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DEVELOPMENT OF BIO-RATIONAL BASED MANAGEMENT TECHNOLOGY AGAINST FOOT AND ROOT ROT AND ROOT-KNOT DISEASES OF CUCUMBER

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Abstract

The experiments were conducted in the field of Plant Pathology Division, BARI during 2022-23 and 2023-24 cropping season to develop eco-friendly integrated management technology against foot and root rot disease caused by *Fusarium oxysporum* and *Sclerotium rolfsii* and root-knot nematode disease caused by *Meloidogyne incognia*. Pathogens infested field soils were treated with different treatment combinations of *Trichoderma* based Tricho-composts, saw dust burning, bio-fungicide Lycomax, poultry refuse, mustard oil cake, chemical fungicide Autostin and nematicide Rugby 10 G. All the treatments gave appreciable reduction of both foot and root rot, and root-knot nematode diseases and thereby enhanced plant growth as well as fruit yield of cucumber. The integration of Tricho-compost with Lycomax effectively reduced the foot and root rot disease upto 85.73% in addition to 44.86% reduction of gall index of root-knot nematodes in cucumber. Combined use of poultry refuses or mustard oil cake with Autostin was also a viable strategy for managing foot and root rot and root-knot nematode diseases in cucumber for enhancing cucumber yield in an eco-friendly manner.

Keywords: Cucumber, foot and root rot, *Fusarium oxysporum, Sclerotium rolfsii,* root-knot nematode, *Meloidogyne incognia,* Tricho-composts, Lycomax, poultry refuse and mustard oil cake.

Introduction

Cucumber (*Cucumis sativus* L.) is one of the most important vegetable crops grown worldwide for its nutritional and economic value. Cucumber is largely planted and produced in Asia (87.2%) with China is dominated the word cucumber production (Meng et al., 2018). Owing to the limited availability of agricultural land and high market demand, continuous cucumber cropping has been widely adopted by majority of farmers. However, its production is severely constrained by several soil-borne diseases, particularly foot and root rot caused mainly by Fusarium solani, Rhizoctonia solani and *Sclerotium rolfsii* and root-knot disease caused by

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Meloidogyne incognita (Noling, 2005; Sikora and Fernandez, 2005). These diseases not only reduce seedling establishment and plant vigour but also cause significant yield losses, often exceeding 30–50% under favourable conditions (Khan *et al*., 2017; Sikder and Vestergård, 2020). These disease causing pathogens are major soil dweller that leads to severe shortage in cucumber supply under greenhouse condition (Shen et al., 2008). Diseases caused by soil borne pathogens are unique because the causal pathogens, which can survive in soil under the pressure of antagonistic soil microorganisms, can invade plants through soil. Therefore, it is very difficult to eradicate from the infested soil. Traditionally, chemical fungicides and nematicides have been used to manage these diseases. However, indiscriminate chemical use has resulted in environmental pollution, pesticide resistance, and adverse effects on beneficial soil microorganisms (Kumar *et al*., 2019). Therefore, there is a growing emphasis on developing bio-rational management technologies that are eco-friendly, sustainable, and compatible with integrated disease management practices. Bio-rational approaches include the use of organic amendments (e.g. poultry refuse, mustard oil cake, neem products), biological control agents such as Trichoderma *spp.*, Pseudomonas fluorescens, and bio-fertilizers, along with novel products like plant-derived biopesticides and compost-based formulations. These interventions not only suppress soil-borne pathogens but also improve soil health, stimulate plant growth, and enhance systemic resistance in cucumber (Howell, 2003; Harman, 2006; Jaiswal *et al*., 2020). Recent studies have shown that integration of Trichoderma harzianum with organic amendments and reduced doses of chemical inputs significantly reduces the incidence of foot and root rot and root-knot nematode infestation in cucurbits, and thereby increasing fruit yield and quality (Singh *et al*., 2016; Hossain *et al*., 2019). Similarly, neem-based products and poultry manure have been reported to improve soil microbial diversity and act synergistically with bio-control agents against root-knot nematodes (Khan *et al*., 2017; Mukhtar *et al*., 2021).

