International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
www.chemijournal.com
IJCS 2020; 8(5): 2334-2340

Received: 06-07-2020
Accepted: 15-08-2020

Evaluations of effective molecules against the pathogen complex causing rhizome rot of ginger

Archana TS, RK Mesta, N Basavaraj, NK Hegde, MP Basavarajappa, KC Kiran Kumar and SR Mulla

Archana TS
Department of Plant Pathology, College of Horticulture, University of Horticultural Sciences, Bagalkot, Karnataka, India

RK Mesta
Department of Plant Pathology, College of Horticulture, University of Horticultural Sciences, Bagalkot, Karnataka, India

N Basavaraj
Department of Plant Pathology, College of Horticulture, University of Horticultural Sciences, Bagalkot, Karnataka, India

NK Hegde
Department of Plant Pathology, College of Horticulture, University of Horticultural Sciences, Bagalkot, Karnataka, India

MP Basavarajappa
Department of Plant Pathology, College of Horticulture, University of Horticultural Sciences, Bagalkot, Karnataka, India

KC Kiran Kumar
Department of Plant Pathology, College of Horticulture, University of Horticultural Sciences, Bagalkot, Karnataka, India

SR Mulla
Department of BCI, College of Horticulture, University of Horticultural Sciences, Bagalkot, Karnataka, India

Corresponding Author:
Archana TS
Department of Plant Pathology, College of Horticulture, University of Horticultural Sciences, Bagalkot, Karnataka, India

DOI: https://doi.org/10.22271/chemi.2020.v8.i5af.10652

Abstract
Rhizome rot disease of ginger has become a major threat to all ginger growing areas causing huge economical losses. The complex nature of the pathogens involved in the disease makes the management strategies cumbersome. There is still a need to develop integrated disease management strategies by targeting all the pathogens involved in the complex disease development. In the present study, we have isolated five pathogens involved in the disease development such as *Pythium, Fusarium, Sclerotium rolfisii, Ralstonea solanacearum* and *Meloidogyne incognita.* A primary *in vitro* evaluation of seven different antibiotics such as Streptocycline, K-cycline, Plantomycine, Validamycin, Bactinash, Bactinashak as well as nine nonsystemic, eleven systemic, and twelve combi products were evaluated under lab conditions against the pathogen complex. Our results revealed that among the different antibiotics Streptocycline followed K-cycline, Bactinash, as well as COC, found most effective against *Ralstonea solanacearum*. Among the different non-systemic chemicals evaluated against the pathogen complex COC and propineb found effective against *Pythium*, mancozeb, captan, kavach were effective against *Fusarium* and all the non-systemic fungicides showed high inhibition against *Sclerotium rolfisii.* Systemic fungicides such as carbendazim, Tricyclazole, Tebuconazole, Alliete were found more effective against *Pythium*. Tricyclazole, Tebuconazole found effective against *Fusarium,* and fungicides such as Hexaconazole, Propiconazole, Tricyclazole, Myclobutanil, Azoxystrobin, Tebuconazole, Diniconazole were found effective against *Sclerotium rolfsii*. As compared to systemic and non-systemic fungicides, combi products were found more effective against all the pathogens involved in the disease complex.

Keywords: Anti fungal, anti bacterial, percent inhibition

Introduction
Ginger is one of the earliest known oriental spices cultivated in India for both fresh vegetables and as a dried spice. It is used as a condiment, flavoring agent, in the preparation of non-alcoholic beverages and also known to have numerous medicinal properties. Ginger is cultivated in most of the states in India. However, states namely Karnataka, Kerala, Orissa, Sikkim, Assam, Meghalaya, Arunachal Pradesh, and Gujarat are the major ginger growing states in India.
The crop is affected by a variety of diseases like soft rot or rhizome rot, leaf spot, and bacterial wilt diseases. Among the major constraints of ginger production, rhizome rot is very important because of severe crop losses. It occurs in several parts of India wherever the crop is grown. The term rhizome rot is commonly used for all the diseases affecting the rhizome irrespective of pathogens involved since the ultimate result is the partial or total loss of rhizome.
This particular disease is caused by the interaction of several plant pathogenic agents such as fungi, Bacteria, and Nematodes. The main pathogens associated with this disease include *Fusarium* spp, *Pythium* spp, *Sclerotium rolfsii*, *Rhizoctonia solani, Pseudomonas spp,*
The infection starts at the collar region of the pseudostem and progresses upwards as well as downwards. The 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 the early stages, the middle portion of the leaves remains 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 pseudostems. Infected rhizomes can be pulled out easily appear black in color and emit foul smell (Dohroo, 2015) [8].

