EFFECT OF SOWING TIMES AND ORGANIC SOIL AMENDMENTS ON FOOT AND ROOT ROT DISEASE OF LENTIL CAUSED BY *SCLEROTIUM ROLFSII*

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CERTIFICATE

*This is to certify that the thesis entitled, "***EFFECT OF SOWING TIMES AND ORGANIC SOIL AMENDMENTS ON FOOT AND ROOT ROT DISEASE OF LENTIL CAUSED BY** ***SCLEROTIUM ROLFSII***" *submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of* ***MASTER OF SCIENCE*** *in* ***PLANT PATHOLOGY****, embodies the result of a piece of bona fide research work carried out by* ***TONUSHRI SARKER, Registration No. 18-09138*** *under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

I further certify that such help or source of information, as has been availed of during the course of this investigation has duly been acknowledged.

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DEDICATED TO MY BELOVED PARENTS

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CONTENTS

CHAPTER	TITLES	PAGE NO.
	ACKNOWLEDGEMENT	i
	LIST OF CONTENTS	ii
	LIST OF TABLES	iii
	LIST OF PLATES	iv
	LIST OF FIGURES	v
	LIST OF SYMBOL AND ABBREVIATIONS	vi
	ABSTRACT	vii
1	INTRODUCTION	1-5
2	REVIEW OF LITERATURE	6-13
3	MATERIALS AND METHODS	14-33
4	RESULT AND DISCUSSION	34-62
5	SUMMERY AND CONCLUSION	63-67
6	REFERENCES	68-76
7	APPENDICES	77-78

LIST OF TABLES

TABLE NO.	TITLES	PAGE NO.
1	Rate of fertilizers and manure applied in the field and pot	25
2	Effect of different sowing times on incidence of foot and root rot disease of lentil at different days after inoculation (DAI)	39
3	Effect of different sowing times on growth parameters of lentil	42
4	Effect of different sowing times on yield and yield contributing characters of lentil	43
5	Effect of different organic soil amendments on incidence of foot and root rot disease of lentil at different days after inoculation (DAI) in pot	46
6	Effect of different organic soil amendments on growth parameters of lentil in pot	50
7	Effect of different organic soil amendments on yield and yield contributing characters of lentil in pot experiment	52
8	Effect of different organic soil amendments on incidence of foot and root rot disease of lentil at different days after sowing (DAS) in field	54
9	Effect of different organic soil amendments on growth parameters of lentil in field	57
10	Effect of different organic soil amendments on yield and yield contributing characters of lentil in field	59

LIST OF PLATES

PLATES NO.	TITLES	PAGE NO.
1	Experimental layout of pot experiment	16
2	Preparation of pots	17
3	Mass culture of *Sclerotium rolfsii* on barley grain	20
4	Pot view of the experiment at the time of counting disease incidence	22
5	Experimental layout of field experiment	25
6	Treatments for pot and field experiment	27
7	Seed sowing in the field	28
8	Field view of the experiment at the time of counting disease incidence	30
9	Preparation of PDA (Potato Dextrose Agar) Medium	31
10	Growing fungi in moist blotting paper	32
11	Growing fungi on Potato Dextrose Agar (PDA) medium	33
12	Diseased plants	35
13	Growth of *Sclerotium rolfsii* at different days after incubation (DAI)	36
14	Microscopic (compound) view of *Sclerotium rolfsii*	37

LIST OF FIGURES

FIGURES NO.	TITLES	PAGE NO.
1	Regression coefficient between disease incidence (%) and total yield/pot (g) in case of different sowing times	60
2	Regression coefficient between disease incidence (%) and total yield/pot (g) in different organic soil amendments in pot	61
3	Regression coefficient between disease incidence (%) and total yield/m^2(g) in different organic soil amendments in field	62

LIST OF SYMBOL AND ABBREVIATIONS

ABBREVIATIONS	FULL WORD
%	Percentage
PDA	Potato Dextrose Agar
G	Gram
^{o}C	Degree celcius
Psi	Per square inch
Cm	Centimeter
et al.	and others (at ell)
CRD	Complete Randomized Design
RCBD	Randomized Complete Block Design
DAI	Days After Inoculation
DAS	Days After Sowing
sp.	Species
etc.	Et cetera
Viz.	Videlicet (namely)

EFFECT OF SOWING TIMES AND ORGANIC SOIL AMENDMENTS ON FOOT AND ROOT ROT DISEASE OF LENTIL CAUSED BY *SCLEROTIUM ROLFSII*

ABSTRACT

In vitro and *in vivo* experiments were conducted to evaluate the effect of sowing times and organic soil amendments for the management of foot and root rot of lentil caused by *Sclerotium rolfsii* at Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from October 2019 to March 2020. Six different sowing times viz. 25 October, 5 November, 15 November, 25 November, 5 December and 15 December and nine organic soil amendments viz. poultry refuse, mustard oil cake, neem oil cake, vermicompost, cowdung, trichocompost, biochar, sawdust and ash were assessed against the disease. Susceptible variety BARI Masur-1 was used in this experiment. In pot experiments, the lowest disease incidence was recorded in seed sowing on 15 December (15.22%) at 60 days after inoculation (DAI) where the highest disease incidence was recorded in seed sowing on 25 October (49.67%) at same DAI. In case of soil amendment, the lowest disease incidence was recorded in Trichocompost (8.96%) applied pot where the highest incidence was in control (57.65%) pot at 60 DAI. In all cases, growth parameters viz. germination (%), plant height (cm), no. of branch, vigor index and other yield contributing characters were the highest in seed sowing on 15 December and in Trichocompost treated pot. In field experiment, Trichocompost showed the best result with lowest disease incidence (11.11%) and the highest yield (170.11 g/m^2). However, the highest disease incidence (58.89%) with the lowest yield (74.44 g/m^2) were recorded in control plot. From the above findings, pre-sowing soil application with Trichocompost with late seed sowing after first week of December is recommended to manage foot and root rot of lentil disease.

CHAPTER 1

INTRODUCTION

Lentil (*Lens culinaris*) occupies a unique position in the world of agriculture. It is one of the first agricultural crops grown more than 8500 years ago in the Middle East. Then, the cultivation and consumption of the lentils have been widespread in developed and developing countries. Lentil is also one of the oldest crops cultivated by humans and the most consumed leguminous seeds in the world. The major lentil-producing countries are India, Canada, Turkey, the United States, Nepal, Australia, Syria, China, Bangladesh, and Iran. Worldwide 6,315,536 tons of lentil is produced per year. Canada is the largest lentil producer in the world with 3,233,800 tons production volume per year, India comes second with 1,055,536 tones yearly production (Anonymous, 2021). Consumption of lentils with small grains provides a balanced diet. It is a cheap source of protein for human beings and also for animals in Bangladesh (Sattar *et al.*, 1996). As the price of animal protein is high so people used to solve the deficiency of protein by consuming lentil and it also called "poor's meat" in Bangladesh. It contains 25.78% of protein and 59% carbohydrate (Bakhsh *et al*., 1991). It also contains several micronutrients such as Fe, Zn and β-carotene (Bhatty, 1998). Lentils are not only contained high amount of macronutrients, such as protein, fatty acids, and carbohydrates, but also contain phytochemicals, such as phenolic acids, flavonols, saponin, phytic acids, and condensed tannin, which can be used as a source of antioxidant (Harlen *et al*., 2018).

In Bangladesh, pulses are important food crops that hold an area about 0.3 million ha (2.34% of the total cropped area) and contribute about 1.07% of the total grain production of the country (Ahmed, 1985). Here, mainly eight pulses are grown yearly and widely, which are chickpea, lentil, mungbean, black gram, lathyrus, field pea, cowpea and pigeon pea (Bakr, 1994). Among all pulses lentil obtained a unique position due to its wide use and common food item of the people of Bangladesh. Lentil is one of the oldest crops cultivated in our country and is a familiar one to the farmers of Bangladesh. Lentil is the second major pulse crop of Bangladesh in respect of acreage and production. It is cultivated as sole and intercrops. Total production of lentil in Bangladesh is about 168,837 metric tons (BBS, 2017). The yield of lentil in our country is much lower than other countries like Syria, Turkey, Canada, U.S.A, Ethiopia (Hossain *et al.*, 1999).

In our country quality and quantity of lentil is low due to use of low quality seed, poor response to high inputs, using disease susceptible variety, lack of proper cultivation knowledge of rural farmers, unwilling to use modern technologies, delay in sowing, susceptibility to disease etc. Rate of production of lentil is decreased due to fungal, bacterial diseases. The most dangerous enemy of lentil (*Lens culinaris*) plants are fungal diseases (BARI, 2005).

Lentil is affected by wide range of fungal diseases (Agarwal,1979). It suffers from attack of a number seed and soil borne diseases such as vascular wilt, collar rot, root rot, stem rot, rust, powdery mildew and downy mildew, which are caused by *Fusarium oxysporum* f. sp. *lentis, Sclerotium rolfsii*, *Rhizoctonia solani*, *Uromycis fabae*, *Erysiphe polygoni* and *Peronospora lentis*, respectively (Singh and Tripathy, 1999).

Seventeen diseases were recorded on lentil of which foot and root rot caused by *Sclerotium rolfsii* is considered as most common and destructive disease of lentil in Bangladesh and also in almost all legume growing countries of the world (Ahmed *et al*.,1985). The soil borne pathogens *Fusarium oxysporum* and *Sclerotium rolfsii* commonly occur in the tropics and sub-tropics of the world causing foot and root rot of many crops (Aycock, 1966). This disease affects mainly the roots, leading to poor emergence of seedlings, stunted growth of plants and reduced yields. Symptoms include sunken lesions and brown or black discoloration on roots, shrinking root system and root decay. Foot rot is a very destructive disease of lentil causing tremendous crop loss. Bakr (1994) reported 84% loss in pulse due to *Sclerotium rolfsii*. In Bangladesh, about 44% lentil plants are infected by foot and root rot disease (Anonymous, 1986). Sometimes it can cause up to 100% mortality in case of foot and root rot and wilt of infected plants (Fakir, 1983). Due to various abiotic and biotic factors, especially the diseases that cause 30-40% yield loss in lentil (Begum, 2003). It causes seedling death at early stage resulting very poor plant stand which ultimately produces very low yield. Being soil borne pathogen, *S. rolfsii* is difficult to control. Wever (1931) and Garret (1956) reported that the fungus survived in the soil for years together by producing sclerotial bodies and causes the disease on various hosts. The fungi can attack the plant in any time during seedling stage to flowering but comparatively more destructive in seedling stage as the vascular system is not well developed.

Management practices are difficult in case of foot and root rot of lentil as, *Sclerotium rolfsii* is a soil borne pathogen. Even there is no effective resistant variety or fungicide for the successfully management of this disease in the field. Several chemicals, cultural practice and bio-gent used to control this disease. Various chemicals are used both in soil and seed treatments. Provax 200 was the most effective followed by Bavistin 50 WP, Neem leaf extract and Garlic extract with respect to disease reduction and increase of seed yield (Rahman *et al*., 2012). Seed treated with Provax 200 showed least foot and root rot incidence of lentil at Madaripur and Jessore in Bangladesh (Anonymous, 2010). These devastating disease can be controlled through various cultural practices like crop rotation (growing lentils only once in four years), use of certified, disease-free seed will help to minimize the disease etc. Bio-control agent like *Trichoderma harzianum* is reported to have great effect against soil borne pathogen (Singh *et al*., 1997; Reddy *et al*., 1998). Successful bio-control of *S. rolfsii* using *Trichoderma* spp. has been reported by many researchers (Elad *et al*., 1980; Sreennivasaprasad and Manibhushanrao, 1993; Dey *et al*., 2004). In general techniques which are based on the molecular techniques like marker assisted selection to deploy resistance has to be applied in the processes of creating resistant variety development.