The development of bio-rational management technology is particularly relevant in Bangladesh, where cucumber is widely cultivated and growers are facing increasing challenges from foot and root rot as well as root-knot nematode diseases. By integrating locally available organic resources with proven biocontrol agents, it is possible to reduce dependency on chemical inputs, ensure environmental sustainability, and increase cucumber yield. Hence, an attempt was made to develop bio-rational based management packages against these diseases in the field by using Poultry refuse, Mustard oil cake, Tricho-compost, Saw dust, Lycomax, Autostin, and Rugby.

Materials and Methods

The experiment was conducted in the field of Plant Pathology Division, Bangladesh Agricultural Research Institute, Gazipur to develop bio-rational based management packages against the diseases combining Poultry refuse, Mustard oil cake, Tricho-compost, Saw dust, Lycomax, Autostin, and Rugby during 2022-23 and 2023-24 cropping seasons. There were six treatment combinations *viz.,* (i) Poultry refuse @ 6 kg/pit + Autostin @ 2g/l water (ii) Mustard oil cake @ 1 kg/pit + Lycomax bio-fungicide @ 3g/l water (iii) Tricho-compost @ 2 kg/pit + Lycomax bio-fungicide @ 3g/l water (iv) Saw dust burning + Lycomax bio-fungicide @ 3g/l water (v) Autostin @ 2 g/l water+ Rugby 10 G 15 g/pit and (viii) Control. The unit pit size was 2 m x 2.5 m. The experiment was conducted in randomized complete block (RCB) design with 3 replications. *Trichoderma harzianum* isolate was collected from Plant Pathology Division and was multiplied in the mixture of Grasspea and wheat bran with mustard oilcake substrates. The formulated *Trichoderma* was used to mass multiplication in organic-compost and it is designated as Tricho-compost. Tricho-compost @ 2 kg/pit was added 5 days before seed sowing and mixed properly with soil and kept 5 days for Trichoderma establishment in soil. Poultry refuse and mustard oil cake was applied 21 days before seed sowing. After application, poultry refuse and mustard oil cake was properly mixed with the soil and kept moist for proper decomposition. In case of saw dust burning, 6 cm thick layer of dry saw dust cover with pit soil and burned the soil properly. After burning the ash was mixed with the soil. The Bio-fungicide, Lycomax (@ 3 g/l water) and chemical fungicide Autostin was applied (@ 2 g/l water) was applied 3 times at 10 days interval started from 20 days after seed sowing. The Nematicide, Rugby 10 G was added at the time of seed sowing. Seeds of cucumber (Lalteer) were sown in the pit soils and each pit received ten seeds. Fertilizers, weeding and irrigation were applied as per recommendation of the crop. After 50-55 days of seed sowing, 3 seedlings were kept in each pit and the rest of the seedlings were uprooted carefully without disturbing the root system and those were used for data recording.

Determination of foot and root rot disease

The experimental plots were routinely inspected to observe the initiation of foot and root rot disease of cucumber in the field. In case of any complexity to identify the disease, the infected plants were collected from the field and brought to the laboratory for further study. From the infected plants, the pathogens were isolated following tissue planting methods (Baxter *et al*., 1999). After incubation, the fungi that grew over potato dextrose agar (PDA) medium were purified by the hyphal tip culture method. The isolated fungus was identified as *F. oxysporum* and *S. rolfsii* according to reference mycology books and manuals (Barnett and Hunter, 1972; Booth, 1971).

Data collection and analysis

The root-knot disease severity was recorded at 50-55 days after seed germination. The additional seedlings from each pit were carefully uprooted and the root systems were cleaned with running tap water. Data on length and weight of shoot and root were recorded. The severity of root gall was recorded in terms of gall index based on a 0-10 scale (Zeck, 1971). The incidence of foot and root rot disease was recorded upto 55 days after seed germination and yield of cucumber were also taken. The percent data were converted into arcsine transformation values before statistical analysis. Data were analyzed statistically by using the MSTATC program. The treatment effects i.e. mean values were compared by applying the least significant different (LSD) test at $P \leq 0.05$ level.