Several cultivars of ginger are grown in India and they are generally named after the localities where they are grown. However, none of the varieties are completely resistant to the pathogen complex (Pattnaik *et al*. 2015) [13]. Rhizome rot disease has now become a major threat to all ginger growing areas causing huge economical losses. There are no curative effective methods for the management of rhizome rot and also preventive options are cumbersome and are not fully encouraging with any chemicals and biological for the effective disease management schedule.

Materials and methods

Evaluation of antibiotics, bioagents and fungicides under *In vitro* conditions against pathogens

Antibiotics, Bio agents, fungicides were evaluated at different concentrations to test the efficacy under the laboratory condition. Antibiotics were evaluated at 100 ppm, 200 ppm, 300 ppm, 400 ppm, and 500 ppm. The systemic fungicides were evaluated at the concentration of 500 ppm, 1000 ppm, 1500, and 2000 ppm. The contact and combi products were evaluated at a concentration of 1500, 2000 ppm, 2500 ppm. The fungicides were evaluated using potato dextrose agar (PDA) as the basal medium and by following the poison food technique (PFT). Antibiotics were evaluated by the agar well diffusion method.

Poison food technique

The requisite quantity of fungicides was weighed by using the formula and mixed properly with the autoclaved and cooled (40-45 ^{0}C) PDA in conical flasks to obtain desired concentrations. The 15-18 ml PDA amended with the fungicides was poured into 90 mm sterilized Petri plates under aseptic condition and allowed for solidification under room temperature. On solidification of PDA each treatment plate was inoculated or seeded in the center with the 5 mm mycelial disc obtained from a one-week old pure culture of fungus under aseptic condition. Each treatment replicated thrice with respective concentrations. Petri plates containing PDA without any fungicides were inoculated with 5 mm disc of the test pathogen and maintained as the suitable untreated control. All the inoculated and control Petri plates were incubated at 28 ± 2^{0}C in incubator till the mycelial growth of the test pathogen in control covers the entire Petri plate. The antibiotics and fungicides used for *In vitro* studies were listed in table 1, 2.

Table 1: List of fungicides used for *In vitro* studies

Sl. No.	Fungicides	Trade name
Non-systemic Fugicides		
1	Copper oxychloride 50 % WP	Blitox
2	Mancozeb 75 % WP	Indofil M-45
3	Captan 50 % WP	Captaf
4	Propineb 70% WP	Antracol
5	Zineb 75% WP	Indofil Z- 78
6	Chlorothalonil 78.12 % WP	Kavach
7	Krezoxim methyl 44.3 % SC	Ergon
8	Copper hydroxide 53.8% WP	Kocide
Systemic Fugicides		
9	Carbendazim 50 % WP	Bavistin
10	Hexaconazole 5 % EC	Contaf
11	Propiconazole 25 % EC	Tilt
12	Tricyclazole 75 % WP	Baan
13	Myclobutanil 10% WP	Myclowin
14	Azoxystrobin 23.1 % w/w SC	Amistar
15	Tebuconazole 25.9 % EC	Folicure
16	Dimethomorph 50% WP	Acrobat
17	Difenconazole 25 % EC	Score
18	Fosetyl 80% WP	Alliette
19	Metalaxyl 35% WS	Superior
Combi products		
20	Carbendazim 12 % + Mancozeb 63 %	SAAF
21	Metalaxyl 4% + mancozeb 64 %	Ridomyl Gold
22	Cymoxanil 8% +Mancozeb 64%	Curzate M8
23	Tebucoazole 50 % + Trifloxystrobin 25 %	Nativo
24	Tebuconazole 50% +Trifloxystrobin 25%	Vitavax
25	Iprovalicarb 5.5% + Propineb 61.25%	Melody
26	Tricyclazole 45%+ Hexaconazole10%	Impression
27	Hexaconazole 5%+ Captan70%	Taqat
28	Tricyclazole 18%+ mancozeb 62%	Merger
29	Fenamidone 10%+Mancozeb 50%	Sectin
30	Metiram 55%+ Pyraclostrobin 5%	Cabrio top
31	Fluxapyroxad 250 g/l + Pyraclostrobin 250 g/l	Merivon

