69.26 (56.36)	24.30	72.96 (58.70)	24.00	73.33 (58.94)	41.70	53.70 (47.15)
	1000	20.30	77.41 (61.65)	20.70	77.03 (61.39)	17.30	80.74 (64.00)	19.30	78.52 (62.42)	23.30	74.07 (59.42)
	1500	15.30	82.96 (65.65)	15.60	82.59 (65.37)	12.30	86.29 (68.30)	16.30	81.85 (64.82)	22.60	74.81 (59.90)
	2000	14.70	83.70 (66.22)	18.60	79.25 (62.93)	10.60	88.15 (69.90)	13.00	85.55 (67.69)	22.60	74.81 (59.90)
	2500	14.30	84.07 (66.51)	14.70	84.44 (66.80)	11.00	87.77 (69.57)	13.00	85.55 (67.69)	21.30	76.29 (60.89)
	3000	13.30	85.19 (67.40)	14.00	83.70 (66.22)	10.70	88.15 (69.90)	11.30	87.40 (69.24)	13.60	84.81 (67.10)
Copper oxy chloride	**500**	24.70	72.59 (58.46)	32.30	64.07 (53.20)	21.60	75.92 (60.64)	23.30	74.07 (59.42)	21.60	75.92 (60.64)
	1000	22.30	75.19 (60.16)	27.70	69.25 (56.35)	13.60	84.81 (67.10)	14.00	84.44 (66.80)	14.00	84.44 (66.80)
	1500	10.00	88.88 (70.56)	24.60	72.59 (58.46)	12.00	86.66 (68.61)	13.60	84.81 (67.10)	14.00	84.44 (66.80)
	2000	00.00	100 (90.05)	24.60	72.59 (58.46)	12.00	86.66 (68.61)	11.70	87.04 (68.93)	13.30	85.18 (67.39)
	2500	00.00	100 (90.05)	14.30	84.45 (66.81)	00.00	100.00 (90.05)	11.30	87.41 (69.25)	14.60	83.70 (66.22)
	3000	00.00	100 (90.05)	14.00	84.07 (66.51)	00.00	100.00 (90.05)	11.00	87.78 (69.57)	00.00	100.00 (90.05)

*Figures in parenthesis are arcsine transformed values; C- Chemicals, c- Concentrations; C*c- Interaction

Table 2: *In vitro* evaluation of systemic fungicides against *P. zingiberi* isolates.

Sr. No.	Systemic fungicides	Conc. (ppm) Mention isolates here	MND		HSN		RNP		HNP		PYP	
			Mean mycelial growth (mm)	Per cent growth inhibition (%)	Mean mycelial growth (mm)	Per cent growth inhibition (%)	Mean mycelial growth (mm)	Per cent growth inhibition (%)	Mean mycelial growth (mm)	Per cent growth inhibition (%)	Mean mycelial growth (mm)	Per cent growth inhibition (%)
1.	Propiconazole	500	00.00	100.00 (90.05)	0.00	100.00 (90.05)	0.00	100.00 (90.05)	0.00	100.00 (90.05)	0.00	100.00 (90.05)
		1000	00.00	100.00 (90.05)	0.00	100.00 (90.05)	0.00	100.00 (90.05)	0.00	100.00 (90.05)	0.00	100.00 (90.05)
		1500	00.00	100.00 (90.05)	0.00	100.00 (90.05)	0.00	100.00 (90.05)	0.00	100.00 (90.05)	0.00	100.00 (90.05)
		2000	00.00	100.00 (90.05)	0.00	100.00 (90.05)	0.00	100.00 (90.05)	0.00	100.00 (90.05)	0.00	100.00 (90.05)
2.	Azoxystrobin	500	63.00	30.00 (33.23)	75.00	16.66 (24.10)	75.00	16.66 (24.10)	79.00	12.22 (20.47)	81.00	10.00 (18.44)
		1000	36.30	59.63 (50.58)	62.30	30.74 (33.69)	69.00	23.33 (28.90)	74.00	17.77 (24.94)	70.30	21.85 (27.88)
		1500	31.60	64.81 (53.64)	43.00	52.22 (46.30)	62.60	30.37 (33.46)	46.00	48.88 (44.38)	44.60	50.37 (45.24)
		2000	00.00	100.00 (90.05)	6.00	93.33 (75.07)	0.00	100.00 (90.05)	0.00	100.00 (90.05)	0.00	100.00 (90.05)
3.	Thiophanate methyl	500	15.60	82.59 (65.37)	22.60	74.81 (59.90)	15.30	82.96 (65.65)	19.30	78.52 (62.42)	16.30	81.85 (64.82)
		1000	13.30	85.18 (67.39)	13.00	85.55 (67.69)	13.60	84.81 (67.10)	16.50	81.66 (64.68)	15.30	82.96 (65.65)
		1500	13.00	85.55 (67.69)	12.00	86.66 (68.61)	13.30	85.18 (67.39)	15.00	83.33 (65.94)	14.30	84.07 (66.51)
		2000	11.30	87.41 (69.25)	4.70	94.81 (76.87)	12.30	86.29 (68.30)	6.00	93.33 (75.07)	7.80	91.29 (72.87)

