EFFECT OF DIFFERENT COMBINATION OF BIOCHAR AND VERMICOMPOST ON YIELD AND SEED QUALITY OF LENTIL

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CERTIFICATE

This is to certify that the thesis entitled ***"EFFECT OF DIFFERENT COMBINATION OF BIOCHAR AND VERMICOMPOST ON YIELD AND SEED QUALITY OF LENTIL"*** *submitted to the Institute of Seed Technology, Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of* ***MASTERS OF SCIENCE (M.S.)*** *in* ***SEED TECHNOLOGY****, embodies the result of a piece of bonafide research work carried out by* ***MD. AL-AMIN****, Registration No. 14-05899 under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

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

June, 2021

Dhaka, Bangladesh

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Dedicated to

My

Beloved Parents

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The Author

EFFECT OF DIFFERENT COMBINATION OF BIOCHAR AND VERMICOMPOST ON YIELD AND SEED QUALITY OF LENTIL

ABSTRACT

The pot experiment was conducted at the farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka-1207 during the period of October 2019 to February 2020 to study the effect of different combination of biochar and vermicompost on yield and seed quality of lentil. Two factors *viz*., Factor A: two lentil varieties; V_1 (BARI masur-6) and V_2 (BARI masur-7) and Factor B: Biochar + vermicompost (6 levels); T_1 (0 ton biochar ha^{-1} + 0 ton vermicompost ha^{-1}), T_2 (5 ton biochar ha^{-1} + 0 ton vermicompost ha^{-1}), T_3 (0 ton biochar ha^{-1} + 5 ton vermicompost ha^{-1}), T_4 (1 ton biochar ha^{-1} + 4 ton vermicompost ha^{-1}), T_5 (4 ton biochar ha^{-1} +1 ton vermicompost ha^{-1}) and T_6 (2.5 ton biochar ha^{-1} +2.5 ton vermicompost ha^{-1}) were considered for the present study. The experiment was laid out in a randomized complete block design (RCBD) with three replications. BARI masur-6 (V_1) and BARI masur-7 (V_2) showed non-significant difference between them for most of the yield and seed quality parameters. Treatment T_5 (4 ton biochar ha^{-1} +1 ton vermicompost ha^{-1}) showed the best performance on seed yield and quality and gave the highest dry weight plant^{-1} (10.16 g), number of pods plant^{-1} (63.08), number of seeds pod^{-1} (1.79), number of seeds plant^{-1} (113.50), seed yield plant^{-1} (2.82 g), stover yield plant^{-1} (3.57 g), biological yield plant^{-1} (6.38 g), harvest index (44.17%) seed germination (91.50%), shoot length (5.32 cm) and root length (3.22 cm) of seedlings after 12 days of germination and seed vigor index (781.00) compared to other treatments including control. treatment combination of V_2T_5 registered the highest dry weight plant^{-1} (10.24 g), number of pods plant^{-1} (63.40), number of seeds pod^{-1} (1.80), number of seeds plant^{-1} (114.70), seed yield plant^{-1} (2.86 g), stover yield plant^{-1} (3.59 g), biological yield plant^{-1} (6.6.45 g), harvest index (44.47%), seed germination (92.00%), shoot length (5.36 cm) and root length (3.26 cm) of seedlings after 12 days of germination and seed vigor index (793.00) compared to other treatment combinations. So, the treatment combination, V_2T_5 (BARI masur-7 with 4 ton biochar ha^{-1} + 1 ton vermicompost ha^{-1}) can be considered as best compared to other treatment combinations.

CONTENTS

CONTENTS (Cont'd)

TABLES

FIGURES

APPENDICES

ABBREVIATIONS AND ACRONYMS

AEZ	=	Agro-Ecological Zone
BBS	=	Bangladesh Bureau of Statistics
BCSRI	=	Bangladesh Council of Scientific Research Institute
cm	=	Centimeter
CV %	=	Percent Coefficient of Variation
DAS	=	Days After Sowing
DMRT	=	Duncan's Multiple Range Test
et al.	=	And others
e.g.	=	exempli gratia (L), for example
etc.	=	Etcetera
FAO	=	Food and Agricultural Organization of the United Nations
g	=	Gram (s)
i.e.	=	id est (L), that is
Kg	=	Kilogram (s)
LSD	=	Least Significant Difference
m^2	=	Meter squares
ml	=	MiliLitre
M.S.	=	Master of Science
No.	=	Number
SAU	=	Sher-e-Bangla Agricultural University
var.	=	Variety
^oC	=	Degree Celceous
%	=	Percentage
NaOH	=	Sodium hydroxide
GM	=	Geometric mean
mg	=	Miligram
P	=	Phosphorus
K	=	Potassium
Ca	=	Calcium
L	=	Litre
µg	=	Microgram
USA	=	United States of America
WHO	=	World Health Organization