The observations on radial mycelial growth were recorded in each treatment and replications and mean colony diameter and percent inhibition of the test pathogen was calculated by applying the formula given by Vincent (1947).

$$\text{Per cent inhibition} = \frac{C-T}{C} \times 100$$

Where,
C= growth of the test fungus in untreated control plates
T= growth of the test fungus in treated plates

Table 2: List of antibiotics used for *In vitro* studies

Sl. No.	Antibiotic	Trade name
1	Streptomycin sulphate 90% + tetracycline 10 %	Streptocycline
2	Streptomycin sulphate 90% + tetracycline 10 %	K-cycline
3	Streptomycin sulphate 90% + tetracycline 10 %	Plantomycin
4	Validamycin 3%	Validamycin
5	2 Bromo 2 nitro- propane-1,3 diol 95%	Bactinash
6	2 Bromo 2 nitro- propane-1,3 diol 95%	Bactinashak
7	Copper oxy chloride 50 % WP	Blitox
8	Copper hydroxide 53.8 %	Kocide

Results and Discussion

Evaluation of antibiotics against *Ralstonea solanacearum*

In vitro evaluation of available antibiotics and fungicides revealed that among the different antibiotics screened against the bacteria, Streptocycline found more effective with inhibition of 22mm, at 100 ppm, 24.33 mm at 200 ppm, 25.66 mm at 300 ppm, 28.00 mm at 400 ppm, and 30.66 mm at 500 ppm concentration Table 3. On average Streptocycline showed 26.13 mm inhibition as compared with other antibiotics. Validamycin was found least effective in all the concentrations. Effective antibiotics are also screened as individuals as well as in combination with an anti-bacterial compound such as COC and Kocide. However, under *In vitro* conditions, a combination of antibiotics with COC and Kocide does not produce significant inhibition against the bacteria.

Table 3: *In vitro* evaluation of antibiotics against *Ralstonea solanacearum*

Treatment no	Antibiotics	Inhibition zone (mm)* Concentration at					Average
		100 ppm	200 ppm	300 ppm	400 ppm	500 ppm	
T_1	Streptocycline	22	24.33	25.66	28.00	30.66	26.13
T_2	K-cycline	17.86	21.33	23.00	24.33	25.66	22.44
T_3	Plantomycine	0	11.66	12.66	15.33	17.00	11.33
T_4	Validamycin	0	0	0	0	0	0
T_5	Bactinash	16.33	20.33	21.33	23	25.33	21.26
T_6	Bactinashak	8.66	12.33	14.00	15.667	19.33	14.00
		1000 ppm	1500 ppm	2000 ppm	2500 ppm	3000 ppm	
T_7	Kocide	15.66	16.33	18.66	18.00	19.66	17.66
T_8	COC	19.33	20.66	22.33	21.33	22.66	21.26
T_9	Streptocycline+COC	17.66	18.00	21.33	22.66	23.66	20.66
T_{10}	Streptocycline+Kocide	11.66	14.66	18.33	18.33	19.66	16.53
T_{11}	K-cycline+COC	14.66	16.33	19.33	22.00	22.66	19.00
T_{12}	K-cycline+Kocide	15.667	16.667	17.667	21.667	22.00	18.73
T_{13}	Bactinash+COC	14.667	16.00	18.00	18.333	20.333	17.46
T_{14}	Bactinashak+ Kocide	11.667	12.00	15.00	15.00	19.66	14.66
T_{15}	Control	0	0	0	0	0	0
SE(m)		0.44	0.45	0.53	0.53	0.43	
C.D.		1.29	1.32	1.54	1.54	1.27	

Evaluation of fungicides against the pathogen complex *In vitro* evaluation of non-systemic fungicides against the pathogen complex

Eight different non-systemic fungicides were evaluated against *Pythium*, *Fusarium*, *Sclerotium rolfisii* at 1500 ppm, 2000ppm, and 2500 ppm concentrations. Among the different nonsystemic fungicides, Copper oxychloride and Propineb found most effective against *Pythium* and percent inhibition of the pathogen has been increased when the concentration of the fungicides increased.