Figures in parenthesis are arcsine transformed values; C-Chemical; c-Concentration; C*c- Interaction

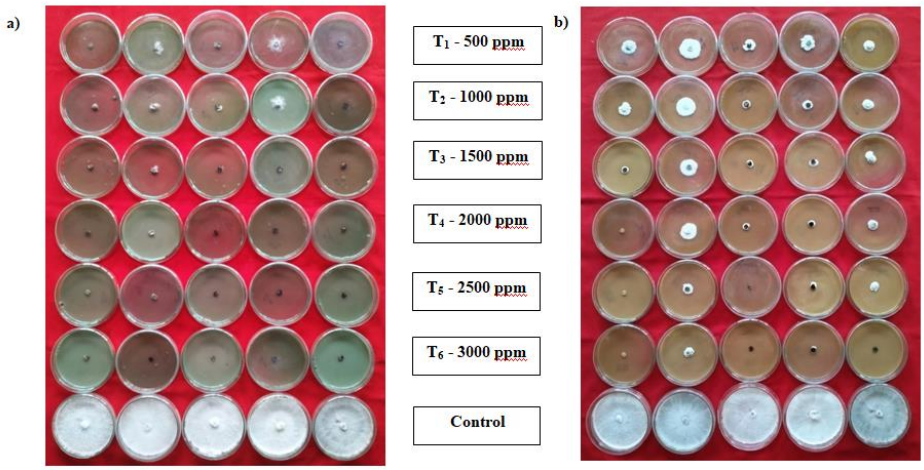


Plate 1. Effect of a) Mancozeb and b) Copper oxy chloride on mycelial growth of *P. zingiberi* isolates.

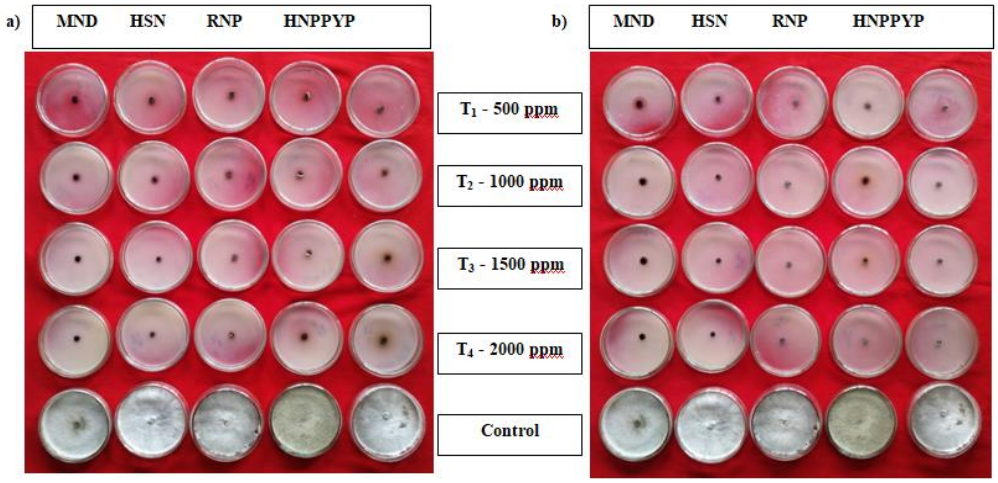


Plate 2. Effect of a) Propiconazole and b) Tebuconazole on mycelial growth of *P. zingiberi* isolates.

***In vitro* evaluation of botanicals against the pathogen.** Efficacy of 12 plant extracts was tested at five different concentrations (1, 5, 10, 15 and 20 %) by following poison food technique. The results obtained are presented in Table 4 and Plate 3. The maximum per cent mycelial inhibition of 100 per cent was recorded by garlic clove (*Allium sativum*) extractat 10% followed by neem (*Azadirachta indica*) at 15 and 20% and chilli (*Capsicum annuum)* extract at 20% concentration. Similar type of result was observed on *P. zingiberi* by Arunakumara and Satyanarayana (2015), wherein they reported that garlic cloves extract was found effective in inhibiting the mycelia growth (75.70%) at 15% concentration. Effectiveness ofgarlic is due to its antifungal property as garlic contains organosulfur compound allicin which reacts with free thiol groups and thus leading to oxidative stress in the cell, these properties are generally thought to be responsible for impart antimicrobial property (Sittisart *et al*., 2017).

***In vitro* evaluation of bioagents against the pathogen.** Among the bioagents tested highest mycelial inhibition of 100 % was recorded by *B. subtilis* followed by *P. fluorescens* (100 %), *T. viridae* (80.37 %). Least per cent mycelial inhibition was recorded by *T. viridae* (40.00 %) followed by *T. asperellum* (43.70 %) (Table 5 and Plate 4). Deshmukh *et al*. (2019) reported that among the bioagents evaluated *B. subtilis* recorded good mycelial inhibition of 88.41 per cent, howerver, maximum mycelial inhibition of 92.38 % was recorded by *T. viride*. The effectiveness of *B. subtilis* maybe due to synthesis of secondary metabolites, cell wall degrading enzymes and antioxidants.