CHAPTER I

INTRODUCTION

Legumes are considered the world's most essential food source after cereals, as they are the main protein and energy sources for humans. It is cultivated in an area of 898 million ha in Bangladesh with 389 million tons of output and 434 kgha^{-1} of productivity (BBS, 2018). Lentil (*Lens culinaris* L. Medik) is one of the most important pulse crops grown in Bangladesh. It belongs to the sub-family Papilionaceae under the family Leguminosae.

Lentil contains 28.6% protein, 3.1 % ash, 4.6 % crude fiber, 44.3 % starch, 36.1 % amylose, 63.1 % total carbonhydrates and 420 cal 100 g^{-1} gross energy (Bhatty and Wu, 1974; Sahi *et al*., 2000). The high level of protein together with a lower level of anti- nutritional factors and a shorter cooking time than most of other pulses, make lentil very suitable for human consumption (Williams *et al*.,1993; Sahi *et al*., 2000).

In Bangladesh, it is popularly known as masur. Totally in Bangladesh, 176,633 metric tons of lentil from an area of 385399 acres were produced during 2017-2018 (BBS, 2018).

Lentil being a legume crop can fix atmospheric nitrogen (101 kg ha^{-1} annum) through root nodules by Rhizobium bacteria, which may reduce the pressure of nitrogenous fertilizer application to the crop (Anonymous, 1984). It is evident that pulse containing cropping pattern helped to increase the organic matter in the soil (Islam, 1988).

There is an acute shortage of lentil in relation to its demand in Bangladesh. The average yield of the different pulses ranges from 700 to 800 kg ha^{-1}. Bangladesh faces an acute shortage of pulses. The country produces a total of 0.53 million tons against the demand of almost 2 million tons (Razzaque, 2000). In Bangladesh, the low yield of lentil may be attributed to many reasons such as lack of quality optimum seed rate, using local varieties as planting material, appropriate time of sowing, lack of judicious fertilizer application and specially decrease of organic matter in the soil. Moreover, the different doses of phosphorus will help to determine the suitable dose, thereby reducing the misuse of phosphorus fertilizer.

Variety plays an important role in producing high yield of lentil because different varieties responded differently for their genotypic characters, input requirements and growth process under prevailing environment during the growing season. BARI has developed some varieties of lentil. Plant height, number of branches, number of pods, 1000 grains weight, grain yield and other contributing characters essentially differ from local variety. The use of varieties with low yield potential also limits lentil growth and yield to a considerable extent (Nazir *et al*., 2004). High yielding cultivars usually have extensive root system, taller in height (Kasole *et al*., 2005), relatively higher number of pods plant^{-1} and grains pod^{-1} (Islam and Islam, 2006). These cultivars consequently give higher growth and biological yield (Minhas *et al*., 2007). Among different released varieties of lentil BINA masur 2, BINA masur 3, BARI masur 4, BARI masur 6, BARI masur 7 are mentionable for their growth performance, yield and seed quality.

Soil degradation processes caused by erosion, organic matter and plant nutrient depletion, and nutrient imbalances are among the major challenges affecting agricultural productivity and food security (Sanchez 2002; Foley *et al*. 2005; Lal 2009). The deterioration of soil fertility is exacerbated by nutrient mining, unsuitable land use and management, competing uses of resources, and application of insufficient external inputs. To increase soil fertility and productivity, organic manures such as cowdung, poultry manure, vermicompost, green manure, biochar etc. are urgently needed to use crop cultivation.

Biochar is charcoal produced by controlled pyrolysis for use as a soil amendment or in carbon (C) sequestration (Lehmann and Rondon 2006).

Various studies have shown that application of biochar to soil can improve soil biophysical and chemical properties and nutrient supply to plants (Sohi *et al*. 2010), enhance plant growth and yield (Chan *et al*. 2007; Major *et al*. 2010), and reduce greenhouse gas emissions through C sequestration (Zhang *et al*. 2012). Biochar helps to improve agricultural productivity by reducing soil acidity and by enhancing CEC and fertilizer-use efficiency (Steiner *et al*. 2008), water retention capacity (Downie 2011) and plant-available water content (Tammeorg *et al*., 2014), and by creating a habitat for beneficial soil microorganisms (Thies and Rillig 2009).