Timely sowing is an important factor. Too early or too late sowing of lentil favors the pathogen that the maximum temperature, maximum relative humidity and rainfall played an important role in the development of diseases of (*Piper betel* L.) (Anonymous, 2006; Maiti and Sen, 1982). Maximum growth of *Sclerotium rolfsii* is occurred at 30°C (Hari *et al*., 1988).

The use of organic soil amendments is very promising to decrease the incidence of plant diseases caused by soil borne pathogens. It is also an ecofriendly approach for controlling soil borne pathogen by developing suppressive soil (Palti and Katan, 1997). Organic amendments, such as animal and green manure (the incorporation of crop residues into the soil), organic wastes, composts and peats, have been proposed to control diseases caused by soil borne pathogens (Baker and Cook, 1974; Hoitink and Fahy, 1986).

Despite of the many contributions in chemical control, organic soil amendments play a strong performance in combating certain destructive plant diseases as it has no environmental hazards. Most of the cultivators prefer to using chemical treatment which is very harmful to our environment. Knowing the management practices to reduce the severity of pathogen is very important for farmers as well as growers so that they can choose the proper management strategies for getting higher yield in lentil like crops.

Considering the above facts, the present research work was designed to achieve the following objectives:

- To detect and identify the causal organisms of foot and root rot disease of lentil
- To evaluate sowing time for management of foot and root rot disease of lentil; and
- To determine the efficacy of organic soil amendments for the management of foot and root rot disease of lentil.

CHAPTER 2

REVIEW OF LITERATURE

Foot and root rot disease of lentil is a common and mostly devastating disease which is caused by *Fusarium oxysporum* and *Sclerotium rolfsii*. This disease causes serious yield loss of the crop. Researchers all over the world have carried out intensive investigation on the foot & root rot of lentil. Literature in relation to management, disease incidence and yield loss assessment of foot & root rot disease of lentil is reviewed and presented in this chapter.

2.1 Foot and root rot disease of lentil

Bakr *et al.,* (2007) reported that, 44.40% yield loss was occurred due to foot and root rot of lentil.

According to Begum and Bhuiyan (2007), among various diseases of lentil, foot and root rot is the important one. It may cause 100% morality of seedlings in the field under monoculture and conducive weather conditions.

Abawi and Ludwig (2005) stated that, root diseases are generally most severe where susceptible crops are grown in short cropping rotation, because pathogen inoculum can build up quickly when environmental conditions are conducive for disease development.

Ahmed (1980) stated that, Foot and root rot (*Sclerotium rolfsii*) is considered as major problems for lentil cultivation in the country.

2.2 Symptoms of foot and root rot disease

Eliane (2017) stated that, root rot symptoms are a major threat because the damage starts below the ground, where the first symptoms are not discernible. When the symptoms become apparent on the above ground part of the plant, yield is already compromised and plant survival is jeopardized.

Weidong, *et al*., (2011) reported that patches are found in the field in case of foot and root rot disease of lentil. Top leaves in the plant may wilt and droop. They can also shrink and curl without defoliating early. Some other symptoms include yellowing, reduced root system with discoloration, poorly developed nodules, and damage at the taproot tip. Seeds may rot, pre-emergence damping off can occur, and the plant may die.

Begum (2003) stated that, foot and root rot disease may cause 100% seedling mortality in field.

Bakr (1986) reported that, foot and root rot is mainly a seedling disease attacking the crop usually up to 30 days of germination. The fungal stands along with mustard seed like sclerotia are generally observed associated with infected portion at soil level. He also explained that the tap roots are infected and normal growth is arrested which may give stunted appearance and finally causing wilting and dying of plants. It may also observe brown discoloration involving pith and xylem.

2.3 Causal organism of foot and root rot disease

Sclerotium rolfsii was proved as highly pathogenic on pulse crops (Yaqub and Shahzad, 2005).

Foot and root rot of plant is mainly caused by *Sclerotium rolfsii*. It can also be caused by *Fusarium oxysporum* (Ahmed and Bakr, 1988).

Maiti and Sen (1984) reported that, sclerotia had 91% survival rate after 222 days in natural soil at 50% water holding capacity.

Katti *et al*., (1983) found that maximum survival rate of fungus at 30-50% soil moisture and at temperature between 20-25°C.

Ahmed (1980) reported that, *Sclerotium rolfsii* is a facultative saprophyte and can survive generation to generation by formation of brown sclerotia.

Punja *et al.*, (1958a) reported that sclerotia of *Sclerotium rolfsii* is produced in huge number on or adjacent to infected plant parts and can survive in soil for 1-3 years. They are also capable to infecting and can be stable without food base of organic matter.

Punja *et al*., (1958b) reported that the mycelial growth rate of *Sclerotium rolfsii* was maximized under optimum temperature and moisture and range was 1-3cm per day.

Treggi (1956) found that, *Sclerotium rolfsii* grew vigorously at temperature between 30°C and 33°C.

2.4 Management of foot and root rot disease by cultural practices

Kumar *et al.,* (2018) conducted an experiment on effect of sowing dates and weather conditions on *Rhizoctonia* root rot disease incidence and green pod yield of french bean in India, where he found that, maximum seed germination (88.91%), lowest pre-emergence (11.02%) root rot was recorded when the French bean crop was sown on 19th September. But lower post emergence (14.59%) and maximum yield (65.7q/ha) were recorded when the crop was sown on 29th September. The crop sown on 19th October and 29th October recorded average maximum pre- and post-emergence root rot disease incidence to the extent of 21.84 percent and 23.25 percent, respectively.

Alam *et al.,* (2017) conducted an experiment in Bangladesh Agricultural Research Institute, Bangladesh. The research work was carried out with a view to evaluate lentil (*Lens culinaris*) varieties at different sowing dates from October 25 to December 6 against *Stemphylium botryosum* in Bangladesh during winter season of 2012-2013.Two lentil varieties viz., BARI Masur-1 and BARI Masur-7 were evaluated at seven different sowing dates viz., October 25, November 1, November 8, November 15, November 22, November 29 and December 6. The highest disease incidence (72.50%) was recorded from the plants grown from October 25 sowing which was statistically identical to that of November 1 (63.5%), November 15 (62.17%)

and November 22 (62.17%). However, disease incidence was drastically reduced at November 29 (42.17%) and December 6 (30.83%) sowings.

Ali *et al.*, (2016), conducted at the research field of Agronomy Division, BARI, Joydebpur, Gazipur and ARS, Burirhat, Rangpur, Bangladesh to evaluate crop growth, yield and seed quality of garden pea in response to temperature variation prevailed at different sowing dates viz. 10 November, 20 November, 30 November, 10 December, 20 December and 30 December. Results revealed that November 20-30 would be optimum time of sowing of garden pea for maximum yield and quality seed.

Ahmed and Bakr (1988) reported that, foot and root rot disease is reduced if the previous cultivated crop residue was removed from the field.

Fakir (1983) evaluated the effect of sowing time on collar rot of lentil and chickpea. The experiment was carried out at the BAU farm during 1979/1980. Six different sowing times were evaluated. The maximum disease was recorded in chickpea in 26 October sowing and minimum disease was recorded on 25 December.

2.5 Management of foot and root rot disease by using organic soil amendments

Faruk (2020) conducted an experiment in the field of Plant Pathology Division, Bangladesh Agricultural Research Institute, Gazipur during 2013-14, 2014-15 and 2015-16 cropping years. The formulated *Trichoderma harzianum* (Tricho-compost for soil amendment and spore suspension for seed treatment) and organic soil amendment poultry refuse either singly or in combination with chemical fungicide Provax 200 WP were tested against soil-borne pathogens, *Sclerotium rolfsii* and *Fusarium oxysporum* f. sp. *ciceri* of chickpea causing foot and root rot and wilt diseases. From this study it was revealed that soil amendment with Tricho-compost or integration poultry refuse with seed treatment by Provax 200 WP performed as the best treatments in reducing seedling disease and increasing plant growth and yield of chickpea which were significantly differed from the other treatments including control. Soil amendment with poultry manure alone showed best performance against the disease and seed treatments with chemical fungicide Provax 200 WP and *Trichoderma* spores suspension which effect at per. All of the treatments reduced seedling mortality and increased plant growth and yield of chickpea.

Faruk (2018) conducted an experiment about the efficacy of formulated *Trichoderma harzianum*-based Tricho-compost, seed treatment with Tricho-inocula, and chemical fungicide Provax 200 WP against foot and root rot diseases of wheat caused by *Sclerotium rolfsii* which was tested in the pot house and in the research field of Plant Pathology Division, Bangladesh Agricultural Research Institute, Gazipur, Bangladesh. Tricho-compost was prepared with a mixed substrate of cow dung, rice bran, and poultry refuse colonized by *T. harzianum*. Seedling mortality of wheat was significantly reduced by the Tricho-compost, Tricho-inocula, and Provax 200 WP both in the pot house as well as in the field experiments. The yield of wheat was sharply increased over the control due to the *T. harzianum* formulations and Provax 200 WP. Among the treatments, soil application of Tricho-compost was more efficient in reducing seedling mortality and accelerating plant growth with an increased yield of wheat with *S. rolfsii*-inoculated pot cultures and field experiments.

Khalequzzaman (2016) conducted an experiment at the sick plot, Pulses Research Centre, Ishurdi, Pabna, Bangladesh during 2011-12 to find out the effect of chemical, botanicals, biocontrol agents & healthy seeds against foot & root rot of lentil. The lowest foot & root rot (21.67%) was obtained from seed treatment with Provax 200 (2.5 g/kg seed) followed by seed treatment with *Trichoderma harzianum* compost (1:5) and apparently healthy seeds, while the highest incidence (41.5%) was obtained from untreated control. The highest number of pod/plant (45.26), number of seeds/plant (87.80), weight of 100 seeds/ plant (2.44 g) and yield (1845 kg/ha) were recorded in case of seed treatment with Provax 200 (2.5 g/kg seed) which were followed by seed treatment with *Trichoderma harzianum* compost (1:5) and apparently healthy seeds.

Mollah (2012) conducted an experiment in the experimental field of Plant Pathology Division, Regional Agricultural Research Station, Bangladesh Agricultural Research Institute, Rahamatpur, Barisal to determine the resistance source against foot and root rot disease of lentil and to develop integrated management package in controlling the disease. 25 lentil lines with two check varieties were evaluated in the experiment. Among 25 lines only two lines namely BD-3916 (38.17%) and BD-3920 (33.85%) showed moderately resistant performance. He also reported that among the management options, straw burning + poultry refuse + Provax 200 seed treatment showed the best performance in respect of yield and yield contributing characteristics followed by poultry refuse + Provax 200 in controlling foot and root rot disease of lentil.

Ahamed *et al*., (2012) conducted field trials in a farmer's field in Talagang (Chakwal) Punjab, Pakistan in 2009 to evaluate the effect of manuring on root rot disease caused by *Fusarium solani*. The experiment was comprised seven treatments viz. (i) Control (no amendment and no inoculation); (ii) *F. solani* (FS)-inoculated control; (iii) poultry manure + FS; (iv) farmyard manure + FS; (v) cattle manure + FS; (vi) *Brassica campestris* straw + FS; (vii) *Cicer ariantum* straw + FS. In the *Fusarium* inoculated control, disease incidence and plant mortality was 85% and 22.2%, respectively whereas, disease incidence and plant mortality were both 0% in non inoculated control. All the manuring treatments reduced the disease to variable extent and influenced agronomic characters of groundnut. Poultry manure was the most effective in disease management followed by cattle manure.

