International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
IJCS 2018; 6(5): 1364-1372
© 2018 IJCS
Received: 01-07-2018
Accepted: 05-08-2018

Avinash
Govind Ballabh Pant University of Agriculture and Technology GBPUA &T), Pantnagar, Udham Singh Nagar, Uttarakhand, India

K Bijendra
Govind Ballabh Pant University of Agriculture and Technology GBPUA &T), Pantnagar, Udham Singh Nagar, Uttarakhand, India

Shivani
Govind Ballabh Pant University of Agriculture and Technology GBPUA &T), Pantnagar, Udham Singh Nagar, Uttarakhand, India

Correspondence
Avinash
Govind Ballabh Pant University of Agriculture and Technology GBPUA &T), Pantnagar, Udham Singh Nagar, Uttarakhand, India

In vitro and glass house evaluation of fungicides against the pathogens associated with rhizome rot complex of ginger in Kumaon region of Uttarakhand

Avinash, K Bijendra and Shivani

Abstract
Of the nine fungicides tested under *in vitro* conditions, carbendazim was found to be most effective fungicide provided complete inhibition of *Fusarium acuminatum* at all the concentrations tested. While, azoxystrobin, pyraclostrobin, tebuconazole, copper oxychloride, carbendazim, propiconazole and metalaxyl-M 4% + mancozeb 64% showed complete inhibition of *Pythium aphanidermatum* at all the tested concentrations. It is evident that all the fungicidal rhizome treatments significantly reduced the rhizome rot incidence and also resulted in improvement in germination as compared to control. However, the treatments wherein rhizomes were treated with fungicidal combinations were proved best compared to single fungicide except carbendazim + copper oxychloride, metalaxyl-M 4% + mancozeb 68%, metalaxyl 8% + mancozeb 64% and carbendazim + tebuconazole @ 0.2% were found best and equally effective.

Keywords: ginger, *Fusarium acuminatum*, *Pythium aphanidermatum*, rhizome rot and fungicides

Introduction
Ginger (*Zingiber officinale* Rosc.) is a perennial cash crop of *Zingiberaceae* family. The term "ginger" originated from Sanskrit word "Sringavera" meaning 'shaped like a deer's antlers (horn) and it is the most popular hot spice in the world. The usable is the underground stem or rhizome which can be consumed either fresh for culinary purposes or as a processed product where it may be salted, dried and or powdered, used as a paste or extracted as ginger oil or oleoresin (Kizhakkayil and Sasikumar, 2011) [19]. The pungent nature of ginger is due to presence of gingerol, shogoal and zingerone while b-sesquiphellendrene and ar-curcumine are responsible for ginger flavor. Several indigenous varieties Maran, Kuruppampadi, Ernad, Wayanad, Himachal and Nadia and two exotic varieties China and Rio-De-Janeiro became very popular among the farmers.

India is the highest producer of ginger with 0.70 million MT production (FAO, 2014) with 0.13 million ha and 4.9 t/ha productivity in 2013-2014 (National Horticulture Database, 2014). In India it is cultivated in all states including Uttarakhand (Kumar *et al.,* 2008; Sharma *et al.,* 2010; Dohroo *et al.,* 2012 and Nath *et al.,* 2014) [20, 37, 8, 29].

In Uttarakhand, ginger is being cultivated over 0.023 million ha area and 0.23 MT production with a very low productivity (National Horticulture Database, 2014) [20] by small and marginal farmers in the state of all the districts of Uttarakhand. The share of Uttarakhand in ginger production is only 3.08 per cent as against 21.64 per cent of Assam. The reason of low productivity seems to be continuous use of degenerated seed which is prone to various diseases, nematodes and insects-pests. Rhizome rot of ginger is complex in nature as several pathogens such as *Pythium aphanidermatum* (Edson) Fitzp; (Subramanian, 1919) [44], *P. myriotylum* Drech, *Fusarium oxysporum* f. sp. *zingiberi* Trujillo (Haware and Joshi, 1974) [13]; *F. solani* (Mort.) Sacc. (Kumar, 1977) [21] and *Sclerotium rolfsii* (Haware and Joshi, 1973) [12] have been reported. In addition, the crop is also attacked by various soil borne nematodes- *Meloidogyne* spp., *Radopholus similis*, *Rotylenchulus reniformis*, *Pratylenchus* spp., *Haplolaimus* spp. *etc.* (Ramana and Eapen, 1995 and Sheela *et al.,* 1995) [36, 39] and insect pests- *Conogethes punctiferalis*, *Aspidiella hartii* and *Holotrichia* spp. (Lodha *et al.,* 1994) [24], which may assist pathogens in easy penetration by creating injury in underground plant parts. Among these, rhizome rot is one of the major limiting factors

in successful cultivation of ginger.

The infection starts at the collar region of the pseudo stem and progresses upwards as well as downwards. Affected pseudo stem becomes water soaked and the rotting spreads to the rhizome resulting in soft rot. Foliar symptoms appear as light yellowing of the tips of lower leaves which gradually spreads to the leaf blades. In early stages, the middle portion of the leaves remain green while the margins become yellow. The yellowing spreads to all leaves of the plant from the lower region upwards and is followed by drooping, withering and drying of pseudo Stems (Dohroo, 2005) [7]. The disease is both seed and soil borne. High soil moisture and high soil temperature are the most important factors for development of rhizome rot. Irrigation water from diseased field also helps in spread of disease (Dohroo *et al.,* 2012) [8]. Management of rhizome rot of ginger is difficult because *Pythium* spp. and *Fusarium* spp. can persist in soil for many years once introduced and single approach does not work effectively to suppress the pathogens under field conditions.