Table 4: Among the different nonsystemic fungicides, Copper oxychloride and Propineb found most effective against *Pythium* and percent inhibition of the pathogen has been increased when the concentration of the fungicides increased

Sl. No	Fungicides	Percent mycelial inhibition and percent inhibition against *Pythium*						Percent mycelial inhibition and percent inhibition against *Fusarium*						Percent mycelial inhibition and percent inhibition against *Sclerotium*					
		1500 ppm	PI	2000 ppm	PI	2500 ppm	PI	1500 ppm	PI	2000 ppm	PI	2500 ppm	PI	1500 ppm	PI	2000 ppm	PI	2500 ppm	PI
1	Copper oxychloride	21.33	76.30 (60.84)	11.67	87.04 (68.87)	0.00	100 (90)	21.33	68.617 (55.91)	12.67	81.37 (64.41)	9.33	86.26 (68.22)	21.67	75.93 (60.59)	0	100 (90)	0	100 (90)
2	Mancozeb	79.67	11.48 (19.79)	61.33	31.85 (34.34)	50.33	44.07 (41.57)	0.00	100 (90)	0.00	100 (90)	0.00	100 (90)	0.00	100 (90)	0	100 (90)	0	100 (90)
3	Captan	41.67	53.70 (47.10)	40.33	55.18 (47.95)	39.00	56.67 (48.81)	21.00	69.107 (56.21)	17.67	74.00 (59.32)	0.00	100 (90)	0.00	100 (90)	0	100 (90)	0	100 (90)
4	Propineb	47.67	47.04 (43.28)	28.67	68.15 (55.62)	0.00	100 (90)	5.33	92.15 (73.72)	0.00	100 (90)	0.00	100 (90)	0.00	100 (90)	0	100 (90)	0	100 (90)
5	Zineb	90.00	0 (0)	87.33	2.96 (9.86)	57.33	36.3 (37.03)	40.67	40.19 (39.33)	39.33	42.14 (40.46)	37.33	45.08 (42.16)	0.00	100 (90)	0	100 (90)	0	100 (90)
6	Kavach	54.67	39.26 (38.78)	52.33	41.85 (40.29)	31.67	64.813 (53.59)	24.67	63.72 (52.94)	20.67	69.603 (56.52)	0.00	100 (90)	0.00	100 (90)	0	100 (90)	0	100 (90)
7	Kresoxim methyl	35.00	61.113 (51.42)	30.00	66.67 (54.71)	23.33	74.073 (59.39)	34.33	49.5 (44.69)	28.33	58.32 (49.77)	27.33	59.79 (50.63)	17.33	80.74 (63.94)	0	100 (90)	0	100 (90)
8	Copper	89.00	1.11	86.67	3.7	85.00	5.56	61.00	10.29	54.33	20.08	44.67	34.30	90.00	0				0

	hydroxide		(6.04)		(11.06)		(13.63)		(18.70)		(26.60)		(35.83)			90	0	90	(90)
9	Control	90.00	0 (0)	90.00	0 0	90.00	0 0	68.00	0	68.00	0	0	0	90	0	90	0	90	0 (90)
	SE(m)	1.083		0.327		0.699		0.543		0.63		0.487							
	C.D at 0.5 %	3.243		0.978		2.092		1.626		1.888		1.458							

Table 5: *In vitro* evaluation of systemic fungicides against the pathogen complex