CHAPTER 3

MATERIALS AND METHODS

The methods followed and materials used in the present research work were stated in this chapter. The experimental site, weather, land preparation, experimental design, layout, inoculation and data collection were included in the chapter.

3.1 Experimental site

The field experiment was conducted in field of Central Farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh. The location for the experimentation site was 23°75N latitude and 90°35E longitude with an elevation of 8.3 meter from sea level. The pot experiment was conducted in the Net House of the Department of Plant Pathology, Sher-e-Bangla Agricultural University, Dhaka-1207, Bangladesh.

3.2 Experimental period

The pot and field experiments were conducted in Rabi (winter) season. Pot experiment was conducted from October 2019 to March 2020. Field experiment was conducted from December 2019 to March 2020. Laboratory research was done from July 2019 to May 2020.

3.3 Weather

The experiment was conducted in winter season (*Rabi*) of Bangladesh. The monthly mean for daily maximum, minimum and average temperature, relative humidity (RH%) and monthly total rainfall received at the experimental field during the period of the experiment had been collected from Bangladesh Meteorological Department, Agargaon, Dhaka (appendix II).

3.4 Planting materials/Test materials

The lentil variety BARI Masur-1 (Utfala) released from Bangladesh Agricultural Research Institute, Joydebpur, Gazipur was used for the experiment. Seeds were collected from Pulse Wing, Bangladesh Agricultural Research Institute, Joydebpur, Gazipur, Bangladesh. This variety is susceptible to foot and root rot disease of lentil.

3.5 Experiments

Both pot and field experiments were conducted.

a. Pot experiments

Pot experiments were conducted in net house under control condition. Two experiments were conducted in net house viz.

Experiment 1: *In vitro* evaluation of sowing times on foot and root rot disease of lentil

Experiment 2: *In vitro* evaluation of organic soil amendments on foot and root rot disease of lentil

b. Field experiment

Experiment 3: *In vivo* evaluation of organic soil amendments against foot and root rot disease of lentil

3.6 Pot experiments

3.6.1 Soil collection

Good tilth soil was used for the experiment and the soil was collected from the experimental field of Sher-e-Bangla Agricultural University, Dhaka. The soil collection was done on 10 October, 2019.

3.6.2 Soil solarization

Solarization was done to s the soil. After removing the debris from the soil, soil was kept under the direct sunlight for 10 days.

3.6.3 Experimental layout and design

The pot experiments were carried out in Completely Randomized Design (CRD) with three replications.

Plate 1. Experimental layout of pot experiment

3.6.4 Preparation of pots

Solarized soils were put in the plastic pot of 12inches height and 10inches width (Plate 5). In the bottom of the pot 2 cm hole was made to minimize the losses of excess water. Each pot was filled with 2/3rd of solarized soil and the pots were arranged according to experimental design. Pot preparation was done on 14 October, 2019.

Plate 2. Preparation of pots

3.6.5 Treatments

For Experiment 1, seeds were sown in different dates to evaluate the sowing times of lentil to manage foot and root rot disease.

The following six treatments were used in the experiment:

T_1 = Seed sowing at 25 October

T_2 = Seed sowing at 5 November

T_3 = Seed sowing at 15 November

T_4 = Seed sowing at 25 November

T_5 = Seed sowing at 5 December

T_6 = Seed sowing at 15 December

For Experiment 2, the following ten treatments were used:

T_0 = Control

T_1 = Poultry refuse @ 500gm/pot

T_2 = Mustard Oil cake @ 100gm/pot

T_3 = Neem oil cake @ 50gm/pot

T_4 = Vermicompost @ 100gm/pot

T_5 = Cowdung @ 500gm/pot

T_6 = Trichocompost @ 100gm/pot

T_7 = Biochar @ 100gm/pot

T_8 = Sawdust @ 150gm/pot

T_9 = Ash @ 150gm/pot

3.6.6 Collection of treatments

Organic soil amendments poultry refuge, cowdung and ash were collected from Sher e Bangla Agricultural University campus. Mustard oil cake, neem oil cake and vermicompost were collected from local nursery. Saw dust was collected from saw mill. Trichocompost was collected from Ispahani Agro Ltd. Biochar was collected from Cristian Commission for Development in Bangladesh (CCDB), Manikganj.

3.6.7 Application of treatments

For Experiment 1, sowing times were used as treatments and for Experiment 2 organic soil amendments were applied to the pot soil 20 days before seed sowing. After 20 days, soil amendments were decomposed and mixed with soil properly and soil was prepared for cultivation.

3.6.8 Seed sowing

In pot experiments, seeds were sown in plastic planting pot (12″). Fifty seeds were sown in each pot. The seeds were sown after 10 days of soil solarization. Seed sowing was done on various dates in case of Experiment 1 and for Experiment 2 seeds were sown on 17 December, 2019.

3.6.9 Intercultural operation

In each pot intercultural operations like irrigation, weeding etc. were done properly.

Here, very first irrigation was done immediately after seed sowing. After, germination irrigation was done several times. Weeding was done properly.

3.6.10 Inoculum preparation

In pot experiments, *Sclerotium rolfsii* the causal organism of foot and root rot disease of lentil was isolated and made pure culture for the infected plant of lentil. Here inoculum was prepared through mass culture. The isolates of *S. rolfsii* was multiplied on barley grains (Gupta and Kolte,1982). In this procedure barley grains were soaked in water containing 2% sucrose solution for overnight, removed the excess solution. These grains were placed in 500ml conical flask @ 20g and autoclaved at 121.6°C temperature, under 15 psi pressure for 15minutes. The conical flasks were allowed to cool at room temperature and were inoculated with 5mm discs culture of *Sclerotium rolfsii* grown on PDA. Seven discs per flask was added and flasks were placed at room temperature for three months.

Plate 3. Mass culture of *Sclerotium rolfsii* on barley grain

3.6.11 Artificial inoculation

At seedling stage (15 DAS), isolates of causal pathogen (*sclerotium rolfsii*) were inoculated in the collar region of plants and adjacent soil. The plants were prepared for inoculation by removing surrounding soil of plant with 2cm depth. A tea spoon of inoculum was added to the soil and covered with removed soil for infection. Irrigation was done after inoculation to keep moist conditions.

3.6.12 Tagging of plants

Randomly 3 plants were selected from each pot tagged for data collection. Mean values were determined to get rating score of each treatment.

3.6.13 Data collection

The data were collected on the following parameters in pot experiments:

1. Germination (%)
2. Plant Height (cm)
3. No. of branch
4. No. of pod
5. Length of pod (cm)
6. No. of seed/pod
7. Shoot length (cm)
8. Root length (cm)
9. Vigor Index
10. Seed yield/pot (gm)
11. Seed yield/ plot (gm)
12. Seed yield/ plant (gm)
13. Seed yield/ m^2 (gm)
14. Disease incidence (%)

3.6.14 Procedure of data collection

a. Disease incidence

The plants under observation were keenly observed to investigate the typical symptoms and sign of the disease. The plant showing typical symptoms by the pathogenic infection were confirmed as diseased plant. In pot experiment, total number of diseased plant recorded at 10 DAI, 20 DAI, 30 DAI, 60 DAI. Disease incidence was calculated by the number of proportion of the plant units diseased in relation to the total number of unit examined

(Agrios, 2005). Disease incidence was calculated by using the following formula:

$$\text{Disease Incidence (\%)} = \frac{\text{Number of infected plants}}{\text{Number of inspected plants}} \times 100$$

Plate 4. Pot view of the experiment at the time of counting disease incidence

b. Germination (%)

The germinated seeds were counted. Germination percentage was calculated by using the following formula (ISTA, 2010):

$$\text{Germination (\%)} = \frac{\text{Number of germinated seeds}}{\text{Total number of seeds}} \times 100$$

c. Vigor Index

30 days after sowing (DAS), 3 plants of each pot was randomly selected and root length and shoot length was measured by using centimeter scale. The average number was used. Then vigor index was calculated as suggested by Abdul-Baki and Anderson (1973):

Vigor Index = (RL+SL) × GP

Where, RL is root length (cm), SL is shoot length (cm) and GP is germination percentage.

d. Plant height

Plant height was measured by using centimeter scale at 30 DAS, 60 DAS, 105 DAS in pot. Here 10 plants were randomly selected for calculating final plant height.

e. No. of branch/plant

Unbiased 10 plants were taken from pots and plots and counted the no. of branch of each plant at 30, 60 and 105 days after sowing (DAS). The average number was used as final branch no. per plant.

f. Harvesting of crops

Plants were harvested when it showed 80% to 90% maturity based on straw color, pod filling, pod color, water content per plant etc. At maturity total plants per plot and pot were harvested and tagged based on plot identity. Total 18 pots of experiment-1 and 30 pots of experiment-2 were separately harvested for data collection.

g. No. of pods/plant

After harvesting, plants were collected from different plots to count the number of pods/ plant through visual counting.

h. Yield (g per pot)

In pot experiments, yield was counted by weighing total harvested grains per plot and pot. The yield was measured in gram for final data calculation.

3.6.15 Statistical analysis

The collected data was statistically analyzed by Statistics 10 computer package program. Analysis of variance (ANOVA) was used to find out the variation of result from experimental treatments. Treatment means were compared by least significant difference test (LSD).

3.7 Field experiment

3.7.1 Soil type

The experimental site was in the sub-tropical zone. The soil of experimental area belongs to the agro-ecological regions of “Madhupur Tract”. The top soil of the region is clay loam in texture and olive gray with common fine to medium distinct black yellow brown mottles. The pH of the soil was 4.47 to 5.55 and organic carbon contents is 0.82 (Appendix I).

3.7.2 Soil preparation

Crop residue, large clods, rocks were removed from the soil. Ploughing was done for two times and laddering was done for one time. Finally leveled the surface of the soil in the field.

3.7.3 Experimental layout and design

The field experiment was conducted in Randomized Complete Block Design (RCBD) with three replications. The total land area was divided into 3 blocks and each containing ten (10) plots of 2m × 1.5m size, providing 30 plots. Here seeds were sown in five rows per unit plot and the row to row distance was kept 35 cm. 20g seeds were sown continuously in lines in the experimental plots. The seeds were planted at about 4 cm depth in the soil.

Plate 5. Experimental layout of field experiment

3.7.4 Application of manures and fertilizers

Manures and fertilizers were mixed with the soil thoroughly by following the recommended dose (*Krishi Projukti Hatboi*, 2015).

Table 1. Rate of fertilizers and manure applied in the field and pot

Fertilizers and manure	Recommended dose (kg/ha)
Urea	40-45
TSP	80-90
MoP	30-40
ZnSo4	5
Boric acid	7.5
Cowdung	5000

3.7.5 Treatments

In the field experiment, the following ten treatments were used same as pot experiment-2 with different quantity

T_0 = Control

T_1 = Poultry refuse @ 1.5 kg/plot

T_2 = Mustard oil cake @ 0.3 kg/plot

T_3 = Neem oil cake @ 0.15 kg/plot

T_4 = Vermicompost @ 0.3 kg/plot

T_5 = Cowdung @ 1.5 kg/plot

T_6 = Trichocompost @ 0.3 kg/plot

T_7 = Biochar @ 0.3 kg/plot

T_8 = Sawdust @ 0.45 kg/plot

T_9 = Ash @ 0.45 kg/plot

3.7.6 Collection of treatments

Treatments were collected same as 3.6.6

3.7.7 Application of treatments

Organic soil amendments were applied to the pot soil 20 days before of seed sowing same as 3.6.7. After 20 days, soil amendments were decomposed and mixed with soil properly and soil was prepared for cultivation.

Vermicompost

Sawdust

Trichocompost

Mustard oil cake

Ash

Poultry refuse

Plate 6. Treatments for pot and field experiment

3.7.8 Seed sowing

20g seeds were sown continuously in lines in each experimental plots ($3m^2$). The seeds were planted at about 4 cm depth in the soil. The seeds were sown on 17 December, 2019.