Rhizome rot of ginger was recorded for the first time in India more than a hundred years ago (Butler, 1907) [4]. Presently, it is prevalent throughout the ginger growing countries (Dohroo, 2005) [7]. Higher field losses have been reported in different countries; for example losses of 5-30 per cent in Japan (Ichitani and Goto, 1982) [14], 18-54 per cent in Korea (Kim *et al.,* 1996) [14], 25 per cent in Nepal (Nepali, 2000) [31], 70 per cent in Taiwan (Lin *et al.,* 1971) [23], 90 per cent in India (Rajan and Agnihotri, 1989) and 100 per cent in some fields in Fiji (Fullerton and Harris, 1998 and Stirling *et al.,* 2009) [10, 43]. In India it is prevalent in almost all the ginger growing states including Uttarakhand (Dohroo *et al.,* 2012) [8]. Crop losses due to this malady vary from place to place. Moderate to severe incidence leading to crop loss of more than 50 to 80 per cent have been reported on account of this disease (Joshi and Sharma, 1982) [17]. The pathogens responsible for rhizome rot of ginger can infect host plants at any stage of growth and even during post-harvest storage when growth from latent infections can cause severe losses. Crop loss depends on the stage of crop growth at which the infection starts. If it occurs early, total crop loss of the affected clump results, whereas the crop loss is partial if affected at a later stage (Sharma, 1994) [38]. In Kerala losses can be as high as 90 per cent during the years of heavy incidence (Rajan and Agnihotri, 1989) [33]. *Pythium* spp. also causes huge losses in storage. Instances of storage losses up to 50-90 per cent have been reported. The disease is also known to cause losses in Uttarakhand (Madhulika, 2010) [25].

Materials and Methods

The proposed investigation entitled "Rhizome rot complex of ginger in Kumaon region of Uttarakhand: etiology and management" was conducted at Department of Plant Pathology, Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, District U.S. Nagar, Uttarakhand during cropping season 2015. Major ginger growing areas in different districts namely Nainital, Champawat, Ranikhet, Almora and Pithoragarh, were surveyed for the incidence of rhizome rot. Isolation of pathogens was done from infected rhizomes or pseudostems of ginger. Rhizomes or pseudo-stems showing disease symptoms were washed thoroughly in running tab water and rhizomes or pseudostems cut into small pieces. The pieces were surface sterilized with 1% sodium hypochlorite solution for 60 seconds followed by three times washing in sterile distilled water. After drying on blotter paper samples were transferred onto the PDA plates. Culture plates were incubated at 25-27^{0}C for one week. Isolated colony of the pathogen was further purified by sub-culturing. Pure culture of the fungus was maintained in slants for further use.

The identities of the pathogens were confirmed based on spore morphology and colony characteristics of the fungus under microscope with the help of standard monograph or literature. The identification of *Fusarium acuminatum* was done on the basis of conidial characters by reffering "The *Fusarium* Laboratory Manual" (Leslie and Summerelle, 2006) [22]. *Pythium aphanidermatum* was identified by reffering "Introductory Mycology" (Alexopoulos and Mims, 1996) [1] and further confirmed by Indian Type Culture Collection, Division of Plant Pathology, IARI, New Delhi. *F. acuminatum* has earlier been isolated from the ginger rhizome by Ingle *et al.* (2008) [1] but they have not proved the pathogenecity. Thus whether it was pathogenic or saprophytic not clearly reported in literature. It seems that this is the first report of *F. acuminatum* causing rhizome rot of ginger in India.

Since several isolates of *Fusarium* and *Pythium* were isolated from infected rhizomes or pseudostems collected from different places, the pathogenicity tests were set up separately for each isolates under glass house condition. Uniformly three healthy rhizomes per pot were sown on 5th November, 2015. The pots were pre-filled with soil sterilized with 3 per cent formaldehyde. Plants were inoculated 60 days after rhizome had been planted in each pot. For pathogenicity tests of *Fusarium* isolates about 100 ml of conidial suspension ($4.5x10^5$ spores ml^{-1}) was poured in each pot.

While for *Pythium* isolates, inoculum of each isolate was prepared separately by placing 50g sorghum seeds in 250 ml conical flasks, soaking the seeds overnight in water, pouring off the excess water, autoclaving twice on successive days and then inoculating the seeds from culture on agar. The inoculum was used after the mycelium had fully colonized the substrate (usually 7-10 days at 25^{0}C). Plants were inoculated 60 days after planting with 1flask/Pot. After inoculum was added, these pots were regularly watered to maintain the soil moisture. The plants were regularly monitored for the development of rhizome rot symptoms as reported in literature (Haware and Joshi, 1974; Pegg and Sirling, 1994; Anonymous, 2005 and Dohroo, 2005) [13, 14, 7].

At the end of each experiment, small pieces of tissue from rotting rhizomes/pseudostems were transferred onto PDA to check the presence of *Fusarium* and *Pythium* as described earlier.

For confirmation and further identification up to species level these isolates were sent to Indian Type Culture Collection, Division of Plant Pathology, Indian Agriculture Research Institute, New Delhi.

In present investigation, initially *in vitro* evaluation of nine fungicides (Table-1) were made at different concentrations (100, 500 and 1000 µg ml^{-1}) against *Fusarium* and *Pythium* isolates separately by poisoned food technique (Dhingra and Sinclair, 1985) [5]. The required amount of each fungicide was weighed and double strength stock solution of each fungicide i.e., 200, 1000 and 2000 µg ml^{-1} were prepared in sterile distilled water. Double strength PDA was prepared and 30 ml PDA was poured in 250 ml capacity conical flask, autoclaved at 15 lbs p.s.i. (121.6^{0}C) for 15 minutes. After autoclaving 30 ml stock solution fungicide suspension was added into the flask containing 30 ml sterilized melted PDA, so as to get final required concentrations of 100, 500 and 1000 µg ml^{-1}. The medium was mixed thoroughly before plating. The media

toxicated with fungicide was poured in three Petri plates. Non toxicated media was poured into Petri plates kept as check. After solidification of media, a 0.5 mm mycelia disc of 7 days old culture of the test pathogens (*Fusarium* and *Pythium*) was cut with sterile cork borer and placed in the centre of each Petri plate. The Petri plates were incubated at 25 ± 1^0C. After 7 days of incubation the radial growth was measured.

The per cent inhibition in growth was determined with the help of mean colony diameter and calculated by using the formula given by Mc Kinney (1923) [27].

$$\text{Per cent Inhibition} = \frac{X - Y}{X} \times 100$$

Where, X = colony diameter in check, Y = colony diameter on fungicide treated plates

The details of fungicides used are given in Table 1.

Table 1: Fungicides evaluated against *Fusarium acuminatum* and *Pythium aphanidermatum* isolates causing rhizome rot of ginger.

