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Application of Organic Soil Amendments in Controlling Rhizome Rot of Ginger

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Authors' contributions

This work was carried out in collaboration between all authors. Authors MKH and SMMH designed the study, wrote the protocol and first draft of the manuscript. Authors SMEH and MMI managed the literature searches and analysis of the study. Authors MAR and MSR managed the experimental process. All authors read and approved the final manuscript.

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ABSTRACT

Aims: To determine the effect of organic soil amendments on rhizome rot of ginger.
Study Design: The study was laid out in a randomised complete block design with three replications.
Place and Duration of Study: The experiment was conducted at the Plant Pathology Research Field of Hajee Mohammad Danesh Science and Technology University, Dinajpur, Bangladesh during 2016-2017.
Methodology: Soil were amended with mustard seed cake (2 t/ha), neem seed cake (2 t/ha), sawdust (2 t/ha), vermicompost (4 t/ha), poultry litter (4 t/ha), cow dung (2 t/ha) with one control (without amendment). The total number of unit plots was 21 and the size of the unit plot was 13 m × 7 m.

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Results: Soil amended plots showed better results by reducing the disease severity and many rhizome rot infected plants. Among the treatment; mustard seed cake exhibited least disease severity (14.76%) of rhizome and maximum yield (5.76 t/ha) of ginger as compared to control plot (65.56% disease severity and 0.82 t/ha rhizome).
Conclusion: Mustard seed cake may be recommended for better performance in controlling of rhizome rot disease of ginger.

Keywords: Ginger; rhizome rot; soil organic amendments and disease severity.

1. INTRODUCTION

Ginger (*Zingiber officinale* Rosc.) is one of the most essential spices crops in the world including Bangladesh. It is a herbaceous tropical and sub-tropical perennial plant that belongs to the family Zingiberaceae. Ginger originated in South-East Asia, probably in India [1,2]. Ginger is used in gingerbread, biscuits, cakes, pudding, soups and pickles. The refreshing, pleasant aroma, biting taste and carminative property of ginger make it an indispensable ingredient in food processing throughout the world. It has particular importance in tropical countries where it is produced and consumed in large quantities [3]. It is also used as curry powder and medicine. A disease is a significant constraint for the production of healthy rhizome and may cause even total failure of the crop [4]. Ginger is affected by various diseases, such as rhizome rot, bacterial wilt, soft rot, leaf blight etc. Among all of these, rhizome rot is the most damaging one [5]. The disease is significant because it causes economic losses to growers resulting in decreased prices of products to the consumers. It is essential to know the factors affecting the severity and control measures of rhizome rot. Control measures such as seed treatment, soil treatment, soil amendment, sanitation, drainage, intercropping etc. have some effects in controlling the disease individually [6]. Many researchers have worked on the chemical control of the disease and they found a very promising result with different chemicals [7]. However, chemical treatment increase the cost of production and continuous use of the chemicals results in the accumulation of harmful chemical residues in soil as well as plant products causing severe environmental pollution, a deleterious effect to non-target beneficial soil microorganisms. In search of eco-friendly approach, several researchers investigated on organic products, bio-agents, plant extracts for the management of rhizome rot [8]. Keeping this in view, the present research was undertaken to investigate the effect of different organic soil amendments in controlling rhizome rot of ginger.

2. MATERIALS AND METHODS

2.1 Experimental Site

The experiment was conducted at the Plant Pathology Research Field of Hajee Mohammad Danesh Science and Technology University, Dinajpur, Bangladesh.

2.2 Duration of the Experiment

The experiment was conducted during April, 2016 to January 2017.

2.3 Soil Type

Soil of the experimental plot was sandy loam with good drainage capacity. The experimental plot was medium high land with the pH range from 5.5 to 6.0.

2.4 Variety and Preparation of Propagating Unit

Local variety ginger rhizomes having 1-2 buds whose average weight 55-60 g. were selected. The collected ginger rhizomes were preserved under soil about one month for pre-sprouting of seed.