Results and Discussion

Shoot growth: Average shoot length of cucumber under control was 70.67 cm $plant^{-1}$ in first year and 104.0 cm/plant in second year. Integrated soil treatment with poultry refuse (PR)+ Autostin, mustard oil cake (MOC) + Autostin, Tricho-compost + Lycomax bio-fungicide, Saw dust burning (SDB)+ Lycomax bio-fungicide and Rugby 10 G + Autostin increased the shoot length ranging from 97.67 to 116.70 cm $plant^{-1}$ in first year and 125.3-164.7 $cmplant^{-1}$ in second year trial. In both the years, integration PR+ Autostin, MOC + Autostin, Tricho-compost + Lycomax bio-fungicide gave the higher shoot length followed by SDB + Lycomax bio-fungicide treatment (Table 1). The least effective treatments to increase shoot length was Rugby 10 G + Autostin (Table 1).

Table 1. Effect of soil treatment with Tricho-compost, organic amendments, saw dust burning and chemical pesticides on shoot growth of cucumber

Treatments	Average shoot length (cm $plant^{-1}$)		Average shoot weight (g $plant^{-1}$)	
	2022-2023	2023-2024	2022-2023	2023-2024
Poultry refuse + Autostin	116.70	161.7	159.00	236.0
Mustard oil cake + Autostin	116.30	163.7	160.70	243.3
Tricho-compost + Lycomax bio-fungicide	115.70	164.7	164.30	248.7
Saw dust burning + Lycomax bio-fungicide	106.30	145.0	137.00	217.7
Autostin+ Rugby 10 G	97.67	125.3	107.30	171.3
Control	70.67	104.0	77.67	135.0
LSD (0.05)	7.716	9.907	12.47	19.58

In first year, the shoot weight of cucumber was only 77.67 g $plant^{-1}$ under control treatment. It increased to 107.3-164.3 g $plant^{-1}$ due to treatments with PR+ Autostin, MOC + Autostin, Tricho-compost + Lycomax bio-fungicide, SDB+ Lycomax bio-fungicide and Rugby 10 G + Autostin. Integrated soil treatement with PR+ Autostin, MOC + Autostin, Tricho-compost + Lycomax bio-fungicide gave the higher shoot weight followed by SDB + Lycomax bio-fungicide treatment (Table 1). In second year, the shoot weight of cucumber was 135.0 g plant^{-1} when both the organic amendments and pesticides were not applied (control). Application of PR+ Autostin, MOC + Autostin, Tricho-compost + Lycomax bio-fungicide gave higher shoot weight over control within the range of 236.0-248.7 g plant^{-1}. The least effective treatment to increase shoot weight was Rugby 10G + Autostin followed by SDB + Lycomax (Table 1).

Root growth: Integrated soil amendment with PR+ Autostin, MOC + Autostin, Tricho-compost + Lycomax bio-fungicide showed positive effects on root growth of cucumber as compared to control. In first year, the minimum root length of 11.87 cm plant^{-1} was recorded under control treatment. Integration of PR+ Autostin, MOC + Autostin, Tricho-compost + Lycomax bio-fungicide gave higher root length by 17.47 cm plant^{-1}, 17.37 cmplant^{-1} and 17.80 cm plant^{-1}, respectively followed by the treatments with SDB+ Lycomax and Rugby 10 G + Autostin giving 14.67 and 13.87 cm plant^{-1} of root length. In second year, the minimum root length of 11.3 cm plant^{-1} was recorded from control treatment. The highest root length of 23.3 cm plant^{-1} was achieved with Tricho-compost + Lycomax bio-fungicide followed by the treatment with PR + Autostin and MOC + Autostin giving 22.0 and 22.0 cm plant^{-1} root length. Other treatments also increased root length over control within the range of 11.3-18.0 cm plant^{-1} (Table 2).

Root weight was 2.77 g plant^{-1} in the first year and 2.5 g plant^{-1} in control plot. Integration of PR+ Autostin, MOC + Autostin, Tricho-compost + Lycomax bio-fungicide gave higher root weight by 4.37 g plant^{-1}, 4.10 g plant^{-1} and 4.40 g plant^{-1} in the first year where 4.39 g plant^{-1}, 4.33 g plant^{-1} and 4.33 g plant^{-1} in the second year, respectively. Other treatments also increased the root weight to some extent over control showing 3.12-3.60 g plant^{-1} in the first year and 2.90-3.43 g plant^{-1} in the second year (Table 2).