Plate 7. Seed sowing in the field

3.7.9 Intercultural operation

In each plot and pot intercultural operations like irrigation, weeding, thinning etc. were done properly.

a. Irrigation

Here, very first irrigation was done immediately after seed sowing. After, germination irrigation was done several times at 7 days interval through sprinkler. Proper drainage system was maintained both in field and pot.

b. Thinning

Thinning was done after 15 days of sowing and at this time proper distance was maintained.

c. Weeding

After 20 days of sowing first weeding was done and another weeding was done 35 days of sowing.

3.7.10 Tagging of plants

Randomly 10 plants were selected from each plot tagged for data collection. Mean values were determined to get rating score of each treatment.

3.7.11 Data Collection

Same data was collected as pot experiment (3.6.13) except germination (%) and vigor index.

3.7.12 Procedure of data collection

Same procedure was followed as pot experiment (3.6.14).

Disease incidence was calculated by selecting 30 plants randomly and disease was recorded at 10, 20, 30 and 60 days after sowing (DAS). Disease incidence was calculated by the number of proportion of the plant units diseased in relation to the total number of unit examined (Agrios, 2005). Disease incidence was calculated by using the following formula:

$$\text{Disease Incidence (\%)} = \frac{\text{Number of infected plants}}{\text{Number of inspected plants}} \times 100$$

Plate 8. Field view of the experiment at the time of counting disease incidence

3.7.13 Statistical analysis

The collected data was statistically analyzed by Statistics 10 computer package program. Analysis of variance (ANOVA) was used to find out the variation of result from experimental treatments. Treatment means were compared by least significant difference test (LSD) same as pot experiment (3.6.15).

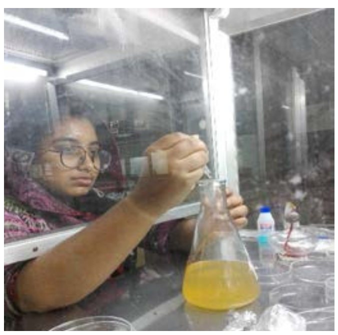
3.8 Isolation and identification of causal organism

3.8.1 Sample collection

Diseased plants showing typical symptoms were collected from research field. Then the samples were carried to the central laboratory of Sher-e-Bangla Agricultural University, Dhaka to examine the visual symptoms and isolation of causal organism (s).

3.8.2 Isolation of causal organism (s) by Tissue Plating Method

Infected plant showing typical disease symptoms were cut into small pieces, washed thoroughly in running water. Some samples were surface sterilized with 70% Ethanol for 30 seconds. Then 1% sodium hypochlorite (NaOCl) for 30 seconds and washed three times in sterile distilled water each for 1min. Some samples were sterilized with 37.5% chlorox for 30 seconds washed three times in sterile distilled water each for 1 min. The surface sterilized roots were placed on Blotter paper and Potato Dextrose Agar (PDA) medium and incubated at 25 ± 2^0C for 6-7 days. Mycelial growth from each developing colony were re cultured on PDA to get pure culture. The causal organism was isolated, identified and recorded. The pathogen was identified from all infected samples. (Agrios, 2005)



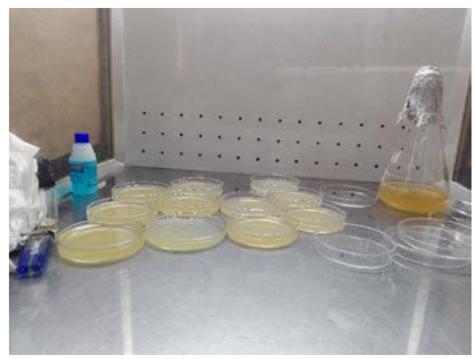


Plate 9. Preparation of PDA (Potato Dextrose Agar) Medium

3.8.3 Identification of causal organism

Identification of causal organism was done by the following methods:

3.8.3.1 Identification by Symptomological Study (Visual Assessment)

In this study, the development of symptoms was closely observed to confirm disease. The diseased plants were closely and carefully examined by magnifying glass to observe the disease symptoms development, sign of the pathogen, source of infection, mode of dissemination and favorable environment. Idea about causal organism was taken from those information (Bakr, 1986; Punja *et al*., 1985; Singh, 1982; Ahmed,1980).

3.8.3.2 Identification by Growing on Blotter Paper (Incubation Method)

The diseased roots were cut into pieces and surface sterilized with 70% Ethanol for 30 seconds. Then the sodium hypochlorite (NaOCl) for 30 seconds and washed three times in sterile distilled water each for 1 min. Then the cut pieces were incubated at room temperature for seven days. When the fungus grew well mycelium and sclerotia were observed by visual observation. The identification of the causal organism was done with the help of relevant literature (Bakr, 1986; Punja *et al*., 1985; Singh, 1982; Ahmed,1980).

Plate 10. Growing fungi in moist blotting paper

3.8.3.3 Identification by Growing on Culture Medium (Tissue Plating Method)

Infected roots were cut into small pieces and some samples were surface sterilized with 70% Ethanol for 30 seconds. Then 1% sodium hypochlorite (NaOCl) for 30 seconds and washed three times in sterile distilled water each for 1min. Some samples were sterilized with 37.5% chlorox for 30 seconds washed three times in sterile distilled water each for 1 min. The surface sterilized roots were placed on Potato Dextrose Agar (PDA) medium in petridish (Mehrota and Aggarwal, 2003). The plates containing root pieces were incubated at room temperature for three days. When the fungus grew well, the organism was re-cultured by mycelium or sclerotia to obtain pure culture. The identification of the causal organism was done with the help of relevant literature (Bakr, 1986; Punja *et al.*, 1985; Singh, 1982; Ahmed,1980).

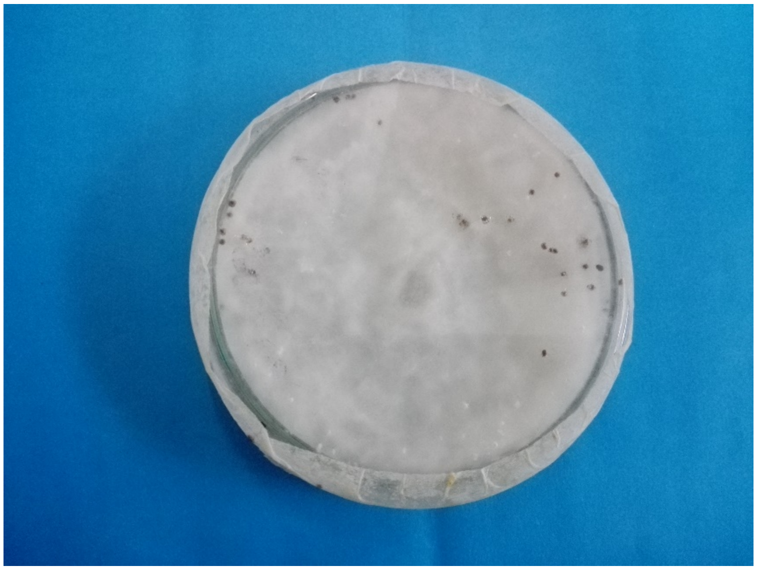


Plate 11. Growing fungi on Potato Dextrose Agar (PDA) medium

CHAPTER 4

RESULT AND DISCUSSION

Among the different disease of lentil, foot and root rot caused by *sclerotium rolfsii* is one of the major and severe soil borne disease responsible for high yield losses. The present study on effect of sowing times and organic soil amendments were carried out during rabi season, 2019-2020. The experimental results are presented hereunder.

4.1 Symptoms of foot and root rot disease of lentil

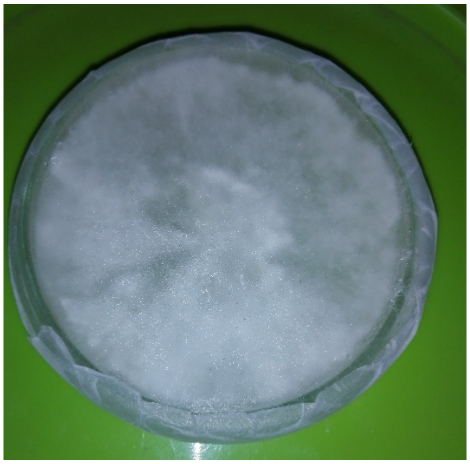
Symptoms of foot and root rot was found from seedling stage to pre flowering stage of lentil plant. The mycelial growth of the fungi was found at the collar zone to root zone of lentil plant. The fungal mycelium along with mustard seed like sclerotia were observed associated with infected portion at soil level. The normal growth was arrested which was given a stunted appearance of plant. Plant showed brown discoloration and finally caused wilting and dying of infected plants. Bakr (1986) also found that, foot and root rot is mainly occurred during the seedling stage. The fungal stands along with mustard seed like sclerotia are generally observed associated with infected portion at soil level. He also explained that the tap roots are infected and normal growth is arrested which may give stunted appearance and finally causing wilting and dying of plants.

Plate 12. Diseased plants

4.2 Identification of causal organism

After well growth of causal organism on Potato Dextrose Agar (PDA) medium, the organism was re-cultured by mycelium or sclerotia to obtain pure culture. It was observed that, mycelial growth of causal organism was formed from second days after incubation (DAI) and it took a week to fill the whole petri dish with mycelium of *Sclerotium rolfsii*. Mustard seed like sclerotia was formed in the pure culture of causal organism within the two weeks of incubation. Ahmed (1980) found that *Sclerotium rolfsii* is a facultative saprophyte and can survive generation to generation by formation of brown sclerotia. Punja *et al*., (1958) found that the mycelial growth rate of *Sclerotium rolfsii* was maximized under optimum temperature.

2 DAI **3 DAI**



5 DAI **7 DAI**

14 DAI

Plate 13. Growth of *Sclerotium rolfsii* at different days after incubation (DAI)

Under compound microscope, mycelial growth was found but no perpendicular formation was observed in the slide.

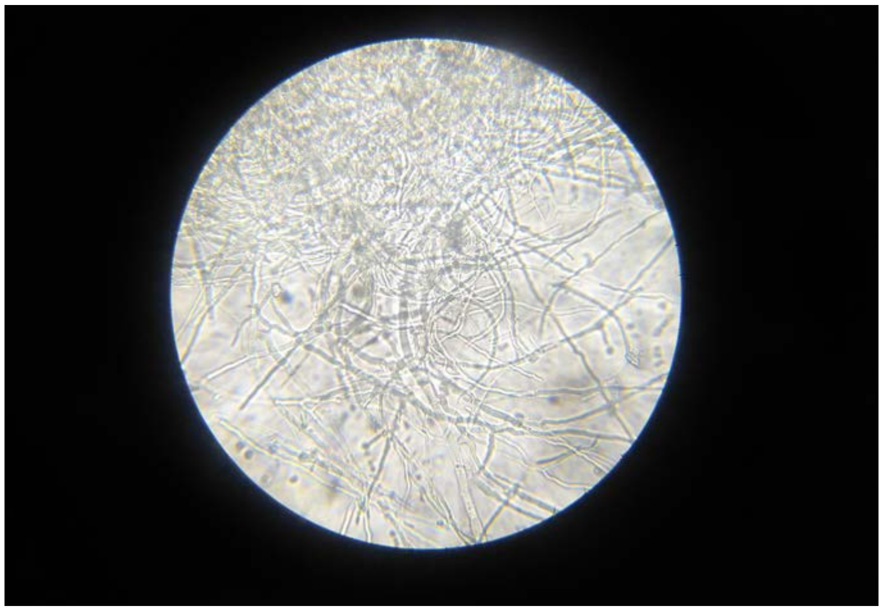


Plate 14. Microscopic (compound) view of *Sclerotium rolfsii*

Pot Experiments

4.3 Experiment 1: *In vitro* evaluation of sowing times against foot and root rot disease of lentil

4.3.1 Effect of different sowing times on disease incidence (%) of foot and root rot disease of lentil at different days after inoculation in pot

Disease incidence at different days after inoculation (DAI) during growth period had been recorded on the basis of visible typical symptoms. Six different sowing times were compared with each other for disease incidence recorded at 10 DAI, 20 DAI, 30 DAI and 60 DAI (Table 2).

