The Bioscan 9(1): 265-269, 2014 (Supplement on Plant Pathology)
AN INTERNATIONAL QUARTERLY JOURNAL OF LIFE SCIENCES
www.thebioscan.in

INTEGRATED DISEASE MANAGEMENT OF *ZINGIBER OFFICINALE* ROSC. RHIZOME ROT

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KEYWORDS
Biocontrol
Ginger
Management
Pythium aphanidermatum
Rhizome rot

Received on :
05.10.2013

Accepted on :
16.02.2014

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ABSTRACT
Ginger is the valuable cash crop and rhizome rot of ginger is a complex disease which is caused by *Pythium aphanidermatum*. Data on disease development was recorded at 90th, 120th, 180th and 210th days after planting. Maximum disease development was recorded at 150th day after planting in all the treatments and was decreased again from 180th day onwards. The highest disease development (28.50 %) was observed in control plots where ginger rhizomes were inoculated with the pathogen (*Pythium myriotylum*) prior to sowing. Copper oxychloride rhizome treatment effectively suppressed the disease development (5.16%) at 150th day after planting in the field. It was observed that plots with neem extract rhizome treatment were less effective in reducing the disease development which gave 12.45 % at 15th day after planting. Amongst the growth parameters, the maximum plant height of 46.46 cm was recorded in plots with *Trichoderma* spp. + neem extract rhizome seed treatment, followed by copper oxychloride rhizome seed treatment (45.28 cm). The lowest was recorded in plots with neem extract rhizome seed treatment (40.22 cm) recorded on the last day of observation. The maximum number of tillers per hill (11.49) was recorded from rhizome treatment with copper oxychloride + neem extract at 180th day of observation. This was followed by rhizome treatment with copper oxychloride (10.54). The minimum (6.56) tillers per hill were recorded from control plots where pathogen (*Pythium myriotylum*.) was inoculated. In respect to yield, even though all the treatments were at par with each other, the highest yield (3.55 kg/plot) was observed in plots with copper oxychloride rhizome seed treatment. Second highest average yield with (2.96 kg/plot) was obtained from the plot with copper oxychloride + neem extract rhizome seed treatment. So in this contrast the per hectare highest yield (59.14 qts/ha) was recorded in plots with copper oxychloride rhizome seed treatment followed by copper oxychloride + neem extract (49.30 qts/ha). The lowest projected yield (9.98 qts/ha) was recorded in control plots where rhizomes were inoculated with the pathogen (*Pythium myriotylum*). It was concluded that all treatments resulted in higher germination compare to the control.

INTRODUCTION

Zingiber officinale Rosc. (Ginger) belonging to the family Zingiberaceae is an important commercial crop grown for its aromatic rhizomes which are used as a spice and a medicine (Sharma *et al*., 2010). It is an important crop that earns a sizeable amount of foreign exchange for the country (Tarafdar and Saha, 2007). India is the largest producer of ginger accounting for about 1/3rd of total world output so it is basic need to develop high yielding varieties with better quality to increase the production and productivity of ginger in India (Ravishanker *et al.,* 2014). Ginger is grown in various states such as Kerala, Karnataka, West Bengal, Andhra Pradesh, Orissa, Arunachal Pradesh and Sikkim (Kumar *et al*., 2008; Sharma *et al*., 2010). The production of ginger, however, is largely affected by diseases caused by bacteria, fungi, viruses, mycoplasma and nematodes. The crop suffers from diseases like bacterial wilt caused by *Ralstonia solanacearum*, rhizome rot caused by *Pythium* species, *Fusarium* species, *Sclerotium* species, *Pseudomonas* species and others (Dake and Edison, 1989; Senapati and Ghose, 2005; Paret *et al*., 2010; Sharma *et al.*, 2010; Kavyashree, 2011). The disease management involves cultural, biological and chemical approaches for pathogen suppression (Bhai *et al*., 2005).

Out of the above mentioned diseases of ginger Rhizome or soft rot is one of the most devastating diseases of ginger causing heavy yield loss, wherever this crop is grown. A recent review by Dohroo (2005) indicates that ginger crops in the Indian states of Kerala and Tamil Nadu are sometimes almost totally destroyed by rhizome rot. The disease reduced potential yields of ginger to a greater extend in field, storage and market and many losses of even more than fifty percent (Ramteke and Kamble, 2011). This disease is mainly caused by the species of *Pythium* but associated with this disease are the fungus *Fusarium* spp. (Stirling *et al.,* 2009). The major constraints involved in the conservation of ginger germplasm are the two soil borne diseases-rhizome rot caused by *Pythium aphanidermatum* and the bacterial wilt caused by *Ralastonia solanacearum* (*Pseudomonas solanacearum*) (Archana *et al.,* 2013).