Sl. No	Fungicides	Mean percent mycelial inhibition and percent inhibition against Pythium								Percent mycelial inhibition and percent inhibition against Fusarium								Percent mycelial inhibition and percent inhibition against Sclerotium							
		500 ppm	PI	1000 ppm	PI	1500 ppm	PI	2000 ppm	PI	500 ppm	PI	1000 ppm	PI	1500 ppm	PI	2000 ppm	PI	500 ppm	PI	1000 ppm	PI	1500 ppm	PI	2000 ppm	PI
1	Carbendazim	0.00	100 (90)	0.00	100 (90)	90.00	100 (90)	0.00	100 (90)	14.67	81.66 (64.62)	13.00	83.75 (66.20)	12.00	85 (67.18)	9.67	87.91 (69.63)	44.67	50.37 (45.19)	40.00	55.55 (48.17)	38.67	57.04 (49.02)	20.33	77.41 (61.59)
2	Hexaconazole	22.67	74.81 (59.85)	20.33	77.41 (61.59)	75.00	83.33 (65.88)	14.33	84.07 (66.45)	38.67	51.66 (45.93)	24.67	69.16 (56.24)	20.33	74.58 (59.70)	18.67	76.66 (61.09)	0.00	100 (90)	0.00	100 (90)	0.00	100 (90)	0.00	100 (90)
3	Propiconazole	22.67	74.81 (59.85)	20.33	77.41 (61.59)	72.33	80.37 (63.67)	14.67	83.7 (66.16)	12.67	84.16 (66.52)	12.33	84.58 (56.24)	10.67	86.66 (68.56)	10.00	87.5 (69.26)	0.00	100 (90)	0.00	100 (90)	0.00	100 (90)	0.00	100 (90)
4	Tricyclazole	23.00	74.44 (59.61)	0.00	100 (90)	90.00	100 (90)	0.00	100 (90)	21.00	73.75 (59.16)	0.00	100 (90)	0.00	100 (90)	0.00	100 (90)	0.00	100 (90)	0.00	100 (90)	0.00	100 (90)	0.00	100 (90)
5	Myclobutanil	34.33	61.85 (51.83)	24.00	73.33 (58.88)	66.33	73.7 (59.12)	20.00	77.78 (61.85)	30.67	61.66 (51.72)	17.67	77.91 (61.94)	16.67	79.16 (62.82)	15.00	81.25 (64.31)	3.33	96.29 (83.5)	0.00	100 (90)	0.00	100 (90)	0.00	100 (90)
6	Azoxystrobin	27.33	69.63 (56.53)	24.67	72.59 (58.40)	66.33	73.7 (59.12)	19.33	78.52 (62.36)	24.33	69.58 (56.53)	20.67	74.16 (59.42)	20.00	75 (59.97)	17.67	77.91 (61.94)	34.00	62.22 (52.05)	26.00	71.11 (57.5)	24.67	72.59 (58.40)	0.00	100 (90)
7	Tebuconazole	0.00	100 (90)	0.00	100 (90)	90.00	100 (90)	0.00	100 (90)	0.00	100 (90)	0.00	100 (90)	0.00	100 (90)	0.00	100 (90)	0.00	100 (90)	0.00	100 (90)	0.00	100 (90)	0.00	100 (90)
8	Dimethomorph	46.33	48.52 (44.13)	39.67	55.93 (48.38)	54.33	60.37 (50.96)	34.33	61.85 (51.83)	62.67	21.66 (27.72)	58.00	27.5 (31.61)	49.00	38.75 (38.48)	48.33	39.58 (38.96)	61.67	31.48 (34.11)	54.33	39.63 (38.99)	47.67	47.04 (43.28)	44.67	50.37 (45.19)
9	Diniconazole	22.33	75.18 (60.10)	21.00	76.67 (61.09)	72.33	80.37 (63.67)	16.33	81.85 (64.76)	22.67	71.66 (57.81)	20.00	75 (59.97)	17.67	77.91 (61.94)	15.33	80.83 (64.01)	0.00	100 (90)	0.00	100 (90)	0.00	100 (90)	0.00	100 (90)
10	Alliete	60.33	32.96 (35.02)	37.00	58.89 (50.10)	50.00	55.56 (48.17)	25.00	72.22 (58.16)	34.33	57.08 (49.05)	32.33	59.58 (50.50)	30.00	62.5 (52.21)	27.67	65.41 (53.95)	66.67	25.92 (30.58)	64.67	28.15 (32.03)	64.67	28.15 (32.03)	44.67	50.37 (45.19)
11	Metalaxyl	86.67	3.70 (6.48)	78.00	13.333 (21.28)	40.00	44.44 (41.79)	45.00	50 (44.98)	46.33	42.08 (40.42)	33.33	58.33 (49.77)	32.33	59.58 (50.50)	30.00	62.5 (52.21)	81.00	10 (18.41)	73.33	18.52 (25.42)	70.00	22.22 (28.11)	65.67	27.04 (31.31)
12	Control	90.00	0	90.00	0	90.00	0	90.00	0	80.00	0	80.00	0	80.00	0	80	0	90.00	0	90.00	0	90.00	0	90.00	0
	SE(m)	1.19		0.87		0.30		0.23		0.78		0.41		0.3		0.41		1.17		0.60		0.62		0.21	
	C.D at 0.5 %	3.51		2.56		0.88		0.70		2.28		1.22		0.99		1.22		3.45		1.76		0.21		0.62	