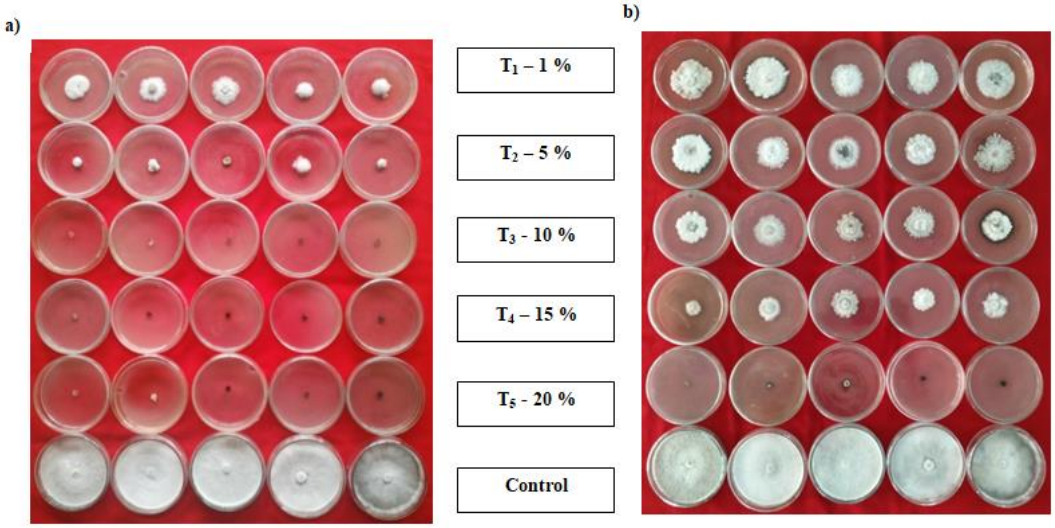
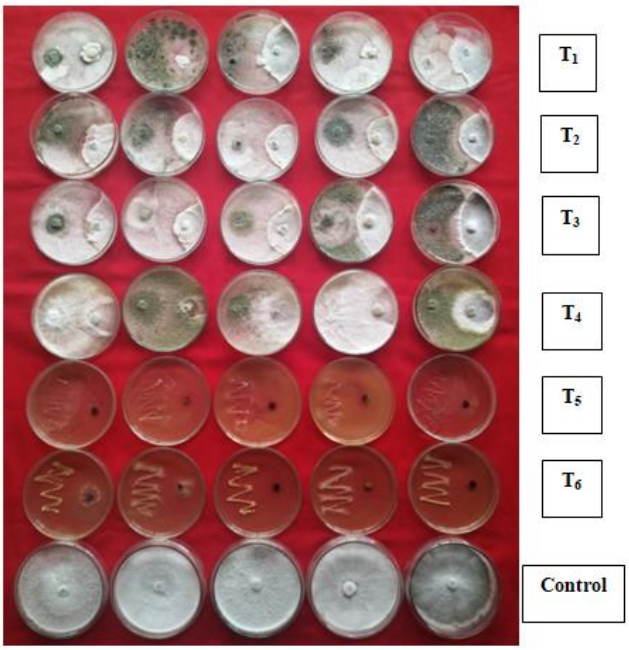


Plate 3. Effect of a) Garlic, b) Chilliextracts on growth of *P. zingiberi* isolates.



T1 - *Trichoderma viridae*; T2 - *T. harzianum*; T3 - *T. asperellum* ; T4 - *T. longibrachiatum*; T5 - *Bacillus subtilis* ; T6 - *Pseudomonas fluorescens*

Plate 4. Efficacy of different bioagents against *P. zingiberi.*

Table 3: *In vitro* evaluation of combination products against *P. zingiberi* isolates.