2.5 Preparation of the Main Field

The selected land was harrowed, ploughed and cross-ploughed several times followed by laddering to get a fine tilth. Weeds, stubbles and rubbishes were removed, proper drainage channel were made around the experimental plots and finally obtained a desirable tilth of soil for planting of ginger rhizomes.

2.6 Application of Manure and Fertilizers

Well decomposed cow dung @ 7 t/ha was applied during land opening. TSP (Triple Super Phosphate) @ 4 t/ha and MOP (Muriate of Potash) @ 3 t/ha, Gypsum @ 2 t/ha were applied at the time of final land preparation. The entire

amount of TSP, MOP and Gypsum were applied during the final land preparation. Urea was applied after first weeding @2 t/ha.

2.7 Design of the Experiment

Single factor RCBD (Randomized Complete Block Design).

2.8 Layout of the Experiment

The experiment was conducted with 3 replications having 7 treatments.

2.9 Treatment of the Experiment

The treatments were as follows:

T_0 = Untreated (Control),
T_1 = Soil amendment of ginger with Mustard seed cake@2 t/ha,
T_2 = Soil amendment of ginger with Neem seed cake@2 t/ha,
T_3 = Soil amendment of ginger with Sawdust@2 t/ha,
T_4 = Soil amendment of ginger with Vermi-compost@4 t/ha,
T_5 = Soil amendment of ginger with Poultry litter@4 t/ha,
T_6 = Soil amendment of ginger with Cow dung@2 t/ha.

2.10 Time of Planting of Rhizome

Pre-sprouted rhizomes were planted on 2nd week of April 2016. Seeds of ginger were sown at the rate of 1.8 t/ha.

2.11 Sowing of Rhizome

Pieces of seed rhizomes were sown at the rate of 60 g (1rhizome) per hole. The seeds (rhizome) were placed individually in the furrows and furrows were covered with soil. The plots were earthen up 20 cm high from the level of drain. Finally, the plots were covered with the straw of dry rice.

2.12 Data Collecting Parameters

Data were collected on no. of tillers per plant, plant height (cm), no. of leaves per plant, healthy plant per plot, infected plant per plot and disease severity of plant (%) before harvesting. Data were recorded on 60, 90, 120, 150 and 180 days after sowing (DAS). Disease severity of plant (%) was calculated by using the formulae –

Disease severity of plants =

$$\frac{\textit{Surface area of plants infected by disease}}{\textit{Total surface area of plants}} \times 100$$

Healthy rhizome, diseased rhizome, wt. of healthy rhizome, wt. of infected rhizome, percent disease severity and yield (t/ha) per plot were recorded at the time of harvest.

2.13 Harvesting

Ginger rhizomes were harvested on10th January, 2017. Rhizomes from each plot were harvested separately. The weight of rhizomes from each plot was recorded in kg and converted into hectare.

2.14 Data Analysis

Collected data were analysed statistically by using the MSTAT-C computer package program [9].

3. RESULTS

3.1 Effect of Organic Soil Amendments on Tiller Number per Plant

Tiller number per plant of ginger was recorded at 60, 90, 120,150 and 180 DAS and the results are presented in Table 1. When tiller number per plant of ginger was recorded at 60 DAS, the highest (4.493) tiller number per plant was found in T_5, where ginger was planted in poultry litter treated plot. The lowest (3.613) number of tiller per plant was found in T_4 (vermicompost), which was statistically similar with T_0, T_1, T_2, T_3 and in T_6 having 3.8, 3.88, 3.85, 3.66 and 3.84 tiller per plant, respectively. At 90 DAS, tiller number per plant ranged from 6.120 to 8.543, where the highest (8.543) was found in T_6, where ginger was planted in cow dung which was statistically similar with T_1 (7.88), T_2 (7.56), T_3 (7.80) and T_4 (7.45) and the lowest (6.120) in T_0, where ginger was planted without any treatment. Tiller number per plant was found the maximum (19.4) in T_6 at 120 DAS, where ginger was planted in cow dung treated plot which was statistically similar with T_1 (18.51). The minimum (14.95) tiller per plant was observed in T_0, which was statistically similar with T_2 (15.73), T_3 (15.15) and T_4 (16.79). The moderate (17.33) number of tiller was recorded in T_5 at 120 DAS. The highest (22.31) tiller number per plant was found in T_5 at 150 DAS, where ginger was planted in poultry litter treated plot which was statistically similar with T_1 (21.50),