S. No.	Common Name	Trade Name	Active Ingredient	Manufacturers
1	Azoxystrobin	Amistar	23% SC	Syngenta India Limited
2	Pyraclostrobin	Headline	20% WG	BASF
3	Tebuconazole	Folicur	25% EC	Bayer Crop Science
4	Copper oxychloride	Blitox-50	50% WP	Rallis India Limited
5	Carbendazim 12% + Mancozeb 63%	Companion	75% WP	Indofil Industries Limited
6	Carbendazim	Bavistin	50% WP	BASF
7	Propiconazole	Dhan	25% EC	Syngenta India Limited
8	Metalaxyl 8% + Mancozeb 64%	Matco	72% WP	Indofil Industries Limited
9.	Metalaxyl-M 4% + Mancozeb 64%	Ridomil Gold	68% WP	Syngenta India Limited

The fungicides proved effective in lab condition were further evaluated either independently or in different combinations under pot culture studies for germination and disease incidence against rhizome rot caused by *F. acuminatum* and *P. aphanidermatum*.

Results and Discussion

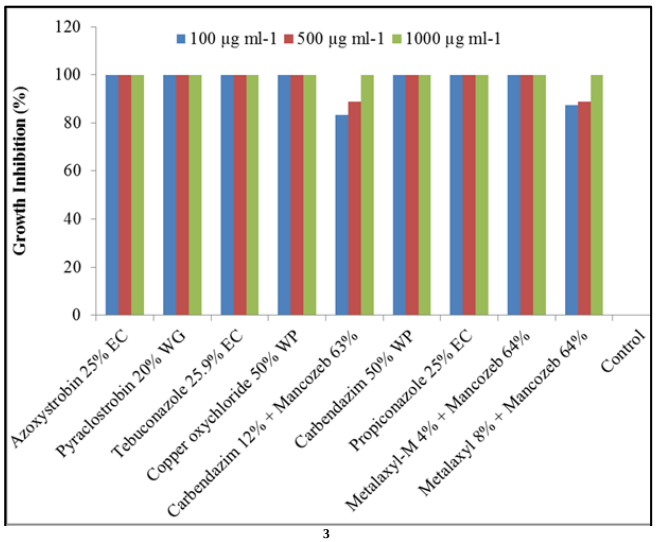
In vitro evaluation of fungicides against *P. aphanidermatum*

The data pertinent to mycelial growth and per cent inhibition in mycelial growth are presented in (Table 2, Plate 4, 5 and 6). It is evident from the table that all the fungicides except carbendazim 12% + mancozeb 63% and metalaxyl 8% + Mancozeb 64% at 100 and 500 µg ml^{-1} concentrations, completely inhibited the mycelial growth of *P. aphanidermatum*. However, metalaxyl 8% + mancozeb 64% and carbendazim 12% + mancozeb 63% provided 87.41 and 83.33 per cent inhibition at 100 µg ml^{-1} while at 500 µg ml^{-1} concentration both the fungicides provided 88.89 per cent inhibition.

The results of present study are in agreement with the work of several researchers (Jayashekhar *et al.*, 2001; Singh, 2011; Mathur *et al.*, 2002; Rajan *et al.*, 2002; Ram and Thakur, 2009; Singh, 2011; Smith and Abbas, 2011; Mishra and Pandey, 2014 and Tripathi, 2014) [40, 26, 34, 35, 45] who reported that ginger rhizome treated with metalaxyl 8% + mancozeb 64% effectively managed the rhizome rot of ginger. Similarly, Dohroo *et al.* (2012) [8] managed rhizome rot of ginger in Solan (Himachal Pradesh) by treating ginger rhizomes with pyraclostrobin @ 0.2% followed by periodic drenching with copper oxychloride @ 0.3%.

Table 2: Effect of fungicides on mycelial growth and percent inhibition of *P. aphanidermatum.*

S. No.	Treatments	Mycelial Growth (mm)			Inhibition (%)		
		100 µg ml^{-1}	500 µg ml^{-1}	1000 µg ml^{-1}	100 µg ml^{-1}	500 µg ml^{-1}	1000 µg ml^{-1}
1	Azoxystrobin 25% EC	0.00	0.00	0.00	100.00	100.00	100.00
2	Pyraclostrobin 20% WG	0.00	0.00	0.00	100.00	100.00	100.00
3	Tebuconazole 25.9% EC	0.00	0.00	0.00	100.00	100.00	100.00
4	Copper oxychloride 50% WP	0.00	0.00	0.00	100.00	100.00	100.00
5	Carbendazim 12% + Mancozeb 63%	15.00	10.00	0.00	83.33	88.89	100.00
6	Carbendazim 50% WP	0.00	0.00	0.00	100.00	100.00	100.00
7	Propiconazole 25% EC	0.00	0.00	0.00	100.00	100.00	100.00
8	Metalaxyl-M 4% + Mancozeb 64%	0.00	0.00	0.00	100.00	100.00	100.00
9	(Metalaxyl 8% + Mancozeb 64%	11.33	10.00	0.00	87.41	88.89	100.00
10	Control	90.00	90.00	90.00	0.00	0.00	0.00
	CD at 5%	0.98	0.76	2.69	1.09	3.41	5.39
	CV	4.96	4.07	7.57	0.74	2.28	3.51
	SEM±	0.33	0.26	1.83	0.37	0.52	4.47



Graph 1: Effect of fungicides on mycelial growth and per cent inhibition of *P. aphanidermatum.*

Jayashekhar *et al.*, 2001; Rajan *et al.*, 2002; Amresh *et al.*, 2004; Mishra and Pandey, 2014; Nath *et al.* (2014) [29, 34, 28] and Tripathi (2014) [45] reported rhizome dipped in copper ocychloride @ 0.3% was effective against rhizome rot of ginger. Similarly, effectivity of mancozeb as rhizome treatment was reported by Singh (2011) [40] and Nath *et al.* (2014) [29]. Carbendazim is reported to inhibit the growth of *Pythium aphanidermatum* causing damping off of chilli (Hanif *et al.*, 2015) [11].

No information is available on the effects of propiconazole, tebuconazole (Azoles group), azoxystrobin (Strobilurins group), against *P. aphanidermatum* causing rhizome rot of ginger. It seems that these novel fungicides were tested against rhizome rot causing pathogen *P. aphanidermatum* for the first time.