Combi Products	Conc. (ppm)	MND		HSN		RNP		HNP		PYP	
		Mean mycelial growth (mm)	Per cent growth inhibition (%)	Mean mycelial growth (mm)	Per cent growth inhibition (%)	Mean mycelial growth (mm)	Per cent growth inhibition (%)	Mean mycelial growth (mm)	Per cent growth inhibition (%)	Mean mycelial growth (mm)	Per cent growth inhibition (%)
Azoxystrobin 11 + Tebuconazole 18.3 SC	**500**	14.00	84.44 (66.80)	11.70	87.04 (68.93)	13.60	84.81 (67.10)	9.00	90.00 (71.60)	0.00	100.00 (90.05)
	1000	12.30	86.29 (68.30)	0.00	100.00 (90.05)	12.00	86.66 (68.61)	6.00	93.33 (75.07)	0.00	100.00 (90.05)
	1500	12.30	86.29 (68.30)	0.00	100.00 (90.05)	11.60	87.04 (68.93)	3.60	95.93 (78.40)	0.00	100.00 (90.05)
	2000	7.60	91.48 (73.07)	0.00	100.00 (90.05)	10.6	88.14 (69.89)	0.00	100.00 (90.05)	0.00	100.00 (90.05)
	2500	5.00	94.44 76.40)	0.00	100.00 (90.05)	0.00	100.00 (90.05)	0.00	100.00 (90.05)	0.00	100.00 (90.05)
	3000	0.00	100.00 (90.05)	0.00	100.00 (90.05)	0.00	100.00 (90.05)	0.00	100.00 (90.05)	0.00	100.00 (90.05)
Tebuconazole 50 + Trifloxystrobin 25 WG	**500**	15.30	82.96 (65.65)	4.60	94.81 (76.87)	20.60	77.03 (61.39)	15.60	82.59 (65.37)	14.30	84.07 (66.51)
	1000	5.30	94.07 (75.94)	5.30	94.07 (75.94)	15.60	82.59 (65.37)	14.00	84.44 (66.80)	8.60	90.37 (71.96)
	1500	0.00	100.00 (90.05)	3.00	96.66 (79.51)	9.30	89.63 (71.25)	11.60	87.04 (68.93)	5.30	94.07 (75.94)
	2000	0.00	100.00 (90.05)	0.00	100.00 (90.05)	7.00	92.22 (73.84)	10.00	88.88 (70.56)	0.00	100.00 (90.05)
	2500	0.00	100.00 (90.05)	0.00	100.00 (90.05)	0.00	100.00 (90.05)	7.00	92.22 (73.84)	0.00	100.00 (90.05)
	3000	0.00	100.00 (90.05)	0.00	100.00 (90.05)	0.00	100.00 (90.05)	5.30	94.07 (75.94)	0.00	100.00 (90.05)
Carbendazim 12 + Mancozeb 63 WP	**500**	0.00	100.00 (90.05)	0.00	100.00 (90.05)	0.00	100.00 (90.05)	0.00	100.00 (90.05)	0.00	100.00 (90.05)
	1000	0.00	100.00 (90.05)	0.00	100.00 (90.05)	0.00	100.00 (90.05)	0.00	100.00 (90.05)	0.00	100.00 (90.05)
	1500	0.00	100.00 (90.05)	0.00	100.00 (90.05)	0.00	100.00 (90.05)	0.00	100.00 (90.05)	0.00	100.00 (90.05)
	2000	0.00	100.00 (90.05)	0.00	100.00 (90.05)	0.00	100.00 (90.05)	0.00	100.00 (90.05)	0.00	100.00 (90.05)
	2500	0.00	100.00 (90.05)	0.00	100.00 (90.05)	0.00	100.00 (90.05)	0.00	100.00 (90.05)	0.00	100.00 (90.05)
	3000	0.00	100.00 (90.05)	0.00	100.00 (90.05)	0.00	100.00 (90.05)	0.00	100.00 (90.05)	0.00	100.00 (90.05)

Metiram 55 + Pyraclostrobin 5 WG	**500**	7.30	91.85 (73.45)	5.60	93.70 (75.50)	7.30	91.85 (73.45)	9.30	89.62 (71.24)	7.60	91.48 (73.07)
	1000	6.30	92.96 (74.65)	0.00	100.00 (90.05)	5.00	94.44 (76.40)	8.30	90.74 (72.32)	0.00	100.00 (90.05)
	1500	5.30	94.07 (75.94)	0.00	100.00 (90.05)	4.60	94.81 (76.87)	0.00	100.00 (90.05)	0.00	100.00 (90.05)
	2000	5.00	94.44 (76.40)	0.00	100.00 (90.05)	4.30	95.18 (77.36)	0.00	100.00 (90.05)	0.00	100.00 (90.05)
	2500	4.30	95.18 (77.36)	0.00	100.00 (90.05)	0.00	100.00 (90.05)	0.00	100.00 (90.05)	0.00	100.00 (90.05)
	3000	0.00	100.00 (90.05)	0.00	100.00 (90.05)	0.00	100.00 (90.05)	0.00	100.00 (90.05)	0.00	100.00 (90.05)
Azoxystrobin 18.2 + Difenconazole 11.4 SC	**500**	14.30	84.07 (66.51)	12.00	86.66 (68.61)	15.60	82.59 (65.37)	11.30	87.40 (69.24)	13.60	84.81 (67.10)
	1000	13.00	85.55 (67.69)	10.00	88.88 (70.56)	14.30	84.07 (66.51)	10.60	88.15 (69.90)	10.60	88.15 (69.90)
	1500	3.60	95.92 (78.39)	5.00	94.44 (76.40)	14.00	84.44 (66.80)	10.60	88.15 (69.90)	10.30	88.52 (70.23)
	2000	1.60	98.15 (82.22)	4.30	95.18 (77.36)	11.60	87.03 (68.93)	4.60	94.81 (76.87)	9.30	89.62 (71.24)
	2500	0.00	100.00 (90.05)	0.00	100.00 (90.05)	9.30	89.63 (71.25)	4.60	94.81 (76.87)	9.30	89.62 (71.24)
	3000	0.00	100.00 (90.05)	0.00	100.00 (90.05)	4.60	94.81 (76.87)	0.00	100.00 (90.05)	5.30	94.04 (75.91)
Cymoxanil 8 + Mancozeb 64 WP	**500**	11.60	87.04 (68.93)	0.00	100.00 (90.05)	10.60	88.14 (69.89)	0.00	100.00 (90.05)	16.60	81.48 (64.54)
	1000	10.60	88.15 (69.90)	0.00	100.00 (90.05)	9.30	89.62 (71.24)	0.00	100.00 (90.05)	13.30	85.18 (67.39)
	1500	10.60	88.15 (69.90)	0.00	100.00 (90.05)	5.60	93.70 (75.50)	0.00	100.00 (90.05)	10.60	88.15 69.90)
	2000	9.30	89.63 (71.25)	0.00	100.00 (90.05)	0.00	100.00 (90.05)	0.00	100.00 (90.05)	0.00	100.00 (90.05)
	2500	5.30	94.07 (75.94)	0.00	100.00 (90.05)	0.00	100.00 (90.05)	0.00	100.00 (90.05)	0.00	100.00 (90.05)
	3000	0.00	100.00 (90.05)	0.00	100.00 (90.05)	0.00	100.00 (90.05)	0.00	100.00 (90.05)	0.00	100.00 (90.05)
S.Em ±	**C**	**0.03**		**0.01**		**0.02**		**0.02**		**0.02**	
	C	**0.03**		**0.01**		**0.02**		**0.01**		**0.02**	
	C*c	**0.07**		**0.03**		**0.06**		**0.04**		**0.06**	
C.D.@1%	**C**	**0.11**		**0.05**		**0.09**		**0.07**		**0.09**	
	C	**0.11**		**0.05**		**0.09**		**0.07**		**0.09**	
	C*c	**0.27**		**0.13**		**0.22**		**0.17**		**0.22**	