T_2 (18.64), T_4 (19.70) and T_6 (20.52). The lowest (17.41) tiller number per plant was found in T_3, where ginger was planted in sawdust treated plot that was similar to control treatment T_0 (18.16). At 180 DAS, the highest (22.70) number of tiller per plant was found in T_5, where ginger was planted in poultry litter treated plot which was statistically similar with T_1 (22.34), T_2 (19.63), T_4 (20.56) and T_6 (21.28). The lowest (18.71) number of tiller per plant was found in T_3, where ginger was planted in sawdust treated plot that was similar with control treatment T_0 (18.92).

3.2 Effect of Organic Soil Amendments on Plant Height (cm)

Plant height (cm) of ginger was recorded at 60, 90, 120,150 and 180 DAS and the results are shown in Table 2. At 60 DAS, plant height ranged from 59.23 to 52.55 cm, where the maximum (59.23 cm) height was found in T_4, where ginger was planted in a vermi-compost treated plot which was statistically similar toT_5 (58.89) where ginger was planted in poultry litter treated plot. The minimum (52.55) plant height was found in T_0, where ginger was planted in control plot. When plant height (cm) of ginger was recorded at 90 DAS, the maximum (76.61 cm) height was found in T_4 where ginger was planted in vermicompost treated plot which was statistically similar with T_1 (70.81 cm), T_2 70.35 cm), T_3 (66.89 cm), T_5 (72.51 cm) and T_6 (73.10 cm). The minimum height (62.92 cm) was in T_0, where ginger was planted in control plot. When plant height (cm) of ginger was recorded at 120 DAS, the maximum (83.16 cm) was found in T_4, where ginger was planted in vermicompost treated plot which was statistically similar with T_5 (81.50) and T_6 (78.05). The minimum (69.62 cm)plant height was found in T_0, where ginger was planted in control. Plant height recorded at 150 DAS, was varied from 71.10 cm to 82.68 cm but their variation was not statistically significant among the treatments. Maximum (85.01 cm) plant height was found in T_4 at 180 DAS, where ginger was planted in vermi-compost treated plot which was statistically similar with T_1 (81.20), T_2 (79.71), T_3 (79.27), T_5 (83.88) and T_6 (79.40) and the minimum (72.56 cm) plant height was found in T_0, where ginger was planted in control plot.

Table 1. Effect of organic soil amendments on tiller number per plant at different dates of sowing

Treatments	60 DAS	90 DAS	120 DAS	150 DAS	180 DAS
Control (T_0)	3.68 b	6.12 b	14.95 d	18.16 bc	18.92 b
Mustard seed cake (T_1)	3.88 b	7.88 a	18.51 ab	21.50 ab	22.34 ab
Neem seed cake (T_2)	3.85 b	7.56 a	15.73 cd	18.64 abc	19.63 ab
Sawdust (T_3)	3.66 b	7.80 a	15.15 d	17.41 c	18.71 b
Vermicompost (T_4)	3.61 b	7.56 a	16.79 bcd	19.70 abc	20.56 ab
Poultry litter (T_5)	4.49 a	8.01 a	17.33 bc	22.31 a	22.70 a
Cow dung (T_6)	3.84 b	8.54 a	19.43 a	20.52 abc	21.28 ab
LSD	0.58	0.91	1.77	3.47	3.33
CV %	8.46	6.73	5.91	9.86	9.10

Figures in a column having a common letter(s) do not differ significantly at 5% level of significance.
CV = Coefficient of variation