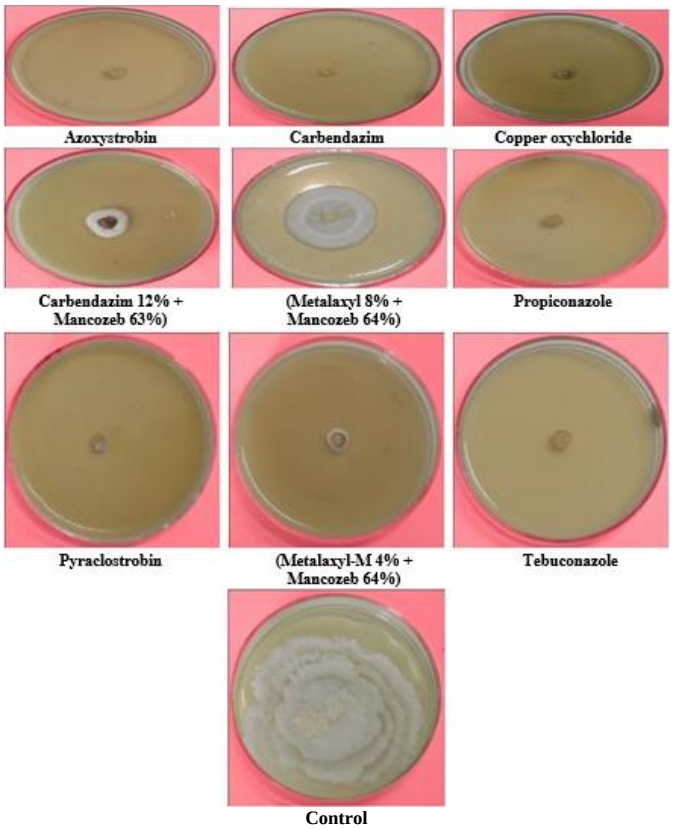


Plate 4: Effect of fungicides on mycelial growth and per cent inhibition of Pythium *aphanidermatum* (100 µg ml^{-1})

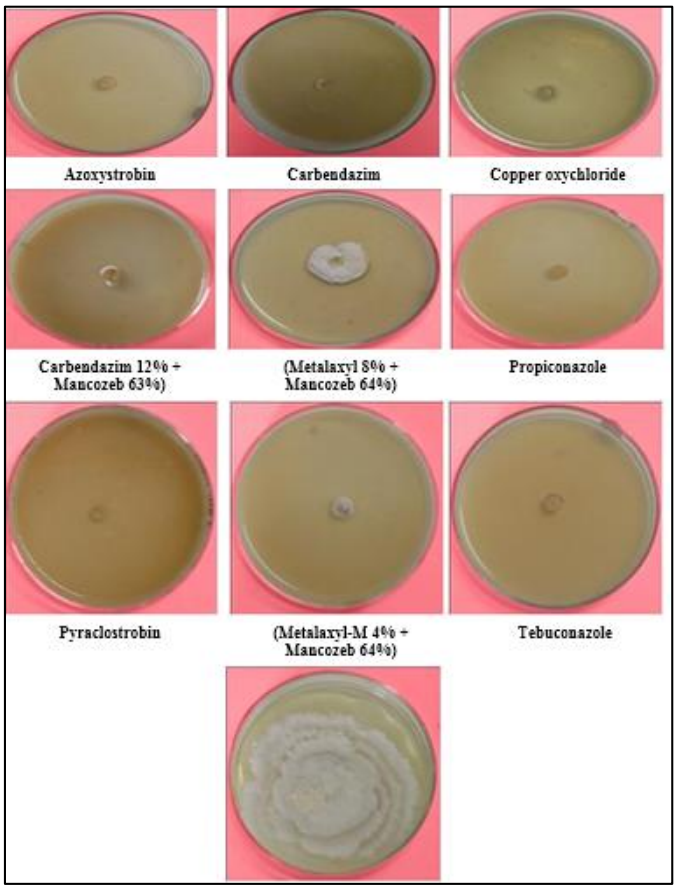


Plate 5: Effect of fungicides on mycelial growth and per cent inhibition of *Pythium aphanidermatum* (500 µg ml^{-1})