At 10 DAI the lowest (7.60%) disease incidence was recorded from treatment T_6 (15 December), whereas treatment T_1 (25 October) showed the highest disease incidence (41.44%), followed by T_2 (29.36%), T_3 (21.36%), T_4 (18.36%) and T_5 (14.53%).

At 20 DAI similiar results were found where the lowest disease incidence was recorded in T_6 (9.91%) and the highest disease incidence (45.50%) was recorded in T_1.

At 30 DAI, the disease incidence was counted where the lowest incidence of disease was also recorded from T_6 (12.69%) and the highest disease incidence was recorded in T_1 (48.56%)

At 60 DAI, the final disease incidence was counted where the lowest incidence of disease was also recorded from T_6 (15.22%) and the highest disease incidence was recorded in T_1 (49.67%).

Table 2: Effect of different sowing times on incidence of foot and root rot disease of lentil at different days after inoculation (DAI)

Treatment	Disease Incidence (%)			
	10 DAI	20 DAI	30DAI	60 DAI
T_1 (25 Oct.)	**41.44 a**	**45.50 a**	**48.56 a**	**49.67 a**
T_2 (05 Nov.)	29.36 b	30.27 b	36.44 b	40.21 b
T_3 (15 Nov.)	21.36 c	24.45 c	30.85 c	32.97 c
T_4 (25 Nov.)	18.36 cd	22.04 c	23.55 d	25.73 d
T_5 (05 Dec.)	14.53 d	15.38 d	22.18 d	25.62 d
T_6 (15 Dec.)	**7.60 e**	**9.91 e**	**12.69 e**	**15.22 e**
CV (%)	11.46	7.59	8.09	7.57
LSD (0.05)	4.5	3.32	4.18	4.24

Means followed by the same letters in a column did not differ at 5% level of significance by LSD.

4.3.2 Effect of different sowing time on different growth parameters of lentil in pot experiment

Effects of different sowing times had been compared on the basis of different growth parameters viz. germination (%), plant height (cm), No. of branch, root length (cm), shoot length (cm) and vigor index.

a. Seed germination (%)

The highest seed germination was recorded on T_6 (75.55%), followed by T_5 (72.77%), T_4 (65.00 %). However, the lowest seed germination was recorded on T_1 (52%), preceded by T_2 (54.08%) and T_3 (60.54%) (Table 3).

b. Plant height (cm)

Plant height at different days after sowing during growth period had been recorded. Six different sowing times were compared with each other for plant height was recorded at 30, 60 and 105 days after sowing (DAS) (Table 3).

At 30 DAS the highest (17.66 cm) plant height was recorded from treatment T_6 (15 December), whereas treatment T_1 (25 October) showed the lowest plant height (12.86 cm), preceded by treatment T_2 (14.93 cm), T_3 (15.05 cm), T_4 (15.05 cm) and T_5 (15.49 cm). At 60 DAS the same of results were found where the highest plant height was recorded in T_6 (17.76 cm) and the lowest plant height was recorded in T_1 (16.22 cm). At 105 DAS, the highest plant height was also recorded from T_6 (21.92 cm) and the lowest plant height was recorded in T_1 (16.76 cm).

c. No. of branch/plant

At 30 DAS the highest (5.89) no. of branch/plant was recorded from treatment T_6 (15 December), whereas treatment T_1 (25 October) showed the lowest branch no. (5.11), preceded by treatment T_2 (5.53) and T_3 (5.66). At 60 DAS the highest branch no. was recorded in T_6 (6.55) and the lowest plant height was recorded in T_2 (5.66). At 105 DAS, the highest plant height was recorded from T_6 (7.33) and the lowest plant height was recorded in T_1 (6.66).

d. Root length (cm)

The highest root length was recorded on T_6 (6.90 cm), followed by T_5 (6.56 cm), T_4 (6.23 cm). However, the lowest root length was recorded on T_1 (3.50 cm), preceded by T_2 (3.66 cm) and T_3 (4.43 cm) (Table 3).

e. Shoot length (cm)

The highest shoot length was recorded on T_6 (17.58 cm), followed by T_5 (15.49 cm), T_4 (15.05 cm). However, the lowest shoot length was recorded on T_1 (12.86 cm), preceded by T_2 (14.93 cm) and T_3 (15.05 cm) (Table 3).

f. Vigor index

The highest vigor index was recorded on T_6 (1416.9), followed by T_5 (1335.5), T_4 (1197.8). However, the lowest vigor index was recorded on T_1 (1008), preceded by T_2 (1145.7) and T_3 (1182.1) (Table 3).

Table 3: Effect of different sowing times on growth parameters of lentil

Treatments	Germination (%)	Plant height (cm)			No. of branch/plant			Root length (cm)	Shoot length (cm)	Vigor Index
		30 DAS	60 DAS	105 DAS	30 DAS	60 DAS	105 DAS			
T_1 (25 Oct.)	**52.00 c**	**12.86 d**	**16.22 c**	**16.76 d**	**5.11 b**	5.89 ab	**6.66 a**	**3.5 d**	**12.86 c**	**1008.0 c**
T_2 (5 Nov.)	54.08 c	14.93 c	16.60bc	18.78 c	5.53 ab	**5.66 b**	6.99 a	3.66 d	14.93 b	1145.7 b
T_3 (15 Nov.)	60.54 b	15.05bc	16.65bc	19.72 c	5.66 ab	6.1 ab	6.87 a	4.43 c	15.05 b	1182.1 b
T_4 (25 Nov.)	65.00 b	15.05bc	16.88 b	20.83 b	5.66 ab	6.11 ab	6.87 a	6.23 b	15.05 b	1197.8 b
T_5 (5 Dec.)	72.77 a	15.49 b	17.58 a	21.10ab	5.66 ab	6.44 a	7.00 a	6.56 ab	15.49 b	1335.5 a
T_6 (15 Dec.)	**75.55 a**	**17.66 a**	**17.76 a**	**21.92 a**	**5.89 a**	**6.55 a**	**7.33 a**	**6.90 a**	**17.58 a**	**1416.9 a**
CV (%)	4.13	1.94	2.12	2.71	7.35	6.51	6.58	2.22	4.31	4.80
LSD (0.05)	4.64	0.52	0.63	0.95	0.73	0.71	0.81	0.40	0.59	103.79

Means followed by the same letters in a column did not differ at 5% level of significance by LSD.

4.3.3 Effect of different sowing times on yield and yield contributing characters of lentil

Effect of different sowing times had been compared on the basis of yield and yield contributing characters of lentil viz. no. of pods per plant, yield/ plant (gm) and yield/pot (gm).

Table 4: Effect of different sowing times on yield and yield contributing characters of lentil

Treatments	No. of pods/plant	Yield/plant (g)	Yield/pot (g)
T_1 (25 Oct.)	**5.55 d**	**0.22 d**	**11.43 e**
T_2 (5 Nov.)	10.44 c	0.30 c	13.03 d
T_3 (15 Nov.)	14.33 b	0.50 b	16.80 c
T_4 (25 Nov.)	14.33 b	0.50 b	16.96 bc
T_5 (5 Dec.)	14.33 b	0.51 b	17.80 ab
T_6 (15 Dec.)	**16.44 a**	**0.56 a**	**18.63 a**
CV (%)	4.99	5.00	3.30
LSD (0.05)	1.11	0.04	0.92

Means followed by the same letters in a column did not differ at 5% level of significance by LSD.

a. No. of pods/plant

The highest pods no. per plant (16.44) was recorded on T_6 (15 December), followed by T_5 (14.33). However, the lowest pods no. per plant (5.55) was recorded on T_1 (25 October), preceded by T_2 (10.44) and T_3 (14.33) (Table 4).

b. Yield/plant (g)

The highest yield/plant was recorded on T_6 (0.56 g), followed by T_5 (0.51 gm), T_3 (0.50 g) and T_4 (0.50 g), T_2 (0.30 g). The lowest yield/plant was recorded on T_1 (0.22 g) (Table 4).

c. Yield/pot (g)

The highest yield/pot was recorded on T_6 (18.63g), followed by T_5 (17.80 g), T_4 (16.96 g). However, the lowest yield was recorded on T_1 (11.43 g), preceded by T_2 (13.03 g) and T_3 (16.80 g). (Table 4). Here, T_5 (5 December) showed statistically similar result with T_6 (15 December).

The efficacy of sowing date on *Rhizoctonia* root rot disease incidence and green pod yield of french bean was reported earlier by Kumar *et al.* (2018). Where, maximum seed germination (88.91%), lowest pre-emergence (11.02%) root rot was recorded when the French bean crop was sown on 19th September. But lower post emergence (14.59%) and maximum yield (65.7q/ha) were recorded when the crop was sown on 29th September. According to Alam *et al.* (2017), the highest disease incidence (72.50%) was recorded from the plants grown from October 25 sowing but disease incidence was drastically reduced at November 29 (42.17%) and December 6 (30.83%) sowings. Maximum yield and quality seed in garden pea were found when seeds were sown on November 20-30 reported by Ali *et al.*, (2016). The maximum disease was recorded in chickpea in 26 October sowing and minimum disease was recorded on 25 December (Fakir, 1983).

4.4 Experiment 2: *In vitro* evaluation of organic soil amendments against foot and root rot disease of lentil

4.4.1 Effect of different organic soil amendments on disease incidence (%) of foot and root rot disease of lentil at different days after inoculation in pot

Disease incidence at different days after inoculation during growth period had been recorded on the basis of visible typical symptoms. Nine different treatments with control were compared with each other for disease incidence recorded at 10, 20, 30, 60 days after inoculation (DAI) (Table 5).

At 10 DAI the lowest (6.71%) disease incidence was recorded from treatment T_6 (Trichocompost), whereas treatment T_0 (Control) showed the highest disease incidence (44.26%), followed by treatment T_9 (28.08%), T_1 (27.02%), T_3 (25.22%), T_2 (24.28%), T_8 (20.98%), T_4 (7.31%), T_5 (7.09%) and T_7 (6.99%).

At 20 DAI the same of results were found where the lowest disease incidence was recorded in T_6 (7.42%) and the highest disease incidence was recorded in T_0 (52.59%).

At 30 DAI, the disease incidence was counted where the lowest incidence of disease was also recorded from T_6 (7.69%) and the highest disease incidence was recorded in T_0 (53.57%).

Table 5: Effect of different organic soil amendments on incidence of foot and root rot disease of lentil at different days after inoculation (DAI) in pot

Treatments	Disease Incidence (%)			
	10 DAI	20 DAI	30DAI	60 DAI
T_0 (Control)	**44.26 a**	**52.59 a**	**53.57 a**	**57.65 a**
T_1 (Poultry refuse)	27.02 b	27.02 b	27.02 b	28.58 bc
T_2 (Mustard oil cake)	24.28 c	26.22 b	26.22 b	26.22 c
T_3 (Neem oil cake)	25.22 bc	26. 54 b	27.47 b	28.12 c
T_4 (Vermicompost)	7.31 e	8.15 d	9.73 d	12.19 e
T_5 (Cowdung)	7.09 e	7.85 d	8.99 d	10.13 ef
T_6 (Trichocompost)	**6.71 e**	**7.42 d**	**7.69 d**	**8.96 f**
T_7 (Biochar)	6.99 e	7.72 d	8.86 d	9.29 ef
T_8 (Sawdust)	20.98 d	21.93 c	23.03 c	23.03 d
T_9 (Ash)	28.08 b	28.08 b	29.11 b	31.65 b
CV (%)	8.90	7.27	7.69	7.66
LSD (0.05)	3.00	2.64	2.90	3.07

Means followed by the same letters in a column did not differ at 5% level of significance by LSD.