Table 2. Effect of organic soil amendments on plant height (cm) at different dates of observation

Treatments	Plant height (cm)				
	60 DAS	90 DAS	120 DAS	150 DAS	180 DAS
Control (T_0)	52.55 c	62.92 c	69.62 c	72.08 a	72.56 b
Mustard seed cake (T_1)	53.95 c	70.81 ab	77.42 b	80.09 a	81.20 a
Neem seed cake (T_2)	53.45 c	70.35 ab	76.70 b	79.20 a	79.71 a
Sawdust (T_3)	56.45 b	66.89 bc	76.50 b	78.76 a	79.27 a
Vermi-compost (T_4)	59.23 a	76.61 a	83.16 a	71.10 a	85.01 a
Poultry litter(T_5)	58.89 a	72.51 ab	81.50 ab	82.68 a	83.88 a
Cow dung(T_6)	54.17 c	73.10 ab	78.06 ab	78.55 a	79.40 a
LSD	2.180	6.486	5.303	18.59	5.673
CV %	2.21	5.17	3.84	13.48	3.98

Figures in a column having common letter(s) do not differ significantly at 5% level of significance.
CV = Coefficient of variation

3.3 Effect of Organic Soil Amendments on Number of Leaves/Plant

Number of leaves/plant of ginger was recorded at 60, 90, 120,150 and 180 DAS and the results are shown in Table 3. Number of leaves/plant was recorded maximum (16.42) in T_5 at 60 DAS, where ginger was planted in poultry litter treated plot which was statistically similar with T_4 (15.87) and T_6 (15.78). Mustard seed cake treated plot produce moderate (15.11) number of leaves per plant in T_1, which was statistically similar with T_2 (14.90) and T_3 (14.93). The minimum (14.58) number of leaves/plant was observed in T_0, where ginger was planted in control plot. When leaves/plant of ginger was recorded at 90 DAS, the maximum (18.28) was found in T_5 where ginger was planted in poultry litter treated plot which was statistically similar with other treatments except T_0 (16.43). The minimum leaves/plant where ginger was planted control plot. At 120 DAS, the highest (28.10) number of leaves/plant was recorded in T_3, where ginger was planted in sawdust treated plot which was statistically similar with T_1 (27.35), T_2 (26.86), T_4 (26.16) and T_6 (25.81). The lowest (21.53) number of leaves/plant was found in T_0, where ginger was planted in control plot. The maximum (30.30) number of leaves/plant was found in T_1 at 150 DAS, where ginger was planted in mustard seed cake treated plot which was statistically similar with other treatments except T_0 (26.58), that produce a minimum number of leaves per plant, where ginger was planted in control plot. At 180 DAS, a number of leaves/plant ranged from 27.40 to 31.80, where the highest (31.80) was found in T_3 and the lowest (27.40) in T_0, where ginger was planted in control.

3.4 Effect of Organic Soil Amendments on Healthy Plant/Plot

Healthy plant/plot of ginger was recorded at 60, 90, 120,150 and 180 DAS and the results are shown in Table 4. The highest (12.00) healthy plant/plot was found in T_1 at 60 DAS, where ginger was planted in mustard seed cake treated plot which was statistically similar with T_2 (11.33), T_5 (11.67) and T_6 (11.67).The lowest (10.6) healthy plant/plot was found in T_0, where ginger was planted in control plot which was statistically similar with T_3 (10.67) and T_4 (10.67). At 90 DAS, the highest (11.33) healthy plant/plot of ginger was recorded in T_1, where ginger was planted in mustard seed cake treated plot which was statistically similar with T_2 (10.67), T_3 (10.33) and T_6 (10.33) and the lowest (9.67) in T_0, where ginger was planted in control plot. At 120 DAS the highest (10.30) healthy plant/plot was found in T_1, where ginger was planted in mustard seed cake and the lowest (8.33) in T_0, where ginger was planted in control plot which was statistically similar with rest of all the treatments. There was no significant difference found in healthy plant per plot at 150 days after sowing. But healthy plant/plot was found the maximum (8.00) in T_1, where ginger was planted in mustard seed cake treated plot and minimum (6.00) healthy plant/plot was observed in T_0, where ginger was planted in control plot. At the maturity of plants, the number of healthy plants reduced among the treatments. When data was recorded at 180 days after sowing it was observed that healthy plant per plot not differ significantly. Though healthy plant per plot at 180 DAS, was not differing significantly maximum was found in T_1 having 6.00 plant and minimum at control treated plot having 4.67 plants per plot.