The present study was designed to investigate inhibitory effect

bio-control agents, fungicide and neem extract against *Pythium aphanidermatum* isolated from rhizome rot specimen of ginger.

MATERIALS AND METHODS

Planting material

Viable ginger rhizome of cv. Nagaland local, for the purpose of the experiment.

Seed treatment with *Trichoderma* spp.

Seed rhizomes were steeped in slurry of *Trichoderma* species (combination of *T. harzianum* and *T. viride in equal proportion*) @ 6 g/lt of water for 1kg of seeds and air dried for 24 hours at normal room temperature.

Seed treatment with *Pseudomonas fluorescens*

Seed rhizomes were steeped in slurry of *Pseudomonas fluorescens* @ 10 g/lt of water for 1 kg of seed and air dried for 24 hours at normal room temperature before sowing.

Seed treatment with fungicide

Seed rhizomes were soaked in copper oxychloride @ 0.3% for 30 minutes and air dried before sowing.

Seed treatment with neem extract

Seed rhizomes were soaked in the extract of neem @ 100 g/lt of water for 1 kg of seed for 30 minutes and air dried at normal room temperature before sowing.

Seed inoculation of pathogen

In the mass culture of *Pythium myriotylum*., sterilized, cutted pieces of ginger were kept @ 1 kg of cutted pieces of ginger per 1 litre of *Pythium myriotylum* culture in 2 litres of conical flask for 3 days before sowing and at the time of sowing. 2-3 of ginger colonized by the pathogen were allotted in each pit where rhizome was sown, untreated rhizomes served as control and those rhizomes inoculated with the pathogen (*Pythium myriotylum*.) only served as inoculated control.

Planting and after care

The treated rhizomes were planted at the rate of 1 kg seed per 2m x 3m area plot with 45 cm row to row and 30 cm plant to plant. Uniform cultural practices like weeding, earthing up were adopted in each plot throughout the cropping season. For recording the different growth characters, three healthy growing plants were tagged randomly in each plot.

Disease development

Observation on ginger rhizome rot disease development was taken at 30 days interval from the time of germination and continued till harvest of the crop. The percentage of disease development was calculated by the following formula (Kushalappa and Ludwig, 1982):

$$\% \text{ of rotting} = \frac{X - Y}{X} \times 100$$

Where, Y = Number of disease free plants

X = Total number of plants

Plant height

The plant height (in cm) were measured ground level to the base of the fully opened terminal leaf commencing from 60 days after planting with the help of linear scale. The observations were taken at 40 days interval.

Number of tillers per hill

Observations on the number of tillers per hill was also taken at 60th day after planting and continued at 40 days interval till harvest.

Yield of ginger

Rhizomes yield per plot was recorded by taking the weight of the entire produce harvested from the plot and the data were expressed in kilogram (kg) (Singh, 2002).

$$\text{Yield/ha} = \frac{\text{Yield per plot}}{\text{Area of the plot}} \times 10{,}000$$

Statistical analysis

To test the fitness of the results obtained the data were analysed statistically as per the method of described by Panse and Sukhatme (1978) and Snedecor and Cochran (1967).

RESULTS

Disease Development

Data on disease development was recorded at 90th, 120th, 180th and 210th days after planting as presented in the *Table 1*. The results of the present investigation revealed that bio-agents, neem extract and fungicide treatments were significantly effective at different days of observations over the control. Maximum disease development was recorded at 150th day after planting in all the treatments and was decreased again from 180th day onwards. The highest disease development (28.50 %) was observed in control plots where ginger rhizomes were inoculated with the pathogen (*Pythium myriotylum*) prior to sowing.

Copper oxychloride rhizome treatment effectively suppressed the disease development (5.16%) at 150th day after planting in the field. It was observed that plots with neem extract rhizome treatment were less effective in reducing the disease development which gave 12.45 % at 15th day after planting.

Growth parameters

Plant height

A thorough scanning of the data for height of plant presented on the Table 2 revealed that plots with bio-agents, neem extract and fungicide rhizome seed treatment had significantly increased the height of plants at 140th day but it did not show any perceptible influence on height of plants at 60th, 100th and 180th days. The maximum plant height of 46.46 cm was recorded in plots with *Trichoderma* spp. + neem extract rhizome seed treatment, followed by copper oxychloride rhizome seed treatment (45.28 cm). The lowest was recorded in plots with neem extract rhizome seed treatment (40.22 cm) recorded on the last day of observation.