Sl. No	Fungicides	Mean Per cent mycelial inhibition and percent inhibition against Pythium						Per cent mycelial inhibition and percent inhibition against Fusarium						Per cent mycelial inhibition and percent inhibition against Sclerotium					
		500 ppm	PI	1000 ppm	PI	1500 ppm	PI	500 ppm	PI	1000 ppm	PI	1500 ppm	PI	500 ppm	PI	1000 ppm	PI	1500 ppm	PI
1	SAAF	18.33	79.63 (63.14)	0	100 (90)	0.00	100 (90)	0.00	100 (90)	0.00	100 (90)	0	100 (90)	80	100 (90)	80	100 (90)	80	100 (90)
2	Ridomyl Gold	0.00	100 (90)	0	100 (90)	0.00	100 (90)	0.00	100 (90)	0.00	100 (90)	0	100 (90)	80	100 (90)	80	100 (90)	80	100 (90)
3	Curzate M8	31.67	64.81 (53.59)	0	100 (90)	0.00	100 (90)	20.33	74.58 (59.70)	17.33	78.33 (62.23)	0	100 (90)	80	100 (90)	80	100 (90)	80	100 (90)
4	Nativo	0.00	100 (90)	0	100 (90)	0.00	100 (90)	0.00	100 (90)	0.00	100 (90)	0	100 (90)	80	100 (90)	80	100 (90)	80	100 (90)
5	Vitavax	0.00	100 (90)	0	100 (90)	0.00	100 (90)	7.67	90.41 (71.94)	0.00	100 (90)	0	100 (90)	80	100 (90)	80	100 (90)	80	100 (90)
6	Melody	25.00	72.22 (58.16)	19	78.88 (62.62)	5.00	94.44 (76.33)	34.67	56.66 (48.81)	24.00	70 (56.76)	0	100 (90)	80	100 (90)	80	100 (90)	80	100 (90)
7	Impression	0.00	100 (90)	0	100 (90)	0.00	100 (90)	0.00	100 (90)	0.00	100 (90)	0	100 (90)	80	100 (90)	80	100 (90)	80	100 (90)
8	Taqat	18.67	79.26 (62.88)	18	79.99 (63.41)	16.67	81.48 (64.49)	5.67	92.91 (74.54)	0.00	100 (90)	0	100 (90)	80	100 (90)	80	100 (90)	80	100 (90)
9	Merger	9.33	89.63 (71.20)	0	100 (90)	0.00	100 (90)	5.00	93.75 (75.49)	3.33	95.83 (78.21)	0	100 (90)	80	100 (90)	80	100 (90)	80	100 (90)
10	Sectin	0.00	100	0	100	0.00	100	0.00	100	0.00	100	0	100	80	100	80	100	80	100

			(90)		(90)		(90)		(90)		(90)		(90)		(90)		(90)		(90)
11	Cabriotop	0.00	100 (90)	0	100 (90)	0.00	100 (90)	13.67	82.91 (65.56)	0.00	100 (90)	0	100 (90)	80	100 (90)	80	100 (90)	80	100 (90)
12	Merivon	0.00	100 (90)	0	100 (90)	0.00	100 (90)	12.00	85 (67.18)	1.00	98.75 (83.54)	0	100 (90)	80	100 (90)	80	100 (90)	80	100 (90)
13	Control	90.00	0	0	0	90.00	0	80.00	0	80.00	0	80	0	0	0	0	0	0	0
	SE(m)	0.272		0.252		0.272		0.258		0.163									
	C.D at 0.5 %	0.794		0.736		0.794		0.755		0.478									

In vitro evaluation of systemic fungicides against the pathogen complex

Eleven different systemic fungicides were evaluated against the pathogen complex. Carbendazim, Tricyclazole, Tebuconazole, and Alliete found effective against *Pythium*. Carbendazim significantly inhibited the pathogen growth at all concentrations. Tricyclazole, Tebuconazole showed 100 percent inhibition at 1000ppm, 1500 ppm, and 2000 ppm concentrations. Tricyclazole, Tebuconazole also showed 100 percent inhibition against *Fusarium* from 1000 ppm concentration onwards. In the case of *Sclerotium rolfsii*, Hexaconazole, Propiconazole, Tricyclazole, Myclobutanil, Azoxystrobin, Tebuconazole, Diniconazole resulted in higher percent inhibition effectively at all the concentrations (Table 5).