Table 3. Effect of organic soil amendments on number of leaves/plant at different dates of observation

Treatments	Number of leaves per plant				
	60 DAS	90 DAS	120 DAS	150 DAS	180 DAS
Control (T_0)	14.58 c	16.43 b	21.53 c	26.58 b	27.40 b
Mustard seed cake (T_1)	15.11 bc	18.24 a	27.35 ab	30.30 a	31.36 a
Neem seed cake (T_2)	14.90 bc	17.60 ab	26.86 ab	29.96 a	31.57 a
Sawdust (T_3)	14.93 bc	17.30 ab	28.10 a	30.06 a	31.80 a
Vermi-compost (T_4)	15.87 ab	18.15 a	26.16 ab	28.40 ab	29.75 a
Poultry litter (T_5)	16.42 a	18.28 a	26.81 ab	29.58 a	30.99 a
Cow dung (T_6)	15.78 ab	18.23 a	25.81 b	28.93 ab	29.94 a
LSD	1.043	1.180	1.783	2.537	2.031
CV %	3.82	3.74	3.84	4.90	3.75

Figures in a column having a common letter(s) do not differ significantly at 5% level of significance.
CV = Coefficient of variation

Table 4. Effect of organic soil amendments on healthy plant/plot at different dates of observation

Treatments	60 DAS	90 DAS	120 DAS	150 DAS	180 DAS
Control (T_0)	10.67 b	9.67 b	8.33 b	6.00 a	4.67 a
Mustard seed cake (T_1)	12.00 a	11.33 a	10.33 a	8.00 a	6.00 a
Neem seed cake (T_2)	11.33 ab	10.67 ab	9.00 b	7.67 a	5.67 a
Sawdust (T_3)	10.67 b	10.33 ab	8.67 b	7.00 a	5.67 a
Vermi-compost (T_4)	10.67 b	10.00 b	9.00 b	7.00 a	5.33 a
Poultry litter (T_5)	11.67 ab	9.67 b	8.67 b	7.00 a	5.67 a
Cow dung (T_6)	11.67 ab	10.33 ab	9.00 b	6.33 a	4.67 a
LSD	1.121	0.99	1.04	5.04	1.88
CV %	5.61	5.41	6.49	13.16	19.59

Figures in a column having common letter(s) do not differ significantly at 5% level of significance.
CV = Coefficient of variation

3.5 Effect of Organic Soil Amendments on Infected Plant/Plot

Infected plant/plot of ginger was recorded at 60, 90, 120, 150 and 180 DAS and the results are shown in Table 5. At 60 DAS, infected plant/plot ranged from 2.00 to 3.33, where the highest (3.33) was found in control plot T_0, which was same with T_3 & T_4 and statistically similar with T_2 (2.67), T_5 (3.00) and T_6 (2.33). On the other hand, the lowest (2.00) infected plant per plot was found in T_1, where ginger was planted in Mustard seed cake treated plot. The highest number of infected plant/plot was found in T_0 and T_5 shaving 4.33 at 90 DAS, where ginger was planted in control and poultry litter treated plot which was statistically similar with T_2, T_3, T_4, and T_6 having 3.33, 3.67, 4.00 and 3.67 infected plant, respectively. The lowest (2.67) infected plant/plot was found in T_1 where ginger was planted in mustard seed cake treated plot. At 120 DAS, the maximum (8.000) infected plant/plot was recorded in T_0 which was statistically similar withT_2 (5.00), T_3 (5.33), T_4 (5.00), T_5 (5.33) and T_6 (5.00). The minimum (3.67) infected plant/plot was found in T_1 where ginger was planted in mustard seed cake treated plot. Infected plant/plot was found maximum in T_0 (8.00) at 150 DAS, where ginger was planted in control plot which was statistically similar with T_2 (6.66), T_3 (7.00), T_4 (7.00), T_5 (7.00) and T_6 (7.67). The minimum (6.00) infected plant/plot was observed in T_1 where ginger was planted in mustard seed cake treated plot. There was no significant variation recorded in infected plant per plot when data was recorded at 180 DAS, but the maximum (9.33) infected plant was recorded in T_0 (control plot) and the minimum (8.00) was recorded in T_1, where ginger was planted in mustard seed cake treated plot.