*Figures in parenthesis are arcsine transformed values; C- Chemicals; c- Concentrations; C*c- Interaction

Table 4: *In vitro* evaluation of botanicals against *P. zingiberi* isolates.

Botanicals	Conc. (%)	MND		HSN		RNP		HNP		PYP	
		Mean mycelial growth (mm)	Percent growth inhibition (%)	Mean mycelial growth (mm)	Percent growth inhibition (%)	Mean mycelial growth (mm)	Percent growth inhibition (%)	Mean mycelial growth (mm)	Percent growth inhibition (%)	Mean mycelial growth (mm)	Percent growth inhibition (%)
Allium sativum	**1%**	30.00	66.66 (54.76)	28.00	68.88 (56.12)	34.00	62.22 (52.10)	23.00	74.44 (59.66)	24.30	72.96 (58.70)
	5%	10.60	88.15 (69.90)	20.60	77.03 (61.39)	15.60	82.59 (65.37)	20.60	77.03 (61.39)	13.00	85.56 (67.70)
	10%	0.00	100.00 (90.05)	0.00	100.00 (90.05)	0.00	100.00 (90.05)	0.00	100.00 (90.05)	0.00	100.00 (90.05)
	15%	0.00	100.00 (90.05)	0.00	100.00 (90.05)	0.00	100.00 (90.05)	0.00	100.00 (90.05)	0.00	100.00 (90.05)
	20%	0.00	100.00 (90.05)	0.00	100.00 (90.05)	0.00	100.00 (90.05)	0.00	100.00 (90.05)	0.00	100.00 (90.05)
Allium cepa	**1%**	32.00	64.44 (53.42)	30.30	66.29 (54.53)	35.00	61.11 (51.45)	29.30	67.40 (55.21)	36.00	60.00 (50.79)
	5%	27.60	69.25 (56.35)	27.30	69.62 (56.58)	25.60	71.48 (57.75)	29.30	67.40 (55.21)	27.60	69.25 (56.35)
	10%	21.60	75.92 (60.64)	26.00	71.11 (57.52)	23.60	73.70 (5918)	25.00	72.22 (58.22)	25.60	71.48 (57.75)
	15%	0.00	100.00 (90.05)	0.00	100.00 (90.05)	0.00	100.00 (90.05)	0.00	100.00 (90.05)	0.00	100.00 (90.05)
	20%	0.00	100.00 (90.05)	0.00	100.00 (90.05)	0.00	100.00 (90.05)	0.00	100.00 (90.05)	0.00	100.00 (90.05)
Capsicum annuum	**1%**	52.70	41.48 (40.11)	54.30	39.62 (39.03)	44.30	50.74 (45.45)	44.00	51.11 (45.66)	50.60	43.70 (41.40)
	5%	46.60	48.14 (43.96)	43.00	52.22 (46.30)	41.30	54.07 47.36)	37.00	58.88 (50.14)	46.00	48.88 (44.38)
	10%	40.60	54.81 (47.78)	39.00	56.66 (48.85)	31.00	65.55 (54.09)	35.30	60.74 (51.23)	39.00	56.66 (48.85)
	15%	18.60	79.26 (62.94)	27.60	69.25 (56.35)	30.60	65.92 54.31)	28.00	68.88 (56.12)	32.00	64.44 (53.42)
	20%	0.00	100.00 (90.05)	5.00	94.44 (76.40)	7.60	91.48 (73.07)	0.00	100.00 (90.05)	0.00	100.00 (90.05)
Datura stramonium	**1%**	90.00	0.00 (0.00)	90.00	0.00 (0.00)	90.00	0.00 (0.00)	90.00	0.00 (0.00)	80.60	10.37 (18.80)
	5%	77.60	13.70 (21.74)	76.60	14.81 (22.65)	37.00	58.88 (50.14)	80.00	11.11 (19.48)	50.00	44.44 (41.83)
	10%	42.30	52.96 (46.72)	42.30	52.96 (46.72)	38.60	57.04 (49.07)	44.30	50.74 (45.45)	36.60	59.25 (50.36)
	15%	37.60	58.15 (49.72)	37.00	58.88 (50.14)	30.00	66.66 (54.76)	34.00	62.22 (52.10)	18.30	79.63 (63.20)
	20%	29.00	67.77 (55.44)	27.60	69.25 (56.35)	11.60	87.03 (68.93)	27.00	70.00 (56.82)	13.00	85.55 (67.69)