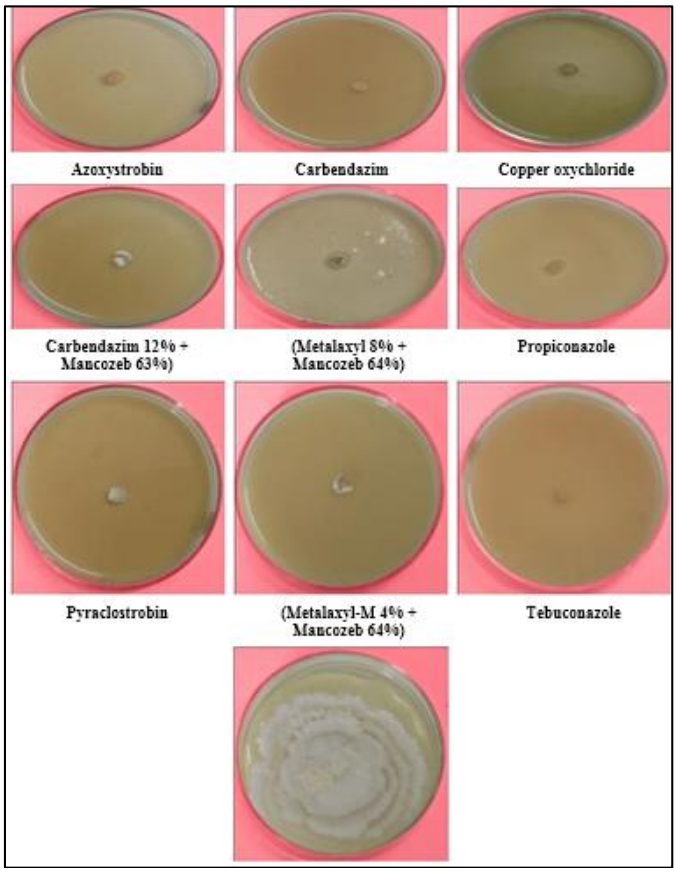


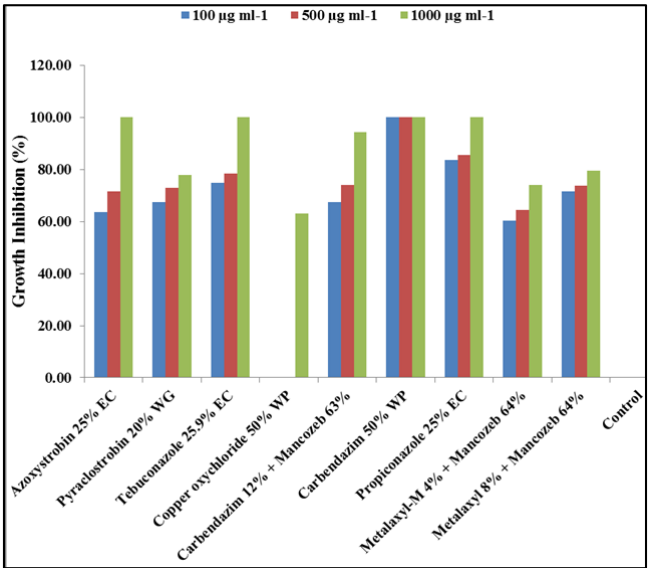
Plate 6: Effect of fungicides on mycelial growth and per cent inhibition of *Pythium aphanidermatum* (1000 µg ml^{-1})

In vitro* evaluation of fungicides against *F. acuminatum

In vitro, efficacy of different fungicides against *F. acuminatum* was studied by poisoned food technique. Inhibition of mycelial growth varied significantly with different fungicides at different concentrations viz., 100, 500 and 1000 µg ml^{-1} (Table 3). Results showed that all the nine fungicides caused significant inhibition in mycelial growth of *F. acuminatum* as compared to check (Table 3, Plate 7, 8 and 9).

Table 3: Effect of fungicides on mycelial growth and per cent inhibition of *F. acuminatum.*

S. No.	Treatments	Mycelial Growth (mm)			Inhibition (%)		
		100 µg ml^{-1}	500 µg ml^{-1}	1000 µg ml^{-1}	100 µg ml^{-1}	500 µg ml^{-1}	1000 µg ml^{-1}
1	Azoxystrobin 25% EC	32.67	25.67	0.00	63.70	71.48	100.00
2	Pyraclostrobin 20% WG	29.30	24.33	20.00	67.44	72.96	77.78
3	Tebuconazole 25.9% EC	22.67	11.67	0.00	74.81	78.33	100.00
4	Copper oxychloride 50% WP	90.00	90.00	33.33	0.00	0.00	62.96
5	Carbendazim 12% + Mancozeb 63%	29.33	23.33	5.00	67.41	74.07	94.44
6	Carbendazim 50% WP	0.00	0.00	0.00	100.00	100.00	100.00
7	Propiconazole 25% EC	14.67	13.00	0.00	83.70	85.55	100.00
8	Metalaxyl-M 4% + Mancozeb 64%	35.67	25.67	23.33	60.36	64.33	74.07
9	Metalaxyl 8% + Mancozeb 64%	25.67	23.67	18.33	71.48	73.70	79.63
10	Control	90.00	90.00	90.00	0.00	0.00	0.00
	CD at 5%	3.50	2.41	4.14	3.89	2.68	4.60
	CV	5.56	4.32	6.78	3.88	2.47	3.42
	SEM±	1.19	0.82	1.40	1.32	0.91	1.56



Graph 2: Effect of fungicides on mycelial growth and per cent inhibition of *F. acuminatum*

However, carbendazim was proved to be most effective fungicide provided complete inhibition at all the tested concentrations (100, 500 and 1000 µg ml^{-1}). It was followed by propiconazole, tebuconazole and azoxystrobin provided hundred per cent inhibition in mycelial growth of pathogen at highest dose (1000 µg ml^{-1}) of fungicides. However, at 500 and 100 µg ml^{-1} concentrations propiconazole provided 85.55 and 83.70 per cent, tebuconazole 78.33 and 74.81 and azoxystrobin provided 71.48 and 63.70 per cent inhibition in mycelial growth of *F. acuminatum*, respectively.

In the present study carbendazim gave complete inhibition of the mycelial growth of *F. acuminatum* at all the concentrations tested (i.e.100, 500 and 1000 µg ml^{-1}) *in vitro*. The results are in accordance with the work of Dohroo (1993); Srivastava (1994) and Rajan *et al.* (2002) [34] who reported that rhizome treatment with carbendazim (0.2%) effectively managed the rhizome rot of ginger. Other fungicides namely, propiconazole, tebuconazole and azoxystrobin also gave similar results. No information is available on the effects of propiconazole, tebuconazole, ergosterol inhibitor fungicides belonging to azole group and azoxystrobin belonging to strobilurins group against rhizome rot of ginger caused by *F. acuminatum*. Therefore, it may be considered as the first report.

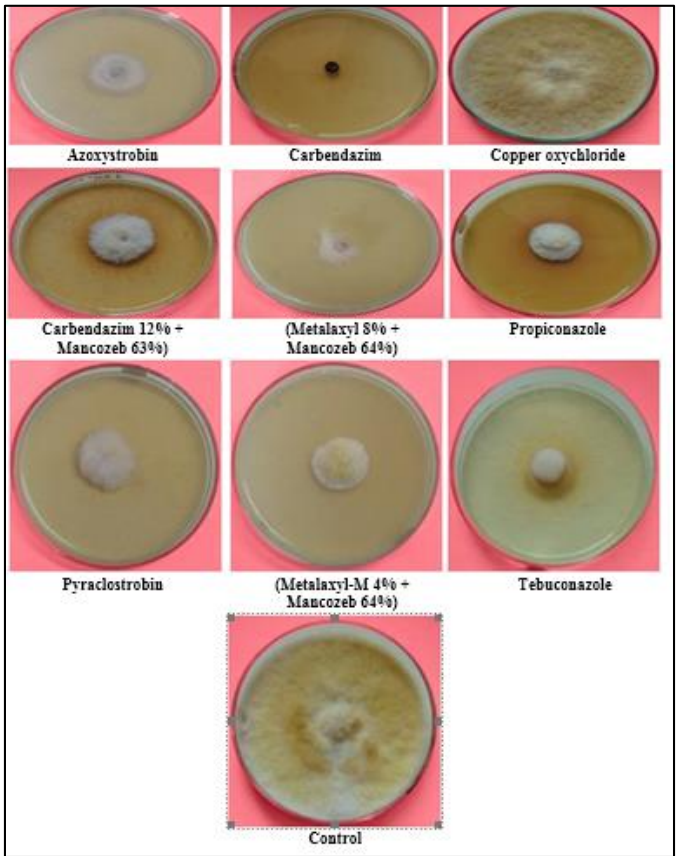


Plate 7: Effect of fungicides on mycelial growth and per cent inhibition of *Fusarium acuminatum* (100 µg ml^{-1})