3.6 Effect of Organic Soil Amendments on Disease Severity of Plant

At 60 DAS, percent disease severity was varied in different treatments, but the variation was not statistically significant. The maximum disease severity of plant was recorded in T_0 (control) and the minimum in T_1, where ginger was planted in mustard seed cake treated plot. Significant

Table 5. Effect of organic soil amendments on infected plant/plot at different dates of observation

Treatments	60 DAS	90 DAS	120 DAS	150 DAS	180 DAS
Control (T_0)	3.33 a	4.33 a	5.67 a	8.00 a	9.33 a
Mustard seed cake (T_1)	2.00 b	2.67 b	3.67 b	6.00 b	8.00 a
Neem seed cake (T_2)	2.67 ab	3.33 ab	5.00 a	6.33 ab	8.33 a
Sawdust (T_3)	3.33 a	3.67 ab	5.33 a	7.00 ab	8.33 a
Vermi-compost (T_4)	3.33 a	4.00 a	5.00 a	7.00 ab	8.67 a
Poultry litter (T_5)	3.00 ab	4.33 a	5.33 a	7.00 ab	8.33 a
Cow dung (T_6)	2.33 ab	3.67 ab	5.00 a	7.67 ab	9.33 a
LSD	1.12	0.99	1.04	1.64	1.88
CV %	22.05	14.98	11.68	13.16	12.23

Figures in a column having common letter(s) do not differ significantly at 5% level of significance.
CV = Coefficient of variation

variation of disease severity of plant was recorded when data was recorded at 90 DAS. The highest disease severity of plant was recorded in control treatment (T_0), which was statistically similar with T_2, T_3, T_4, T_5 and T_6. The lowest disease severity of plant was recorded in T_1, where ginger was planted in mustard seed cake treated plot. More or less similar pattern of disease severity of plant was recorded at 120 DAS as in 90 DAS. The highest disease severity of plant was recorded in control treatment (T_0) which was statistically similar with T_2, T_3, T_4, T_5 and T_6 the lowest disease severity of plant was recorded in T_1, where ginger was planted in mustard seed cake treated plot. Data recorded at 150 DAS and 180 DAS indicate that disease severity was not varied significantly among the treatments. But the maximum disease severity was recorded in the control treatment (T_0) at 150 DAS and 180 DAS, respectively. The minimum disease severity of plants was recorded in mustard seed cake treated plot (T_1) at 150 DAS and 180 DAS, respectively (Fig. 1).