Table 2. Effect of soil treatment with Tricho-compost, organic amendments, saw dust burning and chemical pesticides on root growth of cucumber

Treatments	Average root length (cm plant^{-1})		Average root weight (g plant^{-1})	
	2022-2023	2023-2024	2022-2023	2023-2024
Poultry refuse + Autostin	17.47	22.0	4.37	4.39
Mustard oil cake + Autostin	17.37	22.0	4.10	4.33
Tricho-compost + Lycomax bio-fungicide	17.80	23.3	4.40	4.33
Saw dust burning + Lycomax bio-fungicide	14.67	18.0	3.60	3.43
Autostin+ Rugby 10 G	13.87	13.0	3.12 c	2.90
Control	11.87	11.3	2.77 c	2.50
LSD (0.05)	1.878	5.33	0.418	0.606

Foot and root rot disease incidence: In both the years, the incidence of foot and root rot disease was drastically reduced over control due to integrated application of different treatments (Table 3). In the first year, the highest foot and root rot disease of 38.33% was recorded in the untreated control plot. The percent incidence of foot and root rot disease of cucumber was 10.00% - 11.67% due to application of different treatments (Table 3). Integration of mustard oil cake with chemical fungicide and only application of chemical fungicide Autostin reduced 73.91% foot and root rot diease incidence over control followed by the integration of Tricho-compost and saw dust burning with Lycomax bio-fungicide and poultry refuse with Autostin where the reduction of disease incidence was 69.55%, 69.55% and 69.55%, respectively compared to control.

In the second year, foot and root rot disease incidence was higher 23.33% was recorded in the untreated control plot. The foot and root rot disease incidence of cucumber was 3.33% to 6.67% due to application of different treatments. Integration of mustard oil cake with Autostin, poultry refuse with Autostin and Tricho-compost with Lycomax bio-fungicide reduced foot and root rot disease upto 85.73% followed by the integration of saw dust burning with Lycomax and only Autostin treatment where the reduction of disease incidence was 71.41% compared to control.

Table 3. Effect of soil treatment with Tricho-compost, organic amendments, saw dust burning and chemical pesticides on the foot and root rot disease of cucumber

Treatments	Foot and root rot disease incidence (%)		Reduction of foot and root rot disease (%)	
	2022-2023	2023-2024	2022-2023	2023-2024
Poultry refuse + Autostin	11.67 (19.88)	3.33	69.55	85.73
Mustard oil cake + Autostin	10.00 (18.05)	3.33	73.91	85.73
Tricho-compost + Lycomax bio-fungicide	11.67 (19.88)	3.33	69.55	85.73
Saw dust burning + Lycomax bio-fungicide	11.67 (19.88)	6.67	69.55	71.41
Autostin+ Rugby 10 G	10.00 (19.88)	6.67	73.91	71.41
Control	38.33 (38.19)	23.33	-	-
LSD (0.05)	3.541	-	-	-

Vvalues within the parenthesis are the Arcsin Transformed values.

Severity of root gall: In both the years, the severity of root gall of cucumber was drastically reduced over control due to treatment of soil with mustard oilcake (MOC)+Autostin, poultry refuse (PR)+ Autostin, Tricho-compost+ Lycomax, Saw dust burning (SDB)+ Lycomax and application of Rugby 10G + Autostin. In the first year, the maximum average gall index value of 4.27 was recorded in the control plot. The gall index ranged from 1.60 to 2.33 due to treatments with two organic amendments, Tricho-compost, Saw dust burning and Rugby 10G (Table 4). Soil treatment with poultry refuse (PR)+ Autostin gave the highest reduction of root-knot severity 62.53% compared to control followed by MOC + Autostin, Rugby 10G + Autostin, Tricho-compost+ Lycomax and Saw dust burning (SDB)+ Lycomax where the reduction of root-knot disease severity was 60.89%, 51.52%, 50.12%, and 45.43%, respectively over control. In the second year, the highest gall index value of 3.50 was found in control plot and the values were 1.67 to 2.00 due to application of different treatments. The reduction in disease severity was significant compared to control. The maximum reduction root-knot nematode disease severity was obtained with poultry refuse (PR)+ Autostin 52.29% compared to control followed by MOC + Autostin, Tricho-compost+ Lycomax, Rugby 10G+ Autostin and Saw dust burning (SDB)+ Lycomax where the reduction of root-knot disease severity was 48.57%, 44.86%, 42.86%, and 42.86%, respectively compared to control (Table 4).