Azadirachta indica	**1%**	52.00	42.22 (40.54)	57.60	35.92 (36.84)	64.60	28.14 (32.05)	72.00	20.00 (26.58)	55.60	38.15 (38.16)
	5%	40.00	55.55 (48.21)	52.30	41.85 (40.33)	47.60	47.03 (43.32)	64.60	28.15 (32.06)	54.60	39.25 (38.81)
	10%	37.60	58.14 (49.71)	36.00	60.00 (50.79)	32.00	64.44 (53.42)	35.60	60.37 (51.01)	35.60	60.37 (51.01)
	15%	28.30	68.52 (55.90)	29.30	67.40 (55.21)	30.00	66.66 (54.76)	32.00	64.44 (53.42)	23.30	74.07 (59.42)
	20%	25.30	71.85 (57.99)	26.00	71.11 (57.52)	23.60	73.70 (59.18)	25.30	71.85 (57.99)	13.60	84.81 (67.10)
Ocimum tenuiflorum	**1%**	67.60	24.81 (29.89)	49.30	45.18 (42.26)	67.00	25.55 (30.38)	63.30	29.63 (33.00)	62.30	30.74 (33.69)
	5%	58.00	35.55 (36.62)	44.30	50.74 (45.45)	60.00	33.33 (35.28)	57.60	35.92 (36.84)	50.60	43.70 (41.40)
	10%	33.60	62.59 (52.32)	42.60	52.59 (46.51)	45.00	50.00 (45.02)	49.30	45.18 (42.26)	46.30	48.51 (44.17)
	15%	23.00	74.44 (59.66)	39.30	56.29 (48.64)	34.60	61.48 (51.66)	32.60	63.70 (52.98)	36.60	59.25 (50.36)
	20%	16.00	82.22 (65.09)	36.00	60.00 (50.79)	21.60	75.92 (60.64)	27.00	70.00 (56.82)	14.30	84.07 (66.51)
Eucalyptus globulus	**1%**	90.00	0.00 (0.00)	72.30	19.62 (26.31)	70.00	22.22 (28.14)	90.00	0.00 (0.00)	76.60	14.81 (22.65)
	5%	66.70	25.92 (30.62)	62.60	30.37 (33.46)	58.00	35.55 (36.62)	84.60	5.92 (14.09)	74.30	17.40 (24.67)
	10%	66.30	29.62 (32.99)	53.00	41.11 (39.90)	55.60	38.15 (38.16)	53.60	40.37 (39.47)	67.60	24.81 (29.89)
	15%	51.00	43.33 (41.19)	46.00	48.88 (44.38)	51.30	42.96 (40.97)	44.30	50.74 (45.45)	53.30	40.74 (39.68)
	20%	39.30	56.29 (48.64)	39.30	56.29 (48.64)	47.60	47.04 (43.33)	42.30	52.96 (46.72)	32.30	64.07 (53.20)
Calotropis gigantea	**1%**	64.60	28.15 (32.06)	63.00	30.00 (33.23)	74.60	17.03 (24.39)	72.30	19.62 (26.31)	56.30	37.41 (37.73)
	5%	43.30	51.85 (46.08)	51.00	43.33 (41.19)	62.00	31.11 (33.92)	68.30	24.07 (29.40)	53.60	40.37 (39.47)
	10%	42.00	53.33 (46.93)	52.00	42.22 (40.54)	50.60	43.70 (41.40)	59.30	34.07 (35.73)	54.00	40.00 (39.25)
	15%	33.60	62.59 (52.32)	40.60	54.81 (47.78)	43.00	52.22 (46.30)	34.60	61.48 (51.66)	34.60	61.48 (51.66)
	20%	28.30	68.52 (55.90)	28.60	68.14 (55.66)	28.60	68.14 (55.66)	32.30	64.07 (53.20)	28.60	68.15 (55.67)
Ipomoea carnea	**1%**	88.30	1.85 (7.82)	53.30	40.74 (39.68)	72.60	19.25 (26.04)	58.30	35.18 (36.40)	74.00	17.77 (24.94)
	5%	45.00	50.00 (45.02)	47.60	47.03 (43.32)	57.60	35.92 (36.84)	56.30	37.40 (37.72)	59.30	34.07 (35.73)
	10%	33.30	62.96 (52.54)	46.00	48.88 (44.38)	50.60	43.70 (41.40)	43.60	51.48 (45.87)	54.30	39.62 (39.03)
	15%	27.60	69.25	41.60	53.70	40.60	54.81	40.60	54.81	44.30	50.74