At 60 DAI, the final disease incidence was counted where the lowest incidence of disease was also recorded from T_6 (8.96%) where, T_5 (Cowdung) and T_7 (Biochar) showed statistically similar results with T_6 (Trichocompost) and the highest disease incidence was recorded in T_0 (57.65%).

4.4.2 Effect of different organic soil amendments on different growth parameters of lentil

Effects of different organic soil amendments had been compared on the basis of different growth parameters viz. germination (%), plant height (cm), No. of branch, root length (cm), shoot length (cm), vigor index.

a. Seed germination (%)

The highest seed germination was recorded on T_6 (74.44%), followed by T_7 (73%), T_5 (70.22 %), T_4 (68.33%), T_8 (56.43%). However, the lowest seed germination was recorded on T_0 (49.44%), preceded by T_9 (50.54%), T_1 (51.66 %), T_3 (52.78%) and T_2 (54.41%). (Table 6).

b. Plant height (cm)

Plant height at different days after sowing during growth period had been recorded. Ten different treatments were compared with each other for plant height was recorded at 30, 60 and 105 days after sowing (DAS). (Table 6).

At 30 DAS the highest (18.17 cm) plant height was recorded from treatment T_6 (Trichocompost), followed by T_7 (18.05 cm), T_5 (17.66 cm). whereas treatment T_0 (Control) showed the lowest plant height (16.25 cm), preceded by treatment T_9 (16.33 cm), T_1 (17.14 cm), T_3 (17.27 cm), T_2 (17.44 cm), T_8 (17.48 cm) and T_4 (17.49 cm).

At 60 DAS the same of results were found where the highest plant height was recorded in T_6 (21.27 cm) and the lowest plant height was recorded in T_0 (17.88 cm).

At 105 DAS, the highest plant height was also recorded from T_6 (22.67 cm) and the lowest plant height was recorded in T_0 (19.16 cm).

c. No. of branch/plant

At 30 DAS the highest (4.00) no. of branch was recorded from treatment T_6 (Trichocompost), followed by T_7 (3.89), T_5 (3.65). whereas treatment T_0 (Control) showed the lowest branch no. (1.00).

At 60 DAS the same of results were found where the highest branch no. was recorded in T_6 (4.66) and the lowest branch no. was recorded in T_0 (1.33).

At 105 DAS, the highest branch no. was also recorded from T_6 (5.33) and the lowest branch no. was recorded in T_0 (1.55).

d. Shoot length (cm)

The highest shoot length (18.17 cm) was recorded on T_6 (Trichocompost), followed by T_7 (18.04 cm), T_5 (17.66 cm). whereas treatment T_0 (Control) showed the lowest shoot length (16.22 cm), preceded by treatment T_9 (16.33 cm), T_4 (17.15 cm), T_1 (17.27 cm), T_3 (17.44 cm), T_2 (17.48 cm) and T_8 (17.49 cm) (Table 6).

e. Root length (cm)

The highest root length (6.50 cm) was recorded on T_6 (Trichocompost), followed by T_7 (6.30 cm), T_5 (6.00 cm). However, treatment T_0 (Control) showed the lowest root length (4.46 cm), preceded by treatment T_9 (4.50 cm), T_1 (4.50 cm), T_2 and T_3 (5.33 cm), T_8 (5.66 cm) and T_4 (5.76 cm) (Table 6).

f. Vigor index

The highest vigor index (1782.9) was recorded on T_6 (Trichocompost), followed by T_7 (1696.4), T_5 (1606.1), T_4 (1598.0), T_8 (1276.2). Whereas treatment T_0 (Control) showed the lowest vigor index (1076.8), preceded by treatment T_9 (1119.3), T_1 (1153.4), T_3 (1190.5) and T_2 (1240.1) (Table 6).

Table 6: Effect of different organic soil amendments on growth parameters of lentil in pot

Treatments	Germination (%)	Plant height (cm)			No. of branch/plant			Shoot length (cm)	Root length (cm)	Vigor index
		30 DAS	60 DAS	105 DAS	30 DAS	60 DAS	105 DAS			
T_0 (Control)	**49.44 f**	**16.25 d**	**17.88 c**	**19.16 d**	**1.00 e**	**1.33 e**	**1.55 f**	**16.22 d**	**4.46 d**	**1076.8 f**
T_1 (Poultry refuse)	51.66 ef	17.14 c	20.44 ab	21.16 b	2.67 d	3.32 c	4.00 d	17.27 c	4.50 d	1153.4 d-f
T_2 (Mustard oil cake)	54.41 de	17.44 bc	20.22 b	21.50 ab	3.00 cd	3.44 c	4.22 cd	17.48 bc	5.33 c	1240.1 cd
T_3 (Neem oil cake)	52.78 d-f	17.27 c	19.94 b	20.66 bc	2.78 d	3.44 c	4.00 d	17.44 bc	5.33 c	1190.5 c-e
T_4(Vermicompost)	68.33 c	17.49 bc	20.27 ab	21.16 b	3.33 bc	3.89 b	4.33 b-d	17.15 c	5.76 bc	1598.0 b
T_5 (Cowdung)	70.22 bc	17.66 a-c	20.44 ab	21.50 ab	3.65 ab	4.33 a	4.78 b	17.66 a-c	6.00 a-c	1606.1 b
T_6(Trichocompost)	**74.44 a**	**18.17 a**	**21.27 a**	**22.67 a**	**4.00 a**	**4.66 a**	**5.33 a**	**18.17 a**	**6.50 a**	**1782.9 a**
T_7 (Biochar)	73.00 ab	18.05 ab	20.88 ab	21.67 ab	3.89 a	4.33 a	4.66 bc	18.04 ab	6.30 ac	1696.4 ab
T_8 (Sawdust)	56.43 d	17.48 bc	20.28 ab	21.00 b	3.11 cd	3.67 bc	4.67 bc	17.49 bc	5.66 bc	1276.2 c
T_9 (Ash)	50.54 ef	16.33 d	17.87 c	19.50 cd	1.22 e	1.89 d	2.22 e	16.33 d	4.50 d	1119.3 ef
CV (%)	3.84	2.09	3.00	3.53	10.65	7.13	7.19	2.07	7.49	4.49
LSD (0.05)	3.93	0.61	1.01	1.26	0.51	0.41	0.48	0.61	0.69	104.95

Means followed by the same letters in a column did not differ at 5% level of significance by LSD.

4.4.3 Effect of different organic soil amendments on yield and yield contributing characters of lentil in pot

Effect of different organic soil amendments had been compared on the basis of yield and yield contributing characters of lentil viz. no. of pods per plant, yield/ plant (gm), yield/pot (gm).

a. No. of pods/plant

The highest no. of pods/plant (19.44) was recorded on T_6 (Trichocompost), followed by T_7 (18.77), T_5 (18.00). Whereas treatment T_0 (Control) showed the lowest pod no./plant (5.55), preceded by treatment T_9 (8.66), T_1 (11.22), T_3 and T_8 (12.77), T_2 (13.78) and T_4 (15.55). (Table 7)

b. Yield/plant (g)

The highest seed yield/plant was recorded on T_6 (0.66g) followed by T_7 (0.65 g), T_5 (0.62 g). The lowest seed yield/plant was recorded on T_0 (0.22 g) preceded by treatment T_9 (0.36 g), T_1 (0.32 g), T_8 (0.46 g), T_3 (0.47 g), T_2 (0.48 g) and T_4 (0.54 g). (Table 7)

c. Yield/pot (g)

The highest seed yield/ pot (20.16 g) was recorded on T_6 (Trichocompost) where, there was no statistically difference with T_7 (Biochar). whereas treatment T_0 (Control) showed the lowest seed yield (8.33 g), preceded by treatment T_9 (10 g), T_1 (12.13 g), T_3 (13.16 g), T_2 (13.80 g), T_8 (15.03 g) and T_4 (16.83 g). (Table 7)

Table 7: Effect of different organic soil amendments on yield and yield contributing characters of lentil in pot experiment

Treatments	No. of pods/plant	Yield/plant (g)	Yield/pot (g)
T_0 (control)	**5.55 h**	**0.22 g**	**8.33 h**
T_1 (poultry refuse)	11.22 f	0.32 f	12.13 f
T_2 (Mustard oil cake)	13.78 d	0.48 d	13.80 e
T_3 (Neem oil cake)	12.77 e	0.47 d	13.16 ef
T_4 (Vermicompost)	15.55 c	0.54 c	16.83 c
T_5 (cowdung)	18.00 b	0.62 b	18.93 b
T_6 (Trichocompost)	**19.44 a**	**0.66 a**	**20.16 a**
T_7 (Biochar)	18.77 ab	0.65 ab	19.96 ab
T_8 (Sawdust)	12.77 e	0.46 d	15.03 d
T_9 (Ash)	8.66 g	0.36 e	10.00 g
CV(%)	3.15	3.74	4.64
LSD (0.05)	0.81	0.03	1.17

Means followed by the same letters in a column did not differ at 5% level of significance by LSD.

Faruk (2020) found that, soil amendment with Tricho-compost or integration poultry performed as the best treatments in reducing seedling disease and increasing plant growth and yield of chickpea. The efficacy of manuring on root rot disease on groundnut caused by *Fusarium solani* was reported by Ahamed *et al*. (2012) where Poultry manure was the most effective in disease management followed by cattle manure.

Field experiment

4.5 Experiment 3: *In vivo* evaluation of organic soil amendments against foot and root rot disease of lentil

4.5.1 Effect of different organic soil amendments on disease incidence (%) of foot and root rot disease of lentil at different days after sowing

Disease incidence at different days after sowing during growth period had been recorded on the basis of visible typical symptoms. Nine different treatments with control were compared with each other for disease incidence recorded at 10, 20, 30, 60 days after sowing (DAS) (Table 8).

At 10 DAS the lowest (5.55%) disease incidence was recorded from treatment T_6 (Trichocompost), here T_4 (Vermicompost), T_5 (Cowdung) and T_7 (Biochar) showed statistically similar results with T_6 (Trichocompost). However, treatment T_0 (Control) showed the highest disease incidence (44.44%).

At 20 DAS the same trend of results were found where the lowest disease incidence was recorded in T_6 (7.78%) and the highest disease incidence was recorded in T_0 (46.66%).

At 30 DAS, the disease incidence was counted where the lowest incidence of disease was also recorded from T_6 (8.89%) and the highest disease incidence was recorded from T_0 (52.22%).

At 60 DAS, disease incidence was counted where the lowest incidence of disease was also recorded from T_6 (11.11%) and the highest disease incidence was recorded in T_0 (58.89%).