It has been reported that soil amendment with biochar or vermicompost improves soil physicochemical properties including cation exchange capacity, pH, nutrient and water retention, as well as it has promotion efect on soil microbial communities (Haipeng *et al*., 2017 and Keiluweit 2010). Furthermore, positive synergistic efects of combining biochar with diferent compost types have been reported on soil organic content, nutrients levels and water storage capacity (Alvarez *et al*., 2017 and D'Hose *et al*., 2020).

This pulse is traditionally used in many food items and popularly known as poor man's meat. The yield of lentil is low and as a result, the acreage of lentil is shrinking. If the yield can be increased, the farmers might be interested to include lentil in their cropping pattern. Biochar and vermicompost application has shown to increase legumes yield and seed quality (Rondon *et al*., 2007; Ogawa *et al*., 2010; Mia *et al*., 2014).

Considering above fact, the present study was under taken with the following objectives:

1. To study the growth, yield and seed quality performance of BARI masur-6 and BARI masur-7
2. To study the effect of biochar and/or vermicompost on the yield and seed quality of lentil

CHAPTER II

REVIEW OF LITERATURE

Lentil is an important pulse crop in Bangladesh. The research work so far done in Bangladesh is not adequate and conclusive. Information on variety and biochar and vermicompost application in pulse related studies are reviewed and presented in the following heads.

2.1 Effect of variety

Baidya *et al*. (2018) observed the steep rise in shoot dry weight of all the tested cultivars of lentil between 35 and 50 DAS. They found highest total per plant dry matter accumulation (2.72 g) and its allocation in root (0.34 g), shoot (1.31 g) and leaves (0.69 g) in cultivar ILL-8108 at 65 DAS. In contrast, cultivar WBL-58 (1.19 g), ILL-10951 (1.23 g) and HULL-57 (1.27 g) recorded the lowest cumulative biomass at the same crop growth stage. Although, the accumulation of dry matter in reproductive parts was greater in L-13-113 (0.53 g) and lowest in HULL-57 (0.07 g) among all the twenty cultivars in experimentation.

Biswas *et al*. (2018) in two-year experimentation found that the cultivar PL-406 recorded highest plant height (37.74 and 40.23 cm), branches plant^{-1} (5.88 and 6.27), dry matter accumulation (212.56 and 247.53 g m^{-2}) and leaf area index (1.46 and 1.48) which was immediately followed by cultivar KLS-218 (37.17 and 39.62 cm; 5.83 and 6.21; 210.30 and 244.82 g m^{-2}; 1.35 and 1.38) and Ranjan (36.62 and 39.06 cm; 5.82 and 6.21; 191.58 227.88 g m^{-2}; 1.34 and 1.38) in 2013-14 and 2014-15, respectively. The cultivar BM-6 recorded significantly lowest plant height (30.68 and 32.99 cm), branches plant^{-1} (5.36 and 5.70), dry matter accumulation (156.03 and 182.38 g m^{-2}) and leaf area index (1.13 and 1.14).

Yadav *et al*. (2017) conducted a field experiment to study the performance of lentil varieties under rainfed condition in respect of growth and development, yield and yield contributing characters, quality and economics. Twelve varieties of lentil IPL-81, K-75, NDL-1, IPL-406, DPL-15, PL5, PL-234, PL-4, DPL-62, PL-406, PL-63 and HUL-57 were tested in Randomized Block Design (RBD) with three replications. The performance of PL-406 variety of lentil was found significantly superior over rest of the varieties in respect of all growth, yield and yield contributing characters except plant height and test weight. The maximum plant height was recorded in IPL406 variety while the higher test weight (g) was recorded in DPL-62 variety. The highest net return (Rs. 73743 ha^{-1}) and B:C ratio (4.3) was obtained with PL-406 variety of lentil under the rainfed condition.

Hasan *et al.* (2015) conducted an experiment with three varieties of lentil *(viz.,* BARI Masur-5, BARI Masur-6 and BARI Masur-7) and reported that the highest plant height (45.83 cm), highest dry weight $plant^{-1}$ (1.62 g), highest seeds pod^{-1} (98) and highest 1000-eed weight (22.02g) was found from BARI Masur 5 whereas the lowest plant height (34.67 cm), lowest dry weight $plant^{-1}$ (1.22g), lowest seeds pod^{-1} (49) and lowest 1000-seed weight (20.08g) from BARI Masur 7. Again, in case of yield performance, BARIMasur-5 was the best compared to other varieties.