			(56.35)		(47.15)		(47.78)		(47.78)		(45.45)
	20%	26.00	71.11 (57.52)	29.30	67.40 (55.21)	33.60	62.59 (52.32)	30.00	66.66 (54.76)	27.60	69.25 (56.35)
Curcuma longa	**1%**	90.00	0.00 (0.00)	78.30	12.96 (21.11)	90.00	0.00 (0.00)	85.30	5.18 (13.16)	90.00	0.00 (0.00)
	5%	67.60	24.81 (29.89)	55.00	38.88 (38.59)	66.00	26.66 (31.10)	57.60	35.92 (36.84)	59.30	34.07 (35.73)
	10%	57.60	35.92 (36.84)	47.60	47.03 (43.32)	53.60	40.37 (39.47)	51.30	42.96 (40.97)	53.30	40.74 (39.68)
	15%	43.30	51.85 (46.08)	44.00	51.11 (45.66)	46.00	48.88 (44.38)	32.30	64.07 (53.20)	51.00	43.33 (41.19)
	20%	17.60	80.37 (63.73)	18.30	79.62 (63.20)	23.00	74.44 (59.66)	19.30	78.51 (62.41)	24.60	72.59 (58.46)
Plectranthus amboinicus	**1%**	55.00	38.88 (38.59)	55.60	38.15 (38.16)	50.60	43.70 (41.40)	62.30	30.74 (33.69)	57.00	36.66 (37.28)
	5%	46.30	48.51 (44.17)	51.30	42.96 (40.97)	47.00	47.77 (43.74)	60.60	32.59 (34.83)	50.60	43.70 (41.40)
	10%	42.30	52.96 (46.72)	41.30	54.07 (47.36)	46.00	48.88 (44.38)	55.30	38.51 (38.38)	52.00	42.22 (40.54)
	15%	40.60	54.81 (47.78)	39.30	56.29 (48.64)	42.30	52.96 (46.72)	48.60	45.92 (42.68)	46.60	48.14 (43.96)
	20%	37.00	58.88 (50.14)	35.30	60.74 (51.23)	38.00	57.77 (49.50)	43.30	51.85 (46.08)	43.30	51.85 (46.08)
Parthenium histeroporus	**1%**	47.60	47.03 (43.32)	51.60	42.59 (40.76)	47.00	47.77 (43.74)	62.30	30.74 (33.69)	50.00	44.44 (41.83)
	5%	40.70	54.81 (47.78)	42.60	52.59 (46.51)	42.00	53.33 (46.93)	40.60	54.81 (47.78)	53.00	41.11 (39.90)
	10%	36.60	59.25 (50.36)	35.00	61.11 (51.45)	38.30	57.41 (49.29)	38.30	57.40 (49.28)	44.30	50.74 (45.45)
	15%	31.30	65.18 (53.86)	28.60	68.15 (55.67)	33.00	63.33 (52.76)	32.00	64.44 (53.42)	30.00	66.67 (54.77)
	20%	22.60	74.81 (59.90)	24.00	73.33 (58.94)	26.60	70.37 (57.05)	25.60	71.48 (57.75)	26.70	70.37 (57.05)
S.Em ±	**B**	**0.05**		**0.05**		**0.04**		**0.04**		**0.05**	
	C	**0.03**		**0.03**		**0.03**		**0.03**		**0.03**	
	B×c	**0.11**		**0.11**		**0.10**		**0.09**		**0.12**	
C.D.@1%	**B**	**0.18**		**0.18**		**0.17**		**0.15**		**0.19**	
	C	**0.12**		**0.12**		**0.11**		**0.09**		**0.12**	
	B×c	**0.41**		**0.42**		**0.37**		**0.34**		**0.43**	

*Figures in parenthesis are arcsine transformed values, B- Botanicals, c- Concentrations, B*c- Interactions

Table 5: *In vitro* evaluation of different bioagents against *P. zingiberi* isolates.

Bioagents		MND		HSN		RNP		HNP		PYP	
		Mean mycelial growth (mm)	Per cent growth inhibition (%)	Mean mycelial growth (mm)	Per cent growth inhibition (%)	Mean mycelial growth (mm)	Per cent growth inhibition (%)	Mean mycelial growth (mm)	Per cent growth inhibition (%)	Mean mycelial growth (mm)	Per cent growth inhibition (%)
Trichoderma viridae		24.00	73.33 (58.94)	17.70	80.37 (63.73)	54.00	40.00 (39.25)	43.70	51.48 (45.87)	53.70	40.37 (39.47)
Trichoderma harzianum		42.70	52.59 (46.51)	43.00	52.22 (46.30)	42.30	52.96 (46.72)	42.30	52.96 (46.72)	42.50	52.78 (46.62)
Trichoderma asperellum		44.30	50.74 (45.45)	37.70	58.15 (49.72)	44.30	50.74 (45.45)	47.70	47.04 (43.33)	50.70	43.70 (41.40)
Trichoderma longibrachiatum		26.30	70.74 (57.28)	17.70	80.37 (63.73)	42.30	52.96 (46.72)	26.00	71.11 (57.52)	42.50	52.78 (46.62)
Bacillus subtilis		00.00	100.00 (90.05)	00.00	100.00 (90.05)	00.00	100.00 (90.05)	00.00	100.00 (90.05)	00.00	100.00 (90.05)
Pseudomonas fluorescens		46.00	48.89 (44.39)	23.00	74.44 (59.66)	00.00	100.00 (90.05)	00.00	100.00 (90.05)	00.00	100.00 (90.05)
S.Em±	**B**	0.07									
	I	0.06									
	B*I	0.15									
C.D.@1%	**B**	0.26									
	I	0.23									
	B*I	0.57									