In vitro evaluation of combi products against the pathogen complex

In the case of *Pythium*, all the combi products except Melody showed 100 percent inhibition at 1000 ppm concentration onwards. In the case of *Fusarium* combi products such as SAAF, Ridomyl Gold, Nativo, Vitavax, Impression showed 100 percent inhibition at 1000 ppm concentration onwards (Table 6). As compared to nonsystemic and systemic fungicides, combi products were found more effective against all the pathogens involved in the complex.

References

1. Acharya B, Regmi H. Evaluation and selection of appropriate management package of ginger rhizome rot disease in field condition. IOSR Journal of Agriculture and Veterinary Science. 2015; 8:0-4.
2. Archana TS, Deore PB, Jagtap SD, Patil BS. Effect of Different Cultural Media on Growth of *Sclerotium rolfsii* sacc. Causing Root Rot of Chilli. Int. J. Curr. Microbiol. App. Sci. 2019; 8(2):3019-24.
3. Nagar US. *In vitro* and glass house evaluation of fungicides against the pathogens associated with rhizome rot complex of ginger in Kumaon region of Uttarakhand. IJCS. 2018; 6(5):1364-72.
4. Ayub A, Sultana N, Faruk MI, Rahman MM, Mamun AN. Control of Rhizome Rot Disease of Ginger (*Zingiber officinale* Rose) by Chemicals, Soil Amendments and Soil Antagonis. The Agriculturists, 2009, 57-61.
5. Balouiri M, Sadiki M, Ibnsouda SK. Methods for *in vitro* evaluating antimicrobial activity: A review. Journal of pharmaceutical analysis. 2016; 6(2):71-9.
6. Bamon M, Majumder D, Thakuria D, Rajesh T. *In vitro* efficacy of bacterial endophytes against Pythium sp. causing soft rot of ginger in Meghalaya. Int. J. Curr. Microbiol. App. Sci. 2018; 7(8):367-74.
7. Chauhan HL, Patel MH. Etiology of complex rhizome rot of ginger (*Zingiber officinale*) in Gujarat and *in vitro* screening of fungicides against its causal agents. Indian Journal of Agricultural Sciences. 1990; 60(1):80-1.
8. Dohroo NP. Ginger-The genus Zingiber. Diseases of Ginger: In medicinal and aromatic plants-industrial profiles. Vol. 41 (Ravindaran, PN and Babu, KN, eds).
9. Ekka S, Prasad SM, Sharma RB. Occurence and relative dominance of pathogens in rhizome rot of ginger at Ranchi. Indian Phytopathology. 2009; 62(4):505-8.
10. Kumar S, Chand G. Diseases of Ginger and Turmeric and Their Management. Diseases of Fruits and Vegetable Crops: Recent Management Approaches. 2020; 14:244.
11. Le DP, Smith M, Hudler GW, Aitken E. Pythium soft rot of ginger: detection and identification of the causal pathogens, and their control. Crop Protection. 2014; 65:153-67.
12. Parveen T, Meena M, Jain T, Rathore K, Mehta S, Sharma K. *Pythium aphanidermatum* and Its Control Measures. Pythium: Diagnosis, Diseases and Management, 2020.
13. Pattnaik PK, Kar D, Kuanar A, Mishra B. Screening of Ginger Germplasm for Resistance to Rhizome Rot. Proceedings of the National Academy of Sciences, India Section B: Biological Sciences. 2015; 85(1):303-8.
14. Sharma S, Dohroo NP, Veerubommu S, Phurailatpam S, Thakur N, Yadav AN. Integrated Disease Management of Storage Rot of Ginger (*Zingiber officinale*) caused by Fusarium sp. in Himachal Pradesh, India. Int. J Curr. Microbiol. App. Sci. 2017; 6(12):3580-92.
15. Singh R, Jagtap GP. *In vitro* Evaluation of Antibacterial Chemicals and Bioagents against *Ralstonia solanacearum* Infecting Bacterial Wilt in Ginger. Int. J Curr. Microbiol. App. Sci. 2017; 6(5):2034-45