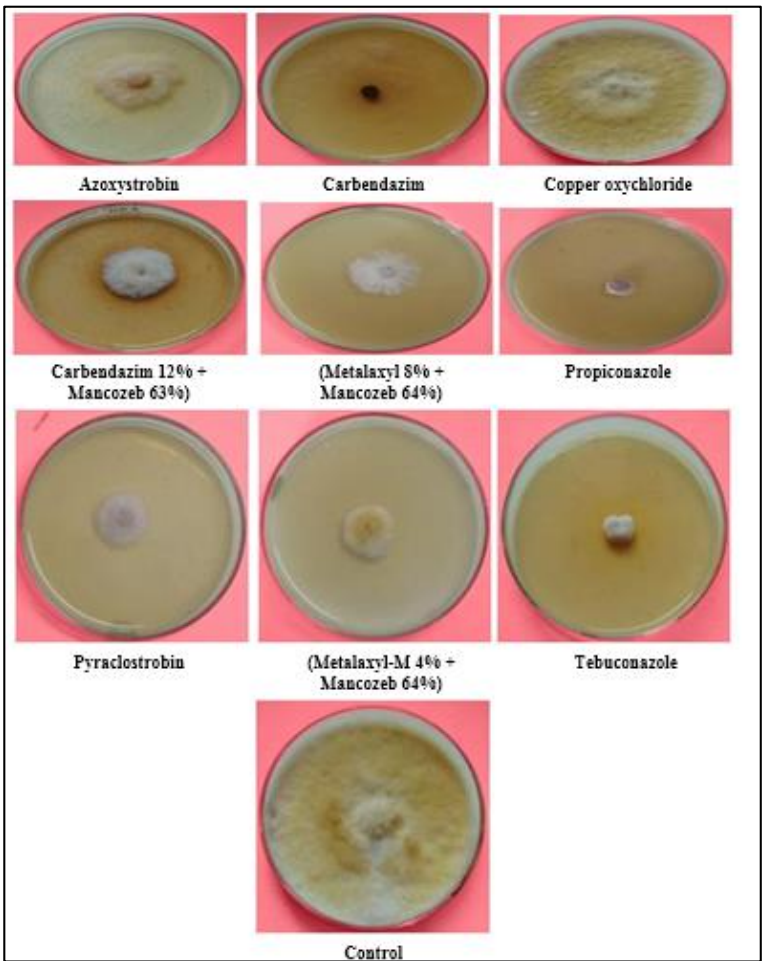


Plate 8: Effect of fungicides on mycelial growth and per cent inhibition of *Fusarium acuminatum* (500 µg ml^{-1})

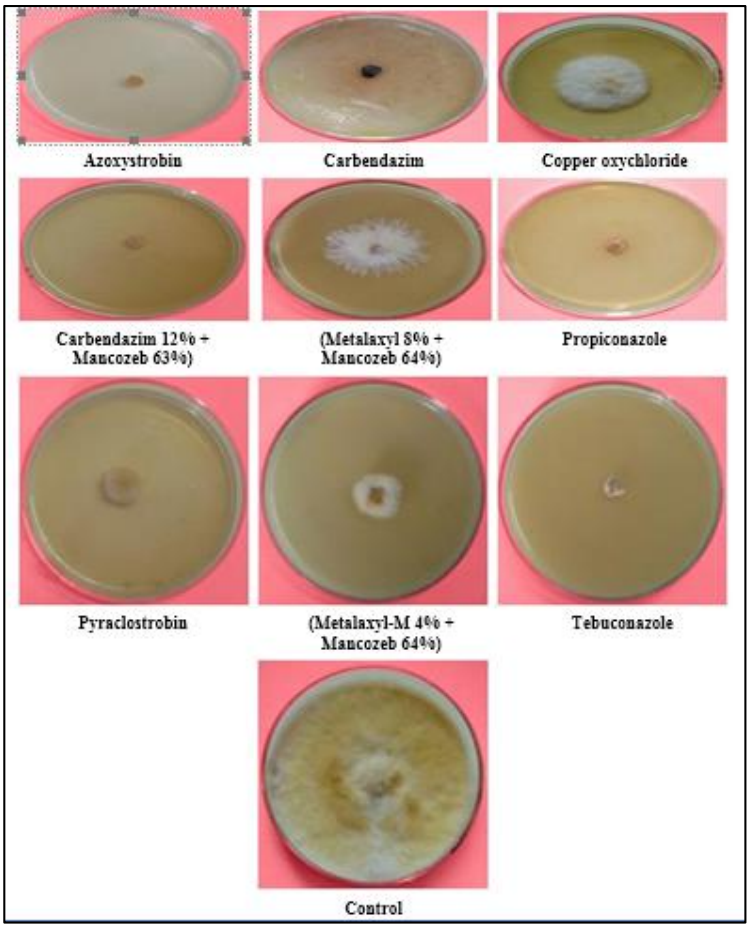


Plate 9: Effect of fungicides on mycelial growth and per cent inhibition of *Fusarium acuminatum* (1000 µg ml^{-1})

Evaluation of fungicides under glasshouse condition for the management of rhizome rot of ginger

It is evident from the data (Table 4) that all the fungicidal rhizome treatments significantly reduced the rhizome rot incidence and also resulted in improvement in germination as compared to control. However, the treatments wherein rhizomes were treated with fungicidal combinations were proved best compared to single fungicide except carbendazim + copper oxychloride, metalaxyl-M 4% + mancozeb 64%, metalaxyl 8% + mancozeb 64% and carbendazim + tebuconazole @ 0.2% were found best and equally effective. Nevertheless, these were significantly at par with carbendazim + azoxystrobin, carbendazim + pyraclostrobin, carbendazim + tebuconazole, carbendazim + propiconazole, carbendazim + copper oxychloride, propiconazole + azoxystrobin, propiconazole + pyraclostrobin, propiconazole + tebucanazole and propiconazole + copper oxychloride (Table 4). The same fungicide metalaxyl-M 4% + mancozeb 64%, was also found best in improving the germination, wherein 88.00 percent germination was recorded. Nevertheless, it was significantly at par with most of the fungicides except carbendazim + copper oxychloride, tested in different combinations (Table 4).