Awal and Roy (2015) conducted an experiment to study the effect of weeding on the growth and yield of three lentil varieties *viz*. Binamasur-1, Binamasur-2 and Binamasur-3. They reported that, the plant height, number of branches $plant^{-1}$, plant dry matter, number of pods $plant^{-1}$, 1000-seed weight, seed weight $plant^{-1}$, seed yield and harvest index of lentil varied significantly due to the different varieties. The tallest plants (21.50 cm) were recorded in Binamasur-3. The Binamasur-1 (19.20 cm) and Binamasur-2 (19.50 cm) showed the similar result. The highest number of branches $plant^{-1}$ was produced in Binamasur-3 (20.32) which was statistically similar with Binamasur-2 (19.53) while the Binamasur-1 variety produced the lowest (18.50) branches $plant^{-1}$. The maximum plant dry matter (184.7 g m^2) was recorded from Binamasur-3 and minimum (161.70 g m^{-2}) from Binamasur-1. The maximum number of pods plant^{-1} (84) was recorded from Binamasur-3 and minimum number of pods plant^{-1} (77) was recorded from Binamasur-2. The maximum number of seeds pod^{-1} (1.43) was recorded from Binamasur -3 and minimum (1.33) from Binamasur-1. The maximum 1000-seed weight (21.30 g) was recorded from Binamasur-3 and minimum (15.50 g) from Binamasur-1. The maximum seed weight plant^{-1} (2.22 g) and seed yield (0.74 t ha^{-1}) was recorded from Binamasur-3 and minimum (1.73 g and 0.57 t ha^{-1}, respectively) was recorded from Binamasur-1. The maximum harvest index (40.20%) was recorded from Binamasur-3 and minimum (32.90%) from Binamasur-2.

Alam *et al.* (2015) conducted a field experiment to study dry matter production and crop growth rate of lentil as influenced by irrigation management. The experiment was laid out by split plot design and comprised of six irrigation levels *viz*. control irrigation, irrigation at pre-sowing, irrigation at post sowing, irrigation at vegetative stage (25-30 DAS), irrigation at pre-flowering (45-50 DAS) and irrigation at post flowering (70 DAS) and four varieties of lentil *viz*. BARI Masur-3, BARI Masur-4, BARI Masur-5 and BARI Masur-6. The results of the study indicated that, at 50 DAS the highest total dry matter (TDM) (29.67 g m^{-2}) was found in V4 (BARI Masur-6) and lowest (25.37 g m^{-2}) in V_1 (BARI Masur-3). At 60 DAS, the highest TDM (47.60 g m^{-2}) was produced by V4 (BARI Masure-6) and lowest (41.49 g m^{-2}) by V1 (BARI Masur-3). At 70 DAS, the highest TDM (98.03 g m^{-2}) was observed in the variety V_4(BARI Masur-6) and the lowest (76.90 g m^{-2}) in V_1 (BARI Masur-3). The highest TDM (157.29 g m^{-2}) and the lowest (135.12 g m^{-2}) were produced by BARI Masur-6 and BARI Masur-3, respectively at 80 DAS.

Hadiuzamman *et al.* (2015) conducted an experiment to validate stove derived biochar's affectivity with biochar and three organic manures i.e. poultry litter, cowdung and vermicompost in two varieties of lentil i.e. BARImusur 4 and BARI musur 7 and reported that BARI musur 7 produced higher seed yield (920.80 kg ha^{-1}) than BARImusur 4 (900.40 kg ha^{-1}). Biochar in combination with BARI musur 7 provided the best yield (1120 kg ha^{-1}), indicating interactive effect between organic matter amendment and variety.

Layek *et al*. (2014) found the taller plants of lentil cultivar IPL-406 (62 cm) at maturity followed by IPL-319 (61.9 cm) and IPL-318 (61.7 cm). Similarly, cultivar TRC L111-6 (35.2 cm) followed by TRC L-11-4 (38.4 cm) obtained significantly shortest plant height. The highest numbers of primary branches per plant were recorded with cultivar L-307 (6.8) followed by DPL-62 (6.7) whereas this figure was lowest with cultivar TRC L-11-4 (4.9) followed by L-305 (5.1). In contrast, secondary branches per plant was the highest with cultivar IPL-406 followed by IPL-313 and DPL 62. Kundu *et al*. (2017) also observed the significant differences in plant height, dry matter accumulation of the lentil crop cultivar from a two consecutive years study (2012-13 and 2013-14) to assess the performances of sixteen pre-released and two standard cultivars of bold seeded lentil for their growth.