Table 8: Effect of different organic soil amendments on incidence of foot and root rot disease of lentil at different days after sowing (DAS) in field

Treatments	Disease Incidence (%)			
	10 DAS	20 DAS	30DAS	60 DAS
T_0 (control)	**44.44 a**	**46.66 a**	**52.22 a**	**58.89 a**
T_1 (poultry refuse)	25.55 b	28.89 bc	32.22 bc	34.44 bc
T_2 (Mustard oil cake)	20.00 c	25.55 cd	27.78 de	31.11 cd
T_3 (Neem oil cake)	23.33 bc	26.66 c	30.00 cd	32.22 bc
T_4 (Vermicompost)	8.89 d	13.33 e	15.55 f	17.78 e
T_5 (cowdung)	8.89 d	11.11 ef	13.33 f	15.55 ef
T_6 (Trichocompost)	**5.55 d**	**7.78 f**	**8.89 g**	**11.11 f**
T_7 (Biochar)	7.77 d	11.11 ef	12.22 fg	14.44 ef
T_8 (Sawdust)	20.00 c	22.22 d	24.44 e	27.78 d
T_9 (Ash)	26.66 b	31.11 b	34.44 b	35.55 b
CV(%)	15.35	9.77	9.11	8.26
LSD (0.05)	5.03	3.76	3.92	3.95

Means followed by the same letters in a column did not differ at 5% level of significance by LSD.

4.5.2 Effect of different organic soil amendments on different growth parameters of lentil in field

Effects of different organic soil amendments had been compared on the basis of different growth parameters viz. plant height (cm), No. of branch.

a. Plant height (cm)

Plant height at different days after sowing during growth period had been recorded. Ten different treatments were compared with each other for plant height which was recorded at 30, 60 and 105 days after sowing (DAS). (Table 9).

At 30 DAS the highest (18.33 cm) plant height was recorded from treatment T_6 (Trichocompost), followed by T_7 (18 cm) and T_5 (17.89 cm). whereas treatment T_0 (Control) showed the lowest plant height (13.82 cm), preceded by treatment T_1 (15.60 cm), T_9 (16.16 cm), T_3 (16.44 cm), T_2 (16.94 cm), T_8 (17.55 cm) and T_4 (17.66 cm).

At 60 DAS the same trend of results were found where the highest plant height was recorded in T_6 (35.66 cm) and the lowest plant height was recorded in T_0 (28.78 cm).

At 105 DAS, the highest plant height was also recorded from T_6 (37.00 cm) and the lowest plant height was recorded in T_0 (30.33 cm).

b. No. of branch/plant

At 30 DAS the highest (3.22) no. of branch was recorded from treatment T_6 (Trichocompost), followed by T_7 (3.11), T_5 (5.78). whereas treatment T_0 (Control) showed the lowest branch no. (2.22) (Table 9).

At 60 DAS the same trend of results were found where the highest branch no. was recorded in T_6 (6.11) and T_5 (6.11) and the lowest branch no. was recorded in T_0 (4.55).

At 105 DAS, the highest branch no. was also recorded from T_6 (6.44) and the lowest branch no. was recorded in T_0 (4.89).

Table 9: Effect of different organic soil amendments on growth parameters of lentil in field

Treatments	Plant height (cm)			No. of branch/plant		
	30 DAS	60 DAS	105 DAS	30 DAS	60 DAS	105 DAS
T_0 (Control)	**13.82 e**	**28.78 e**	**30.33 f**	**2.22 e**	**4.55 d**	**4.89 e**
T_1 (Poultry refuse)	15.60 d	31.22 cd	31.66 ef	2.78 cd	5.22 c	5.44 d
T_2 (Mustard oil cake)	16.94 bc	31.72 c	33.27 d	3.00 b-d	5.55 bc	5.89 c
T_3 (Neem oil cake)	16.44 cd	31.87 c	32.33 de	2.78 cd	5.22 c	6.00 bc
T_4 (Vermicompost)	17.66 ab	34.44 ab	35.10 bc	3.00 b-d	5.66 a-c	6.00 bc
T_5 (Cowdung)	17.89 a	34.88 a	35.50 ab	5.78 a	**6.11 a**	6.33 ab
T_6 (Trichocompost)	**18.33 a**	**35.66 a**	**37.00 a**	**3.22 b**	**6.11 a**	**6.44 a**
T_7 (Biochar)	18.00 a	35.11 a	36.50 ab	3.11 bc	5.77 ab	6.33 ab
T_8 (Sawdust)	17.55 ab	32.44 bc	33.83 cd	3.00 b-d	5.66 a-c	6.00 bc
T_9 (Ash)	16.16 cd	29.05 de	30.33 f	2.66 d	4.66 d	5.00 e
CV (%)	2.90	3.94	2.62	6.88	4.88	3.71
LSD (0.05)	0.83	2.19	1.50	0.37	0.45	0.36

Means followed by the same letters in a column did not differ at 5% level of significance by LSD.

4.5.3 Effect of different organic soil amendments on yield and yield contributing characters of lentil in field

Effect of different organic soil amendments had been compared on the basis of yield and yield contributing characters of lentil viz. no. of pods per plant, yield/pot (gm), yield/m^2 (gm).

a. No. of pods/plant

The highest no. of pods/plant (38.66) was recorded on T_6 (Trichocompost), followed by T_7 (37.77), T_5 (34.55). whereas treatment T_0 (Control) showed the lowest pods no./plant (20.77), preceded by treatment T_9 (27.44), T_1 (30), T_3 (31), T_2 (31.89), T_8 (32.11) and T_4 (34.11) (Table 10).

b. Yield/plot (g)

The highest yield/ plot (510.32 g) was recorded on T_6 (Trichocompost), followed by T_7 (499.67 g) and T_5 (480.92 g). whereas treatment T_0 (Control) showed the lowest yield (223.33 g), preceded by treatment T_9 (265.60 g), T_1 (294.33 g), T_3 (325.58 g), T_2 (333.75 g), T_8 (385.75 g) and T_4 (400.33 g) (Table 10).

c. Yield/m^2 (g)

The highest yield/m^2 (170.11 g) was recorded on T_6 (Trichocompost), followed by T_7 (166.55 g) and T_5 (160.30 g). whereas treatment T_0 (Control) showed the lowest yield (74.44 g), preceded by treatment T_9 (88.53 g), T_1 (98.11 g), T_3 (108.53 g), T_2 (111.25 g), T_8 (128.58 g) and T_4 (133.44 g) (Table 10).

Table 10: Effect of different organic soil amendments on yield and yield contributing characters of lentil in field

Treatments	No. of pods/plant	Yield/plot (g)	Yield/m^2 (g)
T_0 (Control)	**20.77 f**	**223.33 g**	**74.44 g**
T_1 (Poultry refuse)	30.00 d	294.33 e	98.11 e
T_2 (Mustard oil cake)	31.89 cd	333.75 d	111.25 d
T_3 (Neem oil cake)	31.00 d	325.58 d	108.53 d
T_4 (Vermicompost)	34.11 bc	400.33 c	133.44 c
T_5 (Cowdung)	34.55 b	480.92 b	160.30 b
T_6 (Trichocompost)	**38.66 a**	**510.32 a**	**170.11 a**
T_7 (Biochar)	37.77 a	499.67 ab	166.55 ab
T_8 (Sawdust)	32.11 cd	385.75 c	128.58 c
T_9 (Ash)	27.44 e	265.60 f	88.53 f
CV (%)	4.12	4.44	4.43
LSD (0.05)	2.24	28.30	9.43

Means followed by the same letters in a column did not differ at 5% level of significance by LSD.

Soil application of Tricho-compost was more efficient in reducing seedling mortality and accelerating plant growth with an increased yield of wheat with *S. rolfsii*-inoculated pot cultures and field experiments (Faruk, 2018). Mollah (2012) reported that straw burning + poultry refuse + Provax 200 showed the best performance in respect of yield and yield contributing characteristics followed by poultry refuse + Provax 200 in controlling foot and root rot disease of lentil.

4.6 Regression Study

4.6.1 Regression coefficient between disease incidence (%) and yield/pot (g) of lentil in different sowing times in pot experiment

The linear regression analysis found negative relationship between total yield/pot (g) with percent disease incidence. However, total yield response to the intensity of the percent diseased incidence can be determined by the regression equation Y = -0.2248x + 22.87 (R^2=0.9106). The fitted line plot showed the regression results graphically with equation between the dependent variable of total yield/pot (g) and independent variable of percent disease incidence. The equation indicates that total yield decreases at the rate of -0.2248 (g) with an increases of one unit of percent diseased incidence. The R^2 value of 0.9106 indicates that total yield/pot (g) can be explained as 91% by the respective function.

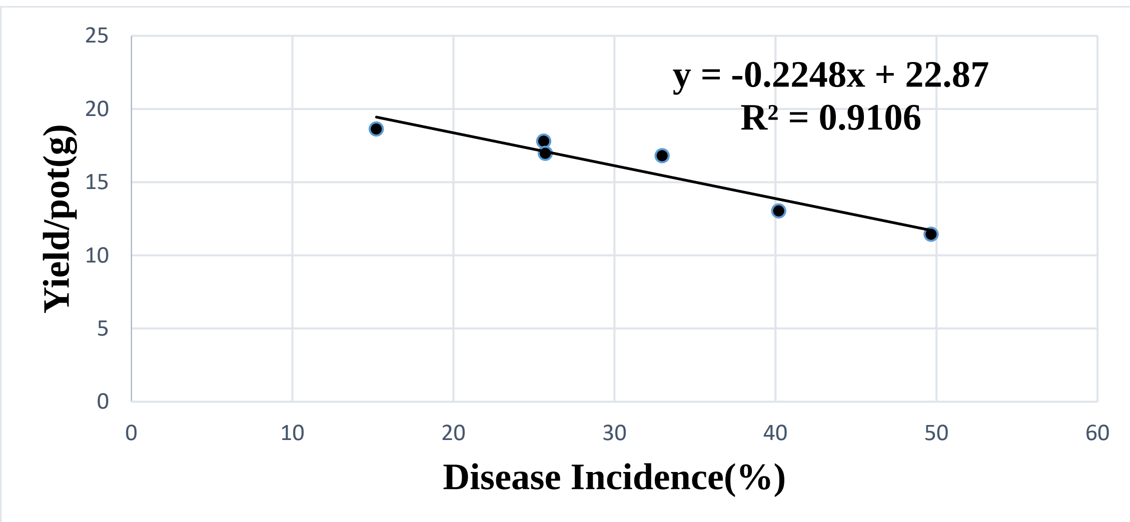


Figure 1: Regression coefficient between disease incidence and total yield/pot in case of different sowing times

4.6.2 Regression coefficient between disease incidence (%) and yield /pot (g) of lentil under evaluation of organic soil amendments in pot

The linear regression analysis found negative relationship between total yield/pot (gm) with percent disease incidence. However, total yield response to the intensity of the percent diseased incidence can be determined by the regression equation Y = -0.2558x + 20.866 (R^2=0.8625). The fitted line plot showed the regression results graphically with equation between the dependent variable of total yield/pot (g) and independent variable of percent disease incidence. The equation indicates that total yield/pot (g) decreases at the rate of -0.2558 (g) with an increases of one unit of percent diseased incidence. The R^2 value of 0.8625 indicates that total yield can be explained as 86% by the respective function.