Number of tillers

Data presented in the Table 2 also revealed that the bio-agents, neems extract and fungicide rhizome treatment had no marked effect on the production of tillers per hills on ginger during the initial growth stages. But interestingly, there was significant influence during 140th and s180th days after planting. The maximum number of tillers per hill (11.49) was recorded from

rhizome treatment with copper oxychloride + neem extract at 180th day of observation. This was followed by rhizome treatment with copper oxychloride (10.54). The minimum (6.56) tillers per hill were recorded from control plots where pathogen (*Pythium myriotylum*.) was inoculated.

Yield of ginger as influenced by bio-agents, neem extract and fungicide

Yield/plot (kg)

The results presented in the *Table 3* revealed that plots with bio-agents, neem extract and fungicide rhizome treatment exhibited marked influence on average yield per plot over control. Even though all the treatments were at par with each other, the highest yield (3.55 kg/plot) was observed in plots with copper oxychloride rhizome seed treatment. Second highest average yield with (2.96 kg/plot) was obtained from the plot with copper oxychloride + neem extract rhizome seed treatment.

Projected yield per hectares (quintal)

Present data revealed that plots with bio-agents, neem extract and fungicide rhizome seed treatment had a significant effect on the projected yield per hectare. The highest yield (59.14 qts/ha) was recorded in plots with copper oxychloride rhizome seed treatment followed by copper oxychloride + neem extract (49.30 qts/ha). The lowest projected yield (9.98 qts/ha) was recorded in control plots where rhizomes were inoculated with the pathogen (*Pythium myriotylum*).

DISCUSSION

Among plant extracts of *Azadirachta indica, Agave americana, Cassia fistula, Eucalyptus terticornis* and *Vitex negundo* tested against *F. oxysporum* f.sp. *zingiberi* and *P. aphanidermatum, Azadirachta indica* and *Agave americana* were found most effective in reducing mycelial growth of *F. oxysporum* f. sp. *zingiberi* and *P .aphanidermatum* (Sharma, 1998). Dohroo and Gupta (1995) also reported that *Azadirachta* and other limonoids, the products of neem, were quite effective in the control of plant disease of diverse nature. Pant *et al.* (1986) also reported that some sulphurous compounds present in *Azadirachta indica* leaves possessed fungicidal properties. However, in the present investigation the treatment was rather found less effective in reducing the disease development as compared to rhizome seed treatment with copper oxychloride which exhibited the most effective in controlling the rhizome rot of ginger.

Biological control of plant pathogens has been considered as

Table 1: Effect of bio-agents, neem extract and fungicide on rhizome rots development of ginger.

Treatments	Disease development (%)				
	90 DAPJuly	120 DAPAugust	150 DAPSept	180 DAPOct	210 DAPNov
Uninoculated Control	13.84	15.62	18.28	16.44	15.32
Inoculated control(*Pythium myriotylum*)	21.67	25.61	28.50	26.72	25.77
Neem extract	7.92	8.56	12.45	11.08	9.58
Trichoderma spp.	5.92	6.59	10.29	9.22	8.38
Pseudomonas fluorescens	6.31	7.29	8.91	7.37	5.78
Copper oxychloride	2.65	3.63	5.16	3.22	2.45
Copper oxychloride + Neem extract	3.56	5.02	6.88	4.32	3.88
Neem extract + *Trichoderma* spp.	4.79	6.87	9.68	8.24	7.03
CD at 1 %	4.25	4.52	2.97	1.93	3.15

* Average of 3 replication

Table 2: Effect of bio-agents, neem extract and Copper oxychloride on average plant height and number of tillers of ginger (cm)

Treatments	Days after planting							
	Plant Height				No. of Tillers			
	60th	100th	140th	180th	60th	100th	140th	180th
Uninoculated Control	18.11	26.71	35.46	40.40	1.11	2.88	5.55	7.33
Inoculated control (*Pythium myriotylum*)	17.82	25.62	33.46	40.44	1.00	2.33	4.65	6.56
Neem extract	19.37	28.27	38.50	40.22	1.11	2.44	5.55	8.62
Trichoderma spp.	17.44	27.61	41.81	44.51	1.22	2.55	6.66	9.08
Pseudomonas fluorescens	16.64	26.26	39.71	40.55	1.33	2.66	6.11	9.75
Copper oxychloride	20.69	25.11	40.60	45.28	1.22	3.10	6.78	10.54
Copper oxychloride + Neem extract	21.23	30.52	41.12	44.47	1.65	3.11	7.66	11.49
Neem extract + *Trichoderma* spp.	22.94	28.52	43.46	46.46	1.22	2.55	7.11	9.57
CD at 1 %	N.S.	N.S.	6.07	N.S.	N.S.	N.S.	1.78	2.58