Haque *et al.* (2014) conducted a field experiment to study the response of three lentil varieties (*viz*., BARI Masur-1, BARI Masur-2 and BARI Masur-3) to *Rhizobium* inoculations regarding yield. There were three *Rhizobium* inoculants *(Rhizobium* strain BINA L4, *Rhizobium* strain TAL 640, and mixed culture) with uninoculated control and urea @ 50 kg ha^{-1}. It was observed that, the maximum plant height was produced by the variety BARI Masur-3 (33.26 cm) and BARI Masur-1 gave the maximum plant height (31.23 cm). BARI Masur-3 also recorded the highest grain yield (1276 kg ha^{-1}), which was statistically superior to both varieties. Results also showed that, the highest crop residue (2482 kg ha^{-1}) was obtained by the variety BARI Masur-3, which was statistically superior to BARI Masur-1 (2199 kg ha^{-1}) but similar to BARI Masur-2 (2404 kg ha^{-1}).

Datta *et al.* (2013) carried out an experiment to study the effect of variety and level of phosphorus fertilizer on the yield and yield components of lentil. Three lentil varieties *viz*. Binamasur-2, Binamasur-3 and BARI Masur-4 and four levels of phosphorus *viz*. 0 kg P ha^{-1} (P0), 15 kg P ha^{-1} (P_{15}), 30 kg P ha^{-1} (P_{30}) and 45 kg P ha^{-1} (P_{45}) were used in this experiment. They reported that, the variety Binamasur-2 gave the highest plant height (38.18 cm) and the cultivar BARI Masur-4 produced the lowest plant height (36.92 cm). The variety Binamasur-2 gave the highest number of pods plant^{-1} (128.5) and BARI Masur-4 produced the lowest number of pods plant^{-1} (111.70) and seeds plant while Binamasur-3 produced the highest number of seeds pod^{-1} (1.68) and the lowest number of seeds pod^{-1} (1.58) was observed from the cultivar BARI masur-4. Again, the cultivar BARI masur-4 produced the highest weight of 1000-seed (18.77 g) and the lowest weight of 1000-seed (16.42 g) was recorded from the cultivar Binamasur-2. Similarly, the highest seed yield (1165 kg ha^{-1}) was recorded from cultivar BARI Masur-4 which was statistically identical with Binamasur-2 (1133 kg ha^{-1}) and the lowest seed yield (1028 kg ha^{-1}) was found in the cultivar Binamasur- 3.

Haque *et al.* (2013) also reported that BARI Masur-3 performed better than other two lentil varieties *(Rhizobium* strain BINA L4 and *Rhizobium* strain TAL 640) in respect of dry matter production.

The growth parameters differ with the genotype of the same crop species. In the same line, Mondal *et al*. (2013) observed the significant variations in plant height, branches per plant and leaf area (LA) among the lentil cultivars. The cultivar LM-149 attained the grater height (50.2 cm) which was statistically comparable with cultivar LM-417 (46.9 cm), and both of these cultivars were significant over LM-504 (43.1 cm), L-5 (41.5 cm), LM-1018 (40.9 cm) and LM-507 (37.1 cm), respectively. Although, LM-507 (14.8), LM-1018 (14.2), L-5 (13.6) and LM-504 (13.1) produced higher number of branches per plant; all of these were significantly superior than LM-149 (12.6) and LM-417 (11.9) with same statistical rank.

Singh *et al.* (2013) conducted a field experiment to study the effect of triacontanol, vermicompost and biofertilizers on growth, yield and quality of lentil genotypes. Treatments comprised four genotypes and six organics. Amongst the lentil genotypes, VL-508 gave maximum LAI, CGR, NAR and chlorophyll content in leaves as well as grain yield (12.08 q ha^{-1}) with the net income of Rs.23730 ha^{-1}.

Rahman *et al.* (2013) conducted a field study to evaluate the effect of nitrogen application on different morpho-physiological traits of three lentil cultivars. They reported that branching plays a vital role in enhancing the yield of a plant. Cultivar NIAB Masur (NM)-2006 produced the maximum number of branches per plant (11.32) followed by NM -2002 and PM-2009, producing 10.28 and 8.62 number of branches per plant, respectively.