3.7 Effect of Organic Soil Amendments on Healthy Rhizome, Diseased Rhizome and Yield (t/ha)

At harvesting time number of healthy rhizome/plot recorded the highest (77.33) was in T_1, where ginger was planted in mustard seed cake treated plot which was statistically similar with T_2 (67.00) and T_4 (66.00). On the other hand, the lowest (15.33) number of healthy rhizome/plot was recorded in control plot T_0, which was similar with T_5 and T_6 having 27.00 and 26.33 healthy rhizome, respectively. Number of disease rhizome/plot was found maximum (34.33) in T_5 at harvesting time where ginger was planted in poultry litter treated plot which was statistically similar with T_0 (28.67), T_2 (29.00), T_3 (20.33), T_4 (23.67) and T_6 (29.00). The minimum (13.33) number of disease rhizome/plot was found in T_1, where ginger was planted in mustard seed cake treated plot. It was recorded maximum (7.345 kg) weight of healthy rhizome/plot in T_1, at harvesting time where ginger was planted in mustard seed cake treated plot which was statistically similar to T_4 (6.62 kg) and the minimum (0.39 kg) weight of healthy rhizome/plot was recorded in control plot (T_0), which was similar with T_5 (2.07 kg) and T_6 (1.72kg). The maximum (1.573 kg) weight of disease rhizome/plot was obtained in T_0, at the time of harvesting where ginger was planted in control plot, which was statistically similar with T_2 (1.02 kg) and T_4 (1.03 kg) and the minimum (0.40 kg) weight of disease rhizome/plot was observed in T_1, where ginger was planted in mustard seed cake treated plot and which was similar with T_0 (0.70 kg), T_3 (0.83 kg), and T_6 (0.54 kg). Percent disease severity of rhizome was recorded maximum (65.56) in T_0, at harvesting time which was statistically similar with T_5 (5.96) and T6 (51.58). The minimum (14.76) percent disease severity of rhizome was observed in T_1, where ginger was planted in mustard seed cake treated plot and which was similar with T_2, T_3 and T_4 having 25.58, 30.03 and 28.75 disease severity, respectively. The highest (5.76 t/ha) yield of rhizome was obtained from T_1 at harvesting time, where ginger was planted in mustard seed

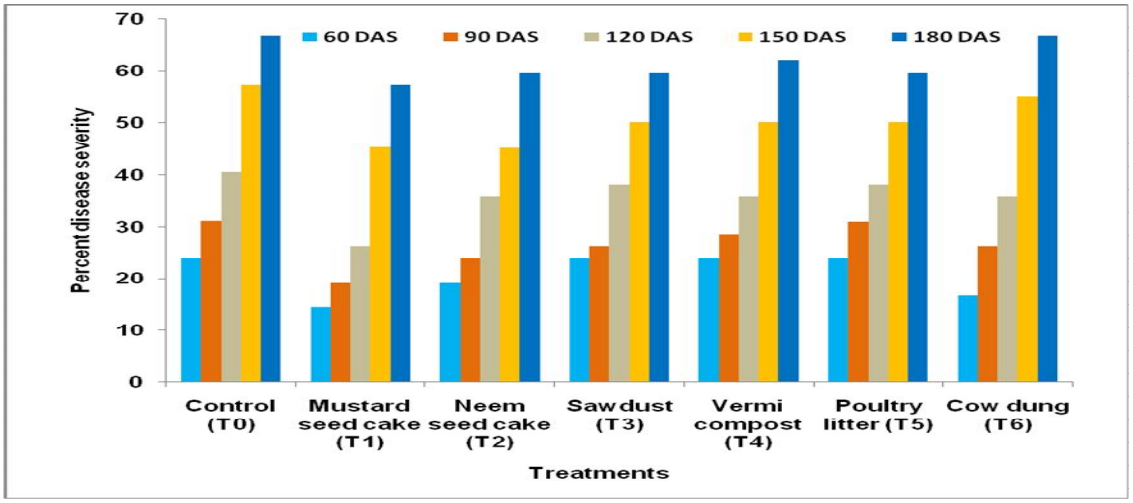

Fig. 1. Effect of organic soil amendments on disease severity of plant at different dates of observation

Table 6. Effect of organic soil amendments on healthy rhizome, diseased rhizome, percent disease severity and yield (t/ha) of rhizome