* Average of 3 replication

Table 3: Effect of bio-agents, neem extract and fungicide on average yield of ginger

Treatments	Yield/ Plot(Kg)	Yield/Ha (Quintal)
Uninoculated Control	1.51	27.37
Inoculated control (*Pythium myriotylum*)	0.60	9.98
Neem extract	1.93	32.14
Trichoderma spp.	2.52	41.92
Pseudomonas fluorescens	2.73	45.53
Copper oxychloride	3.55	59.14
Copper oxychloride + Neem extract	2.96	49.38
Neem extract + *Trichoderma* spp.	2.12	36.63
CD at 1 %	0.56	9.61

* Average of 3 replication

a potential control strategy in recent years and search for potential biological agents has increased (Balai and Singh, 2013). Two bio-control agents namely- *T. harzianum* and flourecent *Pseudomonas* spp., were tested for the biological control of rhizome rot of ginger caused by *F. solani* and *P. myriotylum*. The bio-control agents were introduced into the soil when the ginger was planted and the control was assessed 100 days later. Both agents multiplied in the soil and inhibited growth of pathogens (Ram *et al.,* 1997). Osburn *et al*. (1989) found that *Pseudomonas fluorescens* lowered the colonization of sugar beet seed caused by *P. ultimum* to 6.7 per cent as against 90 per cent in untreated control.

Bhardwaj *et al*. (1988) reported the used of fungal antagonists as seed treatment against rhizome rot. They treated the rhizome by steeping in spore suspension of *T. viride* or smearing with *T. hamatum*. This type of seed treatment was observed quite effective against *P. aphanidermatum* and *F. equiseti*. *T. viride* and *T. harzianum* were potential antagonists to micro-flora of ginger rhizome (Shanmugam *et al.,* 1999). Dohroo and Sharma (1984) reported that ginger treated with *T. viride* showed more than 80 % control of rhizome rot caused by *P. pleroticum* (wet rot) and *F. equiseti* (dry rot). Effective suppression of ginger rhizome rot by use of bio-control agents such as *T. harzianum, T. aureoviride, T. viride* and *T. virens* was reported by Ram *et al*. (2000). The effect of various treatments with *T. viride* and *T. harzianum* under field condition showed significant influence in controlling rhizome rot of ginger and in increasing growth parameters and yield. *T. viride* when applied as seed treatment recorded that highest per cent disease control (84.9 %) reported by Kevimeo (2005). *T. viride* produced non-volatile substances which inhibited the growth of *P. myriotylum* and *F. solani,* causing rhizome rot of ginger by 70 % and 10 % respectively. However, in the present investigation, rhizome seed treated with *Trichoderma* spp. was found less effective (8.38%) in controlling rhizome rot of ginger than that of rhizome seed treatment with *Pseudomaonas fluorescens* and copper oxychloride which exhibited 5.78 % and 2.45 % disease development. It may be the reason that, the two species of *Trichoderma i.e. T. viride* and *T. harzianum* were mixed in equal proportion and used as seed rhizome treatment. Their effectiveness may be reduced in controlling rhizome rot of ginger in comparison to rhizome seed treatment with *T. viride* and *T. harzianum* separately.

In the field experiment, seed of rhizomes dipped in 0.2 % copper oxychloride, 1 % Bordeaux mixture, 0.1 % chlorothalanil, 0.01 % metalaxyl MZ, 0.25 % mancozeb or 0.1 % Emison were found effective in the reduction of ginger rhizome rot caused by *P. aphanidermatum* and increased yield (Jayasekhar *et al.,* 2001). In the present investigation under field condition, the disease development was found lowest in the Copper oxychloride rhizome seed treatment plots (2.45 %) and highest yield (3.5 kg/plot) which is followed by Copper oxychloride + neem extract rhizome seed treatment plots which exhibited (3.88 %) disease development and highest per cent germination (90.42 %) which was in line similar findings of Amaresh *et al.,* 2004, who reported that, the effect of 2 tonnes Neem cake/ha and seed treatment with 0.3% Copper oxychloride on occurrence of rhizome rot of zinger caused by *P. aphanidermatum* was effective and increased crop yield. All treatments resulted in higher germination compare to the control. Hence, the result of the present investigation is in confirmation with the findings of the above-mentioned workers.

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