Singh *et al.* (2011) conducted field experiments to study the effect of four nutrient levels involving nitrogen and phosphorus (0+0, 9.4 + 30, 12.5 + 40 and 15.6 + 50 kg N + P_2O_5 ha^{-1}) on nodulation, growth and yield of four genotypes (LL 147, LL 699, LL 875 and LL 931) of lentil. They reported that, the highest plant height (42.4 cm) was produced by lentil genotype LL 875 and the lowest (36.9 cm) by LL 931. The highest primary branches $plant^{-1}$ (6.40) was produced by lentil genotype LL 875 and the lowest (5.80) by LL 931. The highest secondary branches $plant^{-1}$ (7.00) was produced by lentil genotype LL 699 and the lowest (5.40) by LL 931. The highest pods $plant^{-1}$ (59.40) was produced by lentil genotype LL 699 and the lowest pods $plant^{-1}$ (49.80) was produced by lentil genotype LL 931. They also reported that, the highest seeds pod^{-1} (1.97) was produced by lentil genotype LL 147 and the lowest seeds pod^{-1} (1.52) was produced by lentil genotype LL 931 while the highest 100-seed weight (2.40 g) was produced by lentil genotype LL 931 and the lowest (1.70 g) by lentil genotype LL147. Again, the highest seed yield (2026 kg ha^{-1}) was produced by lentil genotype LL 699 and the lowest seed yield (1433 kg ha^{-1}) was produced by lentil genotype LL875. Similarly, the highest biological yield (5521 kg ha^{-1}) and harvest index (36.60 %) was produced by lentil genotype LL 699 and the lowest biological yield (4598 kg ha^{-1}) and harvest index (31.10%) was by lentil genotype LL875.

Kayan (2008) carried out a study to investigate variation in yield components of two lentil cultivars (Kayi-91 and Sazak-91). The mean values recorded for Kayi 91 were better than Sazak 91. Positive and highly significant correlations determined for the characteristics. The regressions for harvest index, the grain yield per plant and biological yield per plant with root dry weight were positive.

Hakim *et al*. (2006) conducted a study using 13 diverse genotypes of lentil: PL-339319, FLIP-97-28L, FLIP-99- IL, FLIP-2002-IL, FLIP-2002-16L, FLIP-2003-10L, FLIP-2003-13L, 81-S-15-28, FLIP-2004-5L, FLIP-2004-30L, Shenaz-96, Masoor-93 and Masoor-local. Genetic variances, heritability and correlations among different traits (days to flowering and maturity, plant height, pods per plant, seeds per pod, 1000-seed weight and yield) were studied. Differences for all the traits were found statistically significant. Days to flowering ranged from 123 (FLIP-2002-1L) to 131 (Shiraz) while days to maturity ranged from 172 (PL-339319) to 184 days (FLIP-2004-30L). The tallest plants (48.0 cm) were produced by FLIP-2004-30L, while the shortest plants (31.3 cm) were produced by 81-S-15-28 (31.3 cm). Pods per plant varied significantly from 29 (FLIP-2004-5L) to 52 (Masoor-93). Data on 1000-seed weight ranged from 22 g (FLIP-97-28L) to 40 g (FLIP-2003-13L). The highest seed yield of 1713 kg/ha was obtained from the plots of Masoor-93, followed by FLIP-99-IL with 1622 kg/ha.

Vinay *et al.* (2006) evaluated small-seeded (twenty-five) and bold-seeded (eighteen) genotypes of lentil to understand and compare the contribution of various characters to yield. Seed yield was positively associated with pod length, plant height and maturity in both the lentil types. Plant height showed more of direct contribution towards yield than indirect contribution. A significant shift in the association between yields with pods/plant, flowering and maturity was observed. In small-seeded lentil all the characters were important with an emphasis on delayed maturity and tall plant habit, while in bold-seeded lentil, pod length, delayed maturity and tall plant type were important with more emphasis on tall plant type.

Gupta *et al*. (2006) conducted an experiment with forty lentil genotypes for genotype × environment interaction and phenotypic stability under 8 diverse environments. Eleven different growth and yield characters were evaluated: days to 50% flowering, days to maturity, primary branch number per plant, secondary branch number per plant, pod number per plant, 100-seed weight, plant height, seed number per plant, biological yield/plant, harvest index and seed yield/plant. High yielding and stable genotypes included JLS-1, PL 639, PL 81-64, E 153, L3685, Sehore 74-3, PL 81-49, PL-81-67, L4605, L263, PL 4 and P 22127.

Ezzat *et al.* (2005) conducted experiments to evaluate 30 exotic and Egyptian lentil genotypes for earliness, yield, yield components, seed protein content, hydration coefficient before and after cooking, total soluble solids and seed cook ability characters. Correlation and factor analysis procedures were used to determine the contributing characters in yield variation. Field experiments were conducted at Giza Research Station, Egypt during 2001/02 and 2002/03. Genotypes FLIP 88-42L, PKVL-1, FLIP 96-52L, FLIP 97-30L, FLIP 97-33L and Sinai 1 were the earliest in flowering and maturity. FLIP 88-34L had the highest number of pods and seeds per plant, and produced the highest seed yield/fed recording 4.10 ardab, surpassing Giza 9 by 35%.