Present findings are in accordance with the work of several researchers (Jayasekhar *et al.*, 2001; Ram and Thakur, 2009; Singh, 2011; Mishra and Pandey, 2014; Nath *et al.*, 2014; Tripathi, 2014) [40, 29, 35, 28] who reported ginger rhizomes treated with metalaxyl 8% + mancozeb 64% resulted lowest disease incidence and increased germination. Similarly, several researchers (Jayasekhar *et al.*, 2001; Ram and Thakur, 2009; Nath *et al.*, 2014 and Tripathi, 2014) [29, 35, 28, 34] reported ginger rhizomes treated with copper oxychloride @ 0.3% showed minimum disease incidence with increased germination. However, Tripathi (2014) [45] reported ginger rhizomes treated with carbendazim (0.2%) showed lower disease incidence.

However, search for the literature revealed that no one have evaluated of propiconazole and tebuconazole (Azoles group), azoxystrobin, pyraclostrobin (Strobilurins group) and metalaxyl-M 4% + mancozeb 64% independently or carbendazim + azoxystrobin, carbendazim + pyraclostrobin, carbendazim + tebuconazole, carbendazim + propiconazole, carbendazim + copper oxychloride, propiconazole + azoxystrobin, propiconazole + pyraclostrobin, propiconazole + tebucanazole and propiconazole + copper oxychloride in combinations against rhizome rot of ginger. These novel fungicides were not tested against rhizome rot of ginger till date therefore, it should be considered as the first report.

Table 4: Evaluation of fungicides under glasshouse condition for the management of rhizome rot of ginger

S. No.	Treatment	Germination per cent	Per cent disease incidence	Per cent disease control
1	Azoxystrobin	76.00	32.00	58.97
2	Pyraclostrobin	68.00	44.00	43.59
3	Tebuconazole	74.00	40.00	48.72
4	Copper oxychloride	72.00	42.00	46.15
5	Carbendazim	78.00	30.00	61.54
6	Propiconazole	76.00	34.00	56.41
7	Metalaxyl-M 4% + Mancozeb 64%	88.00	20.00	74.36
8	Metalaxyl 8% + Mancozeb 64%	86.00	20.00	74.36
9	Carbendazim + Tebuconazole (1:1)	84.00	20.00	74.36
10	Carbendazim+ Azoxystrobin (1:1)	84.00	22.00	71.79
11	Carbendazim + Propiconazole (1:1)	82.00	22.00	71.79
12	Propiconazole + Azoxystrobin (1:1)	80.00	24.00	69.23
13	Propiconazole + Tebuconazole (1:1)	80.00	26.00	66.67
14	Propiconazole +Pyraclostrobin (1:2)	80.00	28.00	64.10
15	Carbendazim + Pyraclostrobin (1:2)	80.00	30.00	61.54
16	Propiconazole + Copper oxychloride (1:3)	80.00	30.00	61.54
17	Carbendazim + Copper oxychloride (1:3)	78.00	30.00	61.54
18	Control	44.00	78.00	-
	CD at 0.5%	8.81	9.58	
	CV	8.95	23.91	
	SEM±	3.12	3.39	

Acknowledgements
Authors are thankful to Dr. Karuna Vishunavat, Head of Department, Devision of Plant Pathology, and GBPUAT for encouragement. They also thank Dr. A. K. Tewari, Dr. Satya Kumar, Dr. R. P. Singh, Dr. Rashmi Tewari and Dr. Pankaj Audichya for their kind support and guidance.