Table 4. Effect Effect of soil treatment with Tricho-compost, organic amendments, saw dust burning and chemical pesticides on the root knot nematode disease of cucumber

Treatments	Gall index (0-10 scale)		Reduction of gall index value (%)	
	2022-2023	2023-2024	2022-2023	2023-2024
Poultry refuse + Autostin	1.60	1.67	62.53	52.29
Mustard oil cake + Autostin	1.67	1.80	60.89	48.57
Tricho-compost + Lycomax bio-fungicide	2.13	1.93	50.12	44.86
Saw dust burning + Lycomax bio-fungicide	2.33	2.00	45.43	42.86
Autostin+Rugby 10 G	2.07	2.00	51.52	42.86
Control	4.27	3.50	-	-
LSD (0.05)	0.530	1.81	-	-

Crop yield: The yield of cucumber was significantly increased by integration of mustard oil cake and Tricho-compost with Lycomax bio-fungicide and poultry refuse with fungicide Autostin compared to control (Table 5). In first year, the lowest yield of cucumber (15.90 t ha^{-1}) was recorded from control plot followed by saw dust burning with Lycomax and only Autostin treatments but all those treatments were statistically similar. The maximum yield of 29.13 t ha^{-1} was obtained with Tricho-compost + Lycomax treatment followed by MOC + Autostin and PR + Autostin with the yields of 29.10 t ha^{-1} and 28.53 t ha^{-1}, respectively. Efficacy of three treatments to increase yield was statistically similar. Yield of cucumber was higher (45.42%) compared to control due to application of Tricho-compost + Lycomax bio-fungicide where as it were 45.36% and 44.27% due to integration MOC + Autostin, PR + Autostin, respectively. Integrated application of saw dust burning + Lycomax bio-fungicide and Rugby 10 G + Autostin gave 23.56% and 18.34% higher yield over control. In 2nd year, average fruit yield was 18.52 t ha^{-1} under control and 27.93 t ha^{-1} to 34.74 t ha^{-1} under treated plots. The yield of cucumber was significantly increased by 27.93 t ha^{-1} to 34.74 t ha^{-1} due to integration of Tricho-compot + Lycomax, PR + Autostin, MOC + Autostin, saw dust burning + Lycomax and Rugby 10 G + Autostin. The maximum yield of 34.74 t ha^{-1} was obtained with MOC + Autostin, which was statistically similar to Tricho-compot + Lycomax and PR + Autostin. Yield of cucumber was higher upto 46.69% compared to control due to integrated application of mustard oil cake + Lycomax bio-fungicide where as it was 46.46% and 43.69% due to integration of Tricho-compost + Lycomax bio-fungicide and poultry refuse + Autostin, respectively. Integrated application of saw dust burning + Lycomax bio-fungicide and Rugby 10 G + Autostin gave 33.69% and 20.89% higher yield over control.

The present study was designed to determine the potentiality of integration of different eco-friendly disease management approaches like integration of Tricho-compost + Lycomax bio-fungicide, mustard oil cake + Autostin, poultry refuse + Autostin, saw dust burning + Lycomax bio-fungicide and Rugby 10 G + Autostin against foot and root rot disease and also root-knot nematode diseases for increasing plant growth parameters as well as yield of cucumber. The results demonstrated that integration of different eco-friendly disease management approaches like integration of Tricho-compost + Lycomax bio-fungicide, mustard oil cake + Autostin and poultry refuse + Autostin were effective in reducing foot and root rot disease and also root-knot nematode diseases and thereby increasing plant growth parameters as well as yield of cucumber.