Shrestha *et al.* (2005) carried out an experiment with nineteen diverse lentil genotypes, 8 originating from South Asia, 6 from West Asia, and 5 crossbreds using parents from South Asia and West Asia (or other Mediterranean environments), were evaluated for growth, phenology, yield, and yield components. Additionally, dry matter production, partitioning, root growth and water use of 8 selected genotypes from the 3 groups were measured at key phenological stages. The seed yield of the West Asian genotypes was only 330 kg/ha, whereas the South Asian genotypes produced a mean seed yield of 1270 kg/ha. The crossbreds had a significantly greater seed yield (1550 kg/ha) than the South Asian genotypes. The high seed yield of both the South Asian and crossbred genotypes was associated with rapid ground cover, early flowering and maturity, a long reproductive period, a greater number of seeds and pods, high total dry matter, greater harvest index.

Turk *et al*. (2004) carried out an experiment with the aim to (i) investigate the response of 3 lentil cultivars, i.e. FLIP 86-16 L (large seeds), FLIP 89-31 L (small seeds) and FLIP 95-3L (small seeds), to osmotic stress during germination and seedling growth; (ii) identify characters that can be used for screening genotypes; and (iii) determine the effects of cultivars on yield and yield components of rainfed lentil in arid (150 mm rainfall) and semiarid (364 mm) regions in Jordan. Large-seeded cultivars exhibited higher percentage of germination and germination speed under moisture stress than did the small-seeded cultivars. Germination speed was more sensitive to change in osmotic potential than percent germination. Root and shoot weights of all cultivars were reduced when osmotic potential was decreased, but the extent of reduction in root growth was less than that for shoots. Lentil plants at the semi-arid location (Houfa) had greater seed yield, 1000-seed weight and plant height than those grown at the arid location (JUST). Lentil plants from large-seeded cultivars had greater seed yield, 1000- seed weight and plant height than those from small-seeded cultivars.

2.2 Effect of biochar

Glodowska *et al*. (2017) conducted greenhouse experiment in soybean plants to investigate the effect of biochars as carriers of bradyrhizobia in solid inoculant and noticed that application of biochar @ 5 t ha^{-1} significantly increased plant height from 49.87 to 57.07 cm and plant dry weight from 0.48g to 1.24 g and pod dry weight from 0.069 g to 0.133g, respectively.

Sharma *et al*. (2016) reported that poultry biochar was effective in significantly increasing the productivity of soybean when compared to urea and in poultry biochar applied treatment @ 10% the number of pods per plant increased from

6.50 to 15 and number of seeds per pod increased from 2.83 to 6.33 and length of pod from 3.25 to 6.33 cm and 100 seed dry weight from 10.34 to 18.24 g, respectively.

Hadiuzamman *et al.* (2015) reported that biochar amendment to soil is considered to be a sustainable technology as it increases crop yield along with carbon sequestration in soil. Biochar can be produced in many different ways resulting variable biochar qualities. Biochar production using low cost technologies is one of the important issues to be addressed for its extension in developing countries. A low cost biochar stove was developed and biochar was also produced. To validate stove derived biochar's affectivity, an experiment was conducted with biochar and three organic manures i.e. poultry litter, cowdung and vermicompost in two varieties of lentil i.e. BARI musur 4 and BARI musur 7. Among the organic matter amendments, biochar, vermicompost and poultry litter resulted in similar seed yield, respectively 1060, 972 and 988 kg ha^{-1}. However, there was a higher seed production in biochar amended plots compared to cow dung (689 kg ha^{-1}) received plots. Biochar in combination with BARI musur 7 provided the best yield (1120 kg ha^{-1}), indicating interactive effect between organic matter amendment and variety. The higher yield might be manifested due to higher water regime and biological nitrogen fixation in the biochar amended plot.

Xu *et al*. (2015) carried out glass house pot experiment by using peanut shell biochar at various application rates and noticed that at very high application rate of biochar @ 6 %, w/w (equivalent upto 85 t ha^{-1}) peanut yield improvement upto 77-200 % could be observed.

Ndor *et al*. (2015) conducted two year field experiment in 2011 and 2012 of soils having sandy loam texture by using rice husk and saw dust biochar on yield of sesame crop and observed that application of 10 t ha^{-1} of saw dust and rice husk biochar produced the highest number of pods per plant of 68, 71.82

and 63.1, 75.85 and highest seed weight of 0.93, 0.83 t ha^{-1} and 0.90, 0.95 t ha^{-1} in both the years respectively.