*Figures in parenthesis are arcsine transformed values; B- Bioagents; I- Isolates; B*I- Interaction

CONCLUSIONS

Plant Disease management is very much important for preventing productivity losses. In recent years there is an increase in ginger leaf spot disease occurrence and severity which causes significant reduction in yield. The present findings revealed Mancozeb 75%WP, Propiconazole 25%EC and Carbendazim 12% + mancozeb 63%WP fungicides are effective against the pathogen *in vitro*. Also botanicals like garlic clove extract followed by neem and chilli extract and bioagents *B. subtilis*, *P. fluorescens* and *T. viridae* are effective in reducing the fungal growth.

FUTURE SCOPE

The effective fungicides, botanicals and bioagents tested *in vitro* in our study can be tested for the management of the disease in the field and botanicals and bioagents tested can be used as an alternative to fungicides for the eco-friendly management of the disease and to reduce the risk of fungicide resistance, once tested under field conditions.

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Conflict of Interest. None.

REFERENCES

Arunakumar, K. and Satyanarayana, C. (2015). Reaction of ginger cultivars against Phyllosticta zingiberi causing leaf spot and its management. *Int.Quart. J.Life Sci.*,*10*(4), 1895-1899.

Bandyopadhyay, S., Rai, B. and Debnath, A. (2015). Efficiency of different fungicides against leaf spot disease of ginger.*The Bioscan, 10*(1), 1783-1786.

Deshmukh, A. G., Rathod, P. S. and Patil, P. D. (2019). Evaluation of different botanicals, bioagents and fungicide against *Colletotrichum gloeosporioides* under *in vitro* condition. *Int. J. Chem. Sci., 7*(5), 2267-2270.

Mathivanan, M. and Prabavathy, V. R. (2007). Effect of carbendazim and mancozeb combination on Alternaria leaf blight and seed yield in sunflower (*Helianthus annus* L.). *Archives of Phytopathology and Plant Protection, 40*(2), 90-96.

Merga, J. (2021). Epidemiology and Management Strategies of Ginger Leaf spot Disease (*Phyllosticta zingiberi*). *Plant Pathology & Quarantine, 11*(1), 138–143.

Merga Jibat and Abukiya Getu. (2022). Evaluation of efficacy of fungicides against ginger leaf spot (Phyllosticta zingiberi) disease epidemics at Tepi Southwestern Ethiopia. *Int. J. Agril. Res. Innov. Tech., 12*(2), 134-137.

Potnuru, S. K., Kulkarni, V. S., Sajjan, S. S. and Israel, K. S. (2018). Growth performance of area, production and productivity of ginger in India-An economic analysis. *J. Pharmacognosy Phytochem, 3*, 198-200.

Ravikumara, B. M., Narendrappa, T., Manjunatha, L., Yogeesh, K. J. and Kumar, A. C. (2015). *In vitro* Evaluation of Fungicides Against *Phyllosticta musarum* and *Helminthosporium torulosum* Causing Leaf Spot Diseases in Banana. *Trends in Biosciences, 8*(11), 2921-2928.

Sittisart, P., Yossan, S. and Prasertsan, P. (2017). Antifungal property of chilli, shallot and garlic extracts against pathogenic fungi *Phomopsis* spp., isolated from infected leaves of para rubber (*Hevea brasiliensis* Muell.). *Agric. Nat. Resour., 51*(6), 485-491.

Sharma, B. R., Dutta, S., Roy, S., Debnath, A. and Roy, M. (2010). The effect of soil physico-chemical properties on rhizome rot and wilt disease complex incidence of ginger under hill agro climatic region of West Bengal. *Plant Pathol. J., 26*(2), 198–202.

Singh, A. K., Edison, S., Shashank, and Yadav, R. K. (2000). Reaction of ginger germplasm to *Phyllosticta zingiberi* under field conditions. *Indian Phytopathol., 53*(2), 210-212.

Singh, A. K. (2015). Efficacy of fungicides for the control of leaf spot disease of ginger under the field conditions of Chhattisgarh (India). *African J. of Agricultural Research, 10*(11), 1301-1305.

Vincent, J. M. (1947). Distribution of fungal hyphae in the presence of certain inhibitors. *Nature, 159*(4051), 850.

Yang, L. N., He, M. H., Auyang, H, B., Zhu, W., Pan, Z. C., Sui, Q. J., Shang, L. P. and Zhan, J. (2019). Cross-resistance of the pathogenic fungus *Alternaria alternata* to fungicides with different modes of action. *BMC Microbiol., 19*, 205.

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