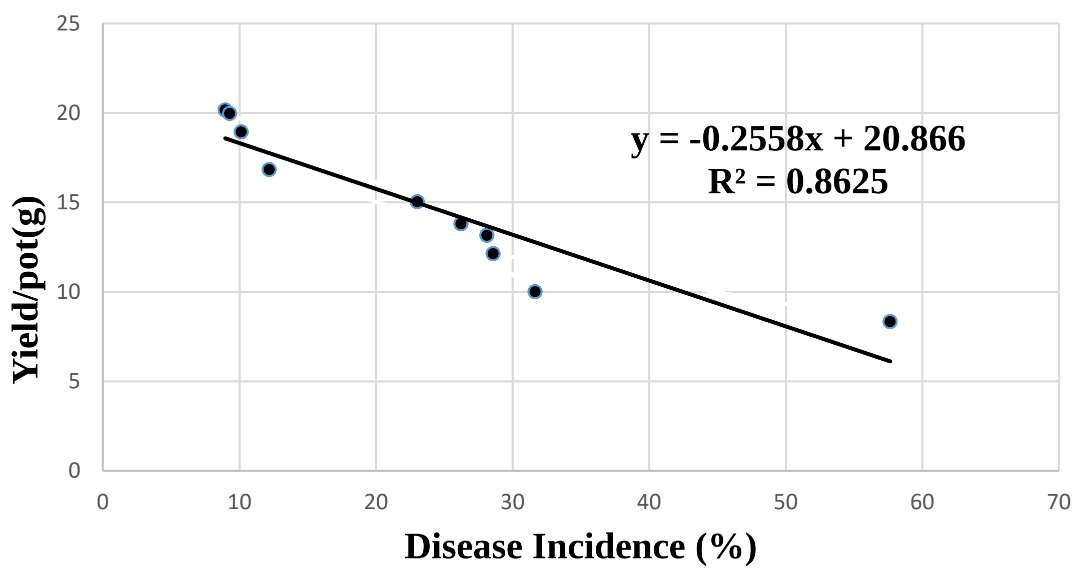


Figure 2: Regression coefficient between disease incidence and total yield/pot in different organic soil amendments in pot

4.6.3 Regression coefficient between percent disease incidence (%) and yield/m^2 (g) of lentil under evaluation of organic soil amendments in field

The linear regression analysis found negative relationship between total yield/m^2 (g) with percent disease incidence. However, total yield response to the intensity of the percent diseased incidence can be determined by the regression equation $Y = -2.1981x + 185.28$ (R^2=0.8609). The fitted line plot showed the regression results graphically with equation between the dependent variable of total yield/m^2 (g) and independent variable of percent disease incidence. The equation indicates that total yield/ m^2 (g) decreases at the rate of -2.1981 (g) with an increases of one unit of percent diseased incidence. The R^2 value of 0.8609 indicates that total yield/ m^2 (g) can be explained as 86% by the respective function.

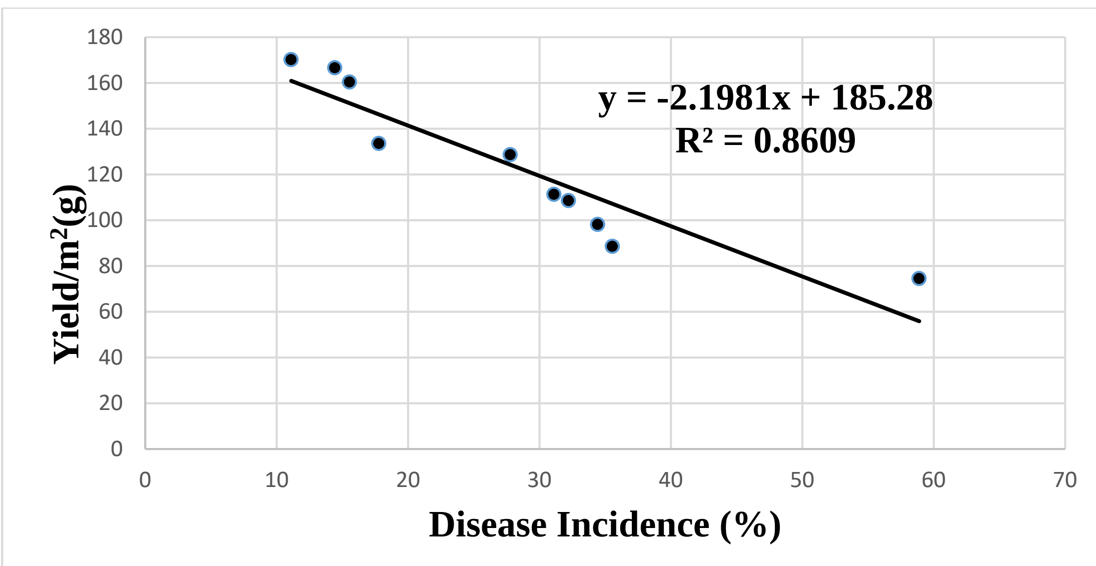


Figure 3: Regression coefficient between disease incidence and yield/m^2 in different organic soil amendments in field

CHAPTER 5

SUMMARY AND CONCLUSION

Lentil (*Lens culinaris*) is a major and important pulse crops in the world. In Bangladesh lentil occupies a unique position as food crops. It is the second major pulse crop in Bangladesh. Lentil contains large amount of protein as well as other micronutrients. But production of lentil is low due to various diseases. Foot and root rot disease caused by *Sclerotium rolsii* is one of the major problems causing yield loss. Proper management practices should be developed to control foot and rot disease of lentil. The experiments were conducted to evaluate sowing times and organic soil amendments against foot and root rot disease of lentil.

In this study, pot experiments were conducted at the net house and field experiment was conducted in the Central Farm of Sher-e-Bangla Agricultural University, Dhaka-1207, during October 2019 to March 2020. Lentil variety BARI Masur-1 was assessed against the disease. Pot experiments were followed by CRD and the field experiment was followed by RCBD with three replications. Two pot experiments were conducted to evaluate the sowing time and organic soil amendments against foot and root rot disease of lentil. Here six different sowing times 25 Oct., 5 Nov.,15 Nov., 25 Nov., 5 Dec. and 15 Dec. and nine organic soil amendments (poultry refuse, mustard oil cake, neem oil cake, vermicompost, cowdung, trichocompost, biochar, sawdust and ash) with control were used. In field experiments, same organic soil amendments were used. Investigation was carried out to find out the effect of different sowing times and various organic soil amendments on foot and root rot disease caused by *Sclerotium rolfsii*.

In experiment 1, the effect of six different sowing times was significant in controlling foot and root rot disease of lentil. Sowing time on 15 December followed by 5 December was found to be the best in management of disease incidence (%) of foot and root rot of lentil, where other sowing time showed lower performance.

At 60 days of inoculation (DAI) the lowest disease incidence (15.22%) was recorded on 15 December whereas the highest disease incidence (49.67%) was recorded on 25 October sowing. Highest germination percentage was recorded by the sowing time on 15 December (75.55%) and the lowest germination percentage was recorded by the sowing time on 25 October sowing (52%).

At 105 DAS, the highest plant height was also recorded from T_6 (21.92 cm) and the lowest plant height was recorded in T_1 (16.76 cm). At 105 DAS, the highest branch no./plant was also recorded from 15 December (7.33) and the lowest branch no. was recorded on 25 October (6.66). Shoot length, root length and vigor index was recorded highest on 15 December and these were 17.58 cm, 6.90 cm and 1416.9 respectively; and the lowest data was recorded sowing on 25 October, 12.86cm, 3.50 cm and 1008 respectively.

When seeds were sown on 15 December the highest pod number (16.44) was recorded and lowest number was recorded on 25 October (5.55). Sowing time on 15 December provided high yield/pot (18.63g) than others and yield/pot was lowest at sowing time on 25 October (11.43g).

In this experiment, when seeds were sown on 15 December it showed the best result considering disease incidence, growth parameters and yield contributing characters of lentil against foot and root rot disease of lentil.

In experiment 2, the effect of the nine different organic soil amendments were significant in controlling disease of foot and root rot of lentil. Soil treatment with Trichocompost followed by treatment with biochar was found to be the best in controlling disease incidence of foot and root rot of lentil, where other organic soil amendments showed lower performance.

Number of pods/ plant, yield / plot/pot, plant height was significantly affected by different organic soil amendments at some extent. Among the treatments Trichocompost was found to be effective in increasing number of pods/ plant, yield/ pot, plant height of lentil plant.

At 60 DAI, disease incidence was counted where control showed the highest incidence of disease (57.65%) and the lowest disease incidence was recorded from Trichocompost (8.96%). The highest seed germination was recorded on Trichocompost (74.44%), the lowest seed germination was recorded on control treatment (49.44%).

At 105 DAS, the highest plant height was also recorded from Trichocompost (22.67 cm) and the lowest plant height was recorded in control (19.16 cm).

The highest branch no./plant was recorded on Trichocompost and lowest one was recorded on control at 30, 60 and 105 days after sowing (DAS). At 105 DAS highest branch no./plant was recorded on Trichocompost (5.33) and the lowest data was recorded on control (1.55). Shoot length, root length and vigor index was recorded highest on Trichocompost and these were 18.17

cm, 6.50 cm and 1782.9 respectively; and the lowest data was recorded on control, 16.22cm, 4.46 cm and 1076.8 respectively. Trichocompost showed the highest pods number/plant (19.44) and lowest number was recorded on control (5.55). Highest yield/pot (20.16 g) was recorded in Trichocompost and yield/pot was lowest in control treatment (8.33g).

The findings of the experiment have clearly pointed out that among all the organic soil amendments, Trichocompost showed the best result in controlling foot and root rot disease with increasing the yield of lentil.

In experiment 3, nine different organic soil amendments were effected significantly against foot and root rot disease of lentil.

At 60 DAS, disease incidence was counted where Trichocompost showed the lowest incidence of disease (11.11%) and the highest disease incidence was recorded from control (58.89%).

At 105 DAS, the highest plant height was also recorded from Trichocompost (37 cm) and the lowest plant height was recorded in control (30.33 cm). Branch number per plant was recorded whereas Trichocompost showed the highest number (6.44) and control (4.89) showed the lowest number of branch at 105 DAS.

The highest pods number/plant was counted from the plot which was treated with Trichocompost (38.66) and the lowest was counted from control (20.77). Highest yield/plot was recorded in case of Trichocompost (510.32 g) and the lowest yield/plot was recorded in control (223.33 g). Highest yield/m^2 was recorded in case of Trichocompost (170.11g) and the lowest yield/ m^2 was recorded in control (74.44 gm).

Here it was found that, Trichocompost showed best result in controlling foot and root rot of lentil. Trichocompost performed best also in case of growth parameters and yield contributing characters.

The findings of the experiments have clearly pointed out that among the different sowing times, seed sowing on 15 December appeared to be the best to escape foot and root rot disease of lentil in Bangladesh. For soil application of organic soil amendments, Trichocompost showed the best result in controlling foot and root rot disease with increasing the yield of lentil. Thus, the lentil growers are suggested to sow the lentil seeds on 15 December and use Trichocompost as organic soil amendments during plowing to manage foot and root rot disease of lentil caused by *Sclerotium rolfsii*, However, further investigations may be carried out to clarify and justify the results.

Considering the findings of the present experiment, further studies in the following areas may be suggested:

- This experiment may be conducted in different agro-ecological zones (AEZ) of Bangladesh for regional trial before final recommendation.
- Further experiments are suggested with combination of sowing times and organic soil amendments.

CHAPTER 6

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CHAPTER 7

APPENDICES

Appendix I: Particulars of the Agro-ecological Zone of the Experimental site

Agro-ecological region	Madhupur Tract (AEZ-28)
Land Type	Medium high land
General Soil Type	Non-calcareous dark gray floodplain soil
Topography	Up land
Soil series	Tejgaon
Drainage	Fairly good
Field level	Above flood level
Firmness	Compact to friable when dry
Soil p^H	4.47-5.55
Organic matter content	0.82

Appendix II: Monthly mean weather of the experimental site

Monthly mean of average temperature (°c), average Relative humidity (%), Rainfall and Pressure (mbar) from October/2019 to March/2020 are given bellow-

Year	Month	Average Temperature (°C)	Relative Humidity (%)	Rainfall (mm)	Air Pressure (mbar)
2019	October	27.6	78	188	1010.1
	November	24.9	74	37	1011.5
	December	19.3	74	5	1015.2
2020	January	18.5	76	21	1014.7
	February	21.6	59	1	1014.5
	March	26.4	57	30	1010.7

Source: Bangladesh Meteorological Department (Climate Division), Agargaon, Sher-e-Bangla Nagar, Dhaka-1207.