These results were supported by the findings of other researchers. It was reported that poultry refuse significantly reduced the population of Fusarium and Pythium species, as well as nematodes in cucumber-growing soils (Akhtar and Malik, 2000; Kaskavalci, 2007). According to Singh *et al*. (2011)**,** poultry manure reduced Fusarium oxysporum population in cucumber rhizosphere, decreasing foot and root rot severity by up to 45%. Chatterjee *et al*. (2006) observed that poultry manure incorporated into soil reduced incidence of root rot in cucurbits by 40–

60%. Mustard oil cake, a by-product of mustard seed oil extraction, contains glucosinolates that hydrolyze to form allyl isothiocyanate, a natural biofumigant toxic to many soil pathogens and nematodes. When applied to soil, mustard oil cake significantly reduced Meloidogyne incognita infestation and improved cucumber plant growth and yield (Chahal *et al*., 2005; Rao *et al*., 2014). The integration of poultry refuse, mustard oil cake, and chemical fungicide was a viable strategy for managing foot and root rot and root-knot nematode diseases in cucumber. This integrated approach did not only reduced pathogen pressure but also enhanced soil health and crop productivity in an eco-friendly manner. Das *et al.* (2017) reported that integrated application of poultry refuse + Carbendazim and mustard oil cake + fungicide increased cucumber yield by 52% and 45–50%, respectively compared to untreated control. Kaskavalci (2007) observed improved plant height, fruit length, and total marketable yield in cucumber treated with poultry manure and *Trichoderma*. Gogoi and Ali (2012) demonstrated that poultry manure + fungicide reduced disease severity index (DSI) and increased cucumber yield and fruit quality under field conditions. Rai *et al*. (2010) found that application of MOC with Carbendazim reduced disease severity index (DSI) by 70% and improved cucumber yield by 40% over control.

Different workers reported the role of Tricho-compost having bio-control agent *Trichoderma*, different composts against soil-borne and air borne plant pathogens and increasing plant growth and yield of different crops (Hossain and Naznin, 2005; Shaban and El-Bramawy, 2011; Olabiyi and Oladeji, 2014). For instance, T. harzianum significantly reduced disease incidence of foot rot and improved plant vigour and root architecture in cucumber (Elad *et al*., 2000). Harman *et al*. (2004) and Yedidia *et al*. (2001) reported that *Trichoderma* application enhanced cucumber root and shoot biomass, chlorophyll content, and fruit yield under both controlled and field conditions. Rai *et al*. (2011) showed that Tricho-compost reduced root rot incidence by up to 60% and increased cucumber yield significantly. Hossain *et al*. (2016) demonstrated suppression of M. incognita and improved soil health with Tricho-compost application in cucurbits. Islam *et al*. (2018) reported that Lycomax-treated cucumber plants showed better vegetative growth and resistance to root stress, resulting in up to 35% yield increase. Begum *et al*. (2020) found that combined use of biocompost and Lycomax improved cucumber root development and plant vigour under nematode-infested conditions. Akter *et al*. (2021) found that cucumber plants treated with both Tricho-compost and Lycomax had 45% greater plant height and *Fusarium* wilt was reduced by 55% and increased cucumber yield by 48% compared to untreated plots.

Table 5. Effect Effect of soil treatment with Tricho-compost, organic amendments, saw dust burning and chemical pesticides on the yield of cucumber

Treatments	Yield (t ha^{-1})		Yield increased over control (%)	
	2022-2023	2023-2024	2022-2023	2023-2024
Poultry refuse + Autostin	28.53	32.89	44.27	43.69
Mustard oil cake + Autostin	29.10	34.74	45.36	46.69
Tricho-compost + Lycomax bio-fungicide	29.13	34.59	45.42	46.46
Saw dust burning + Lycomax bio-fungicide	20.80	27.93	23.56	33.69
Autostin+ Rugby 10 G	19.47	23.41	18.34	20.89
Control	15.90	18.52	-	-
LSD (0.05)	4.999	2.228	-	-

Conclusion

The integration of Tricho-compost and Lycomax was a highly effective strategy for the management of foot and root rot and root-knot nematodes in cucumber. The integration of poultry refuses or mustard oil cake with the chemical fungicide Autostin was also seemed to be a viable strategy for managing foot and root rot and root-knot nematode diseases in cucumber. These integrated approaches not only reduced foot and root rot and root-knot nematode diseases but also enhanced crop yield in an eco-friendly manner.

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