References

1. Alexopoulos CJ, Mims CW, Blackwell M. Introductory Mycology. John Wiley and Sons, New York. 1996; 4:868.
2. Amresh YS, Raveendra BH, Divatar AB. Effect of organic amendments on rhizome rot of green ginger (*Zingiber officinale* Rosc.). Advanced in Plant Science. 2004; 17(2):537-539.
3. Bhatia M, Sharma A. Antibacterial activities of *Trigonella foenum-graecum* and *Zingiber officinale*. International Journal of Pharmaceutical Sciences and Research. 2012; 3(9):3228-3232.
4. Butler EJ. An account of the genus *Pythium* and some *Chytridiaceae*. In: Memoirs of the Department of Agriculture, India. 1907; 1(5):1-162.
5. Dhingra OD, Sinclair JB. Basic Plant Pathology Methods. CRC Press, Florida. 1985, 325.
6. Dohroo NP. Final ICAR report on Multilocational Project on Rhizome Rot of Ginger. UHF, Solan, 1993, 38.
7. Dohroo NP. Diseases of ginger. *In:* Ravindran, P.N., Babu, K.N. (Eds.), Ginger, the Genus Zingiber. CRC Press, Boca Raton, 2005, 305-340.
8. Dohroo NP, Kansal S, Ahluwalia A. Evaluation of eco-friendly disease management practices against soft rot of ginger caused by Pythium aphanidermatum. Plant Disease Research. 2012; 27(1):1-5.
9. FAO. http://faostat3.fao.org/site/567 default.aspx (retrieved on 15-10-15), 2014.
10. Fullerton RA, Harris FM. Control of Rhizomes Rot of Ginger in Fiji. A report to the Ginger Council of Fiji. Australasian Plant Pathology. 1998; 38:453-460.
11. Hanif A, Lal AB, Simon S. Eco-friendly management of damping off (*Pythium aphanidermatum*) of chilli. International Journal of Agricultural Science and Research. 2015; 5(1):1-6.
12. Haware MP, Joshi LK. Effect of post-harvest treatment of aureofungin on rhizome rot and viability of ginger seed rhizomes. Hindustan Antibiotic Bulletin. 1973; 15(3):84-85.
13. Haware MP, Joshi LK. Studies on soft rot of ginger from Madhya Pradesh. Indian Phytopathology. 1974; 27:158-161.
14. Ichitani T, Goto H. Distribution of *Pythium zingiberum* causing rhizome rot in ginger-growing and its surrounding uncultivated soils. Annual Phytopathological Society of Japan. 1982; 48:674-676.
15. Ingle A, Gade A, Pierrat S, Sonnichsen C, Rai M. Mycosynthesis of Silver Nanoparticles Using the Fungus *Fusarium acuminatum* and its Activity Against Some Human Pathogenic Bacteria. Current Nanoscience. 2008; 4:141-144.
16. Jayasekhar M, Joshua JP, Pillai OAA. Management of rhizome rot of ginger caused by *P.* aphanidermatum. Madras Agricultural Journal. 2001; 87(3):170-171.
17. Joshi LK, Sharma ND. Diseases of ginger and turmeric and their control. Indian Cocoa, Arecanut and Spices Journal. 1982; 9:61-62.
18. Kim CH, Hahn KD, Park KS. Survey of rhizome rot incidence of ginger in major production areas in Korea. Korean Journal of Plant Pathology. 1996; 12:336-344.
19. Kizhakkayil J, Sasikumar B. Diversity, characterization and utilization of ginger: a review. Plant Genetic Resources. 2011; 9(3):464-477.
20. Kumar A, Reeja ST, Bhai RS, Shiva KN. Distribution of *Pythium myriotylum* Drechsler causing soft rot of ginger. Journal of Spices and Aromatic Crops. 2008; 17(1):5-10.
21. Kumar SNS. Ginger rot by Fusarium solani. Journal of Plantation Crops. 1977; 5(2):122.
22. Leslie JF, Summerell BA. The *Fusarium* Laboratory Manual". Blackwell Publishing Asia. 2006, 387p.
23. Lin LT, Chang SS, Leu LS. Soft rot of inger. Plant Protection Bulletin Taiwan. 1971; 13:54-67.
24. Lodha BC, Mathur K. Management of rhizome rot of ginger: Progress and perspective. *In*: Agnihotri, V.P. and Singh, D.V. eds. Management of Threatening Plant Disease of National Importance. Malhotra Publishing House, New Delhi, 1994, 249-262.
25. Madhulika S. Studies on etiology of ginger rhizome rot and its management in Uttaranchal hills. *Thesis*, Ph.D. H.N.B. Garhwal University, Srinagar (Garhwal), 2010, 141.
26. Mathur K, Ram D, Poonia J, Lodha BC. Integration of soil solarization and pesticides for management of rhizome rot of ginger. International Journal of Plant, Animal and Environmental Sciences. 2002; 55:345-347.
27. Mckinney HH. A new system of grading plant diseases. Journal of Agricultural Research. 1923; 26:195-218.
28. Mishra RS, Pandey VP. Management of soft rot of ginger through bio-fumigation, fungicides and bio-agents. Journal of Plant Disease Sciences. 2014; 9(1):128-130.
29. Nath BC, Bora LC, Srisvastava S, Singh JP. Integrated disease management of *Zingiber officinale* Rosc. Rhizome rot. The Bioscan. 2014; 9(1):265-269.
30. National Horticulture Database, 2014. http://nhb.gov.in/area-pro/NHB_Database, 2015. (Retrieved on 15-10-15).
31. Nepali MB, Prasad RB, Sah DN. Survey of Ginger Growing Areas in Syanja, Palpa, Gulni and Arghaknach Districts with Special Emphasis in Rhizome Rot Disease. Bulletin, Lumle Agricultural Research Station, Nepal, 2000, 43.
32. Pegg KG, Stirling GR. Ginger. *In:* Persley, D. (Ed.*)*, Diseases of Vegetable Crops. Department of Primary Industries, Queensland, 1994, 55-57.
33. Rajan KM, Agnihotri VP. *Pythium* induced rhizome rot of ginger, problems and progress. *In*: Agnihotri, V.P., Sing, N., Chaube, H.S., Sing, V.S., Dwivedi, T.S. eds. Perspective in Phythopathology. Today and Tomorrow Printers and Publishers, New Delhi, 1989, 189-198.
34. Rajan PP, Gupta SR, Sharma YR, Jackson GVH. Diseases of Ginger and their control with *Trichoderma harzianum* in India. Phytopathology. 2002; 55(2):173-177.
35. Ram J, Thakur BBL. Loss of Ginger Rhizome during storage and its management by fungicides. Journal of Mycology and Plant Pathology. 2009; 39:432-435.
36. Ramana KV, Eapen SJ. Parasitic nematodes and their management in major spices. Journal of Spices and Aromatic Crops. 1995; 4(1):1-16.
37. Sharma BR, Dutta S, Roy S, Debnath A, Roy MD. 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 Pathology Journal. 2010; 26(2):198-202.
38. Sharma YR. Rhizome rot disease of ginger (*Zingiber officinale* Rosc.) and turmeric (*Curcuma longa* Linn.). In Chadha, K.L. and Rethium, P. eds. *Advances in Horticulture*. V.10, part 2. Malhotra Publishing House, New Delhi, 1994, 1113-1138.
39. Sheela MS, Bai H, Jiji T, Kuriyan KJ. Nematodes associated with ginger rhizosphere and their management in Kerala. Pest Management in Horticulture Ecosystems. 1995; 1(1):43-48.
40. Singh AK. Management of rhizome rot caused by *Pythium*, *Fusarium* and *Ralstonia* sp. in ginger (*Zingiber officinale)* under natural field conditions. Indian Journal of Agricultural Sciences. 2011; 81(3):268-270.
41. Smith M, Abbas R. Controlling *Pythium* and Associated Pests in Ginger. Rural Industries Research and Development Corporation, 2011 28.
42. Srivastava LS. Management of soft rot of ginger in Sikkim. Plant Disease Research. 1994; 9(2):146-149.
43. Stirling GR, Turaganivalu U, Stirling AM, Lomavatu MF, Smith MK. Rhizome rot of ginger (*Zingiber officinale*) caused by *Pythium myriotylum* in Fiji and Australia. Australasian Plant Pathology. 2009; 38:453-460.
44. Subramanian LS. A *Pythium* disease of ginger, tobacco and papaya. Memoirs of the Department of Agriculture, India, (Botanical Series). 1919; 10(4):181-194.
45. Tripathi AK. Management of rhizome rot disease of ginger in Bundelkhand region of Madhya Pradesh. International Journal of Current Research. 2014; 6(4):6435-6436.