Treatments	Healthy rhizome		Diseased rhizome		Disease severity of rhizome	Yield (t/ha)
	Number /plot	Weight kg /plot	Number /plot	Weight kg /plot		
Control (T_0)	15.33 d	0.39 e	28.67 ab	1.57 a	65.56 a	0.82 c
Mustard seed cake (T_1)	77.33 a	7.35 a	13.33 b	0.40 b	14.76 b	5.76 a
Neem seed cake (T_2)	67.00 ab	4.84 bc	29.00 ab	1.02 ab	29.58 b	3.65 ab
Sawdust (T_3)	48.33 bc	2.97 cd	20.33 ab	0.83 b	30.03 b	2.37 bc
Vermi-compost (T_4)	66.00 ab	6.62 ab	23.67 ab	1.03 ab	28.75 b	3.37 b
Poultry litter (T_5)	27.00 cd	2.07 de	34.33 a	0.70 b	55.96 a	2.43 bc
Cow dung (T_6)	26.33 cd	1.72 de	29.00 ab	0.54 b	51.58 a	1.69 bc
LSD	22.46	2.35	14.69	0.67	18.73	2.15
CV %	26.99	35.57	32.42	42.98	26.68	35.61

Figures in a column having common letter(s) do not differ significantly at 5% level of significance.
CV = Coefficient of variation

cake treated plot which was statistically similar with T_2 (3.65 t/ha), and the lowest (0.82 t/ha) yield was obtained from T_0, which was similar with T_6 (1.69 t/ha) and T_3 (2.37 t/ha) shown in Table 6.

4. DISCUSSION

Rhizome rot is one of the most destructive diseases of ginger which may cause total loss of the crop. The potentials of different soil amendments to minimize losses caused by the disease was investigated. The result of the present experiment showed significant variation among the treatment on tiller number per plant. Significant higher number of tiller was recorded when soil was amended with organic matter compared to control. This might have happened due to reduction of primary inocula of pathogen present in the soil. Poultry litter was found as the most effective followed by mustard seed cake and neem seed cake, respectively in ensuring maximum number of tillers per plant at 180 DAS. The results indicated that at 180 DAS the maximum, 22.70 numbers of tillers were found in the plots of poultry litter amendment whereas in the treatment control numbers of tillers were found as18.92. The organic amendments of soil were also found effective to increase the height of plant and number of leaves per plant compared to the treatment control. Maximum number of leaves per plant is the indication of minimum amount of disease. Basal application of mustard seed cake produced higher number of healthy plants and lower number of infected plants compared to the treatment control. The present findings also corroborated with Awasthi and Singh [10] who reported that the application of *Boerhaavia diffusa* root extract induced the disease resistance exhibiting minimum disease incidence under field conditions. Srivastava et al. [11] also reported the antifungal properties of natural plant based products like Neem (*Azadirachta indica*), Datura (*Datura festilosa*), Marigold (*Tagets erecta*) and a phytochemical organic formulation (MATW-2) against different soil borne fungal pathogens. Organic amendments treated plots were recorded with better results reducing disease severity and rhizome rot infected plants. But mustard seed cake performed as the best among all the treatments. The present findings were found in line with Ghorpade and Ajri [12] and Kausal and Siddique [13] who worked with a good number of seed cake against wide range of soil borne plant pathogens including *Pythium* spp. They observed that seed cake reduced the incidence of ginger rhizome rot markedly and increased yields. Considering the yield, all the treatments with organic amendments produced more yield than control. It was recorded that basal application of mustard seed cake significantly produced the highest yield of ginger (5.76 t/ha). The present findings were in agreement with Haque et al. [14] who found that the compost treatment enhanced plant growth and healthy plants by reducing the disease severity of ginger. Higher yield of ginger was obtained with compost treatment which increased the total rhizome yield of about 1.66% more than the control plot.

5. CONCLUSION

From the present study, it can be concluded that the application of different organic amendments in soil have significant importance on plant height, number of tillers, number of leaves,

infected plants, disease severity of plants and yield of ginger. But among all the treatments, mustard seed cake was found to be most effective producing highest yield of ginger by increasing other yield contributing parameters and reducing disease severity.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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