Carnaje *et al*. (2015) reported that application of bamboo biochar @ 2% on acidic soil increased the mung bean production by 27% in height, 8.5%- 15.7% for root nodules and up to 102% of pods.

Agegnehu *et al*. (2015) conducted a field experiment in Ferralsol and noticed that application of biochar @ 10 t ha^{-1} along with inorganic fertilizers significantly increased peanut seed and pod yield @ 5048 kg ha^{-1} and 6910 kg ha^{-1} than application of inorganic fertilizers alone @ 4167 kg ha^{-1} and 5617 kg ha^{-1}.

Islami *et al*. (2011) noticed significant yield improvement in peanut with the application of 15 t ha^{-1} farm yard manure biochar while Rondon *et al*. (2007) reported increase in bean yield by 46% and biomass production by 39% over the control by addition of 60 g kg^{-1} biochar.

2.3 Effect of vermicompost

Ceritoglu and Erman (2020) carried out this study to determine the effects of vermicompost on plant growth, seed yield and yield components depending on different sowing times. According to results, seedling emergence time and flowering time varied between 11.0-25.3 days and 130.7-181.7 days, respectively by vermicompost. Plant height, number of pods per plant, number of seeds per pod and seed yield changed between 35.8-57.1 cm, 20.8-54.5 pod $plant^{-1}$, 1.13-1.51 pieces $pod^{-1}$and 922- 2527 kg ha^{-1}, respectively. Therefore, 250 kg da^{-1} vermicompost applied in December 1^{st} is recommended to gain the highest seed yield. Accordingly, vermicompost might be an effective alternative to reduce harmful effects of chemical fertilizer to environment.

Ahmadpour and Hosseinzadeh (2017) conducted a study aimed to improve plant performance under moisture deficit stress in a greenhouse environment. Two factors were involved: addition of vermicompost to soil at four ratios: 0:100; 5:95; 15:85 and 25:75 and moisture deficit stress: 75, 50, and 25% of field capacity, respectively. Application of vermicompost in soil, especially at the levels of 15 and 25 Wt% significantly increased all studied traits under non-stress conditions. Under temperate and severe stress conditions, vermicompost at 25 Wt% treatment resulted in a significant increase in the plant height (+ 10% + 21%), number of pod (+44% + 65%), root dry weight (+63% +66%), shoot dry weight (+50% +89%), leaf area (+6% +7%), root area (+65% +35%).

Hadiuzamman *et al.* (2015) conducted an experiment to validate stove derived biochar's affectivity with biochar and three organic manures i.e. poultry litter, cowdung and vermicompost in two varieties of lentil i.e. BARImusur 4 and BARImusur 7. Among the organic matter amendments, biochar, vermicompost and poultry litter resulted in similar seed yield, respectively 1060, 972 and 988 kg ha^{-1}. However, there was a higher seed production in biochar amended plots compared to cow dung (689 kg ha^{-1}) received plots.

Singh *et al.* (2013) conducted a field experiment to study the effect of triacontanol, vermicompost and biofertilizers on growth, yield and quality of lentil genotypes. Treatments comprised four genotypes and six organics. Amongst the organics, vermicompost (4 t ha^{-1}) with Rhizobium + phosphate-solubilizing bacteria recorded significantly higher physiological parameters and grain yield (12.36 q ha^{-1}), but the highest net income (Rs.20270 ha^{-1}) was obtained from biofertilizers alone instead of triacontanol or vermicompost.

Mohammad *et al*. (2014) compared various organic sources for their effect of lentil production. In case of pods $plant^{-1}$, the vermicompost @ 1.5 t ha^{-1} performed the best (40.17), followed by biochar @ 2.2 t ha^{-1} (33.17) and poultry litter @ 4.4 t ha^{-1} and the lowest was in plot where no treatment was applied (29.50). Likewise, the number of seeds pod^{-1} was the maximum in the vermicompost @ 1.5 t ha^{-1} (1.56) which was statistically comparable with biochar @ 2.2 t ha^{-1} (1.55) and the lowest was recorded in the control one. Even though, the seed yield of lentil was the highest with biochar (1060 kg ha^{-1}) which was statistically at par to poultry litter (988 kg ha^{-1}) and vermicompost application (972 kg ha^{-1}). Therefore, overall, we can see that soil incorporation of vermicompost contributed their significant role in performance of lentil crop. To take advantage of organic source in production potential of lentil, this was further integrated with synthetic fertilizers. The experiment of Aggarwal and Ram (2011) proved the significance of integrated use of organic and inorganic fertilizers towards improvement in the yield attributing character and yield of lentil. They advocated enhanced pods $plant^{-1}$ (46.3) and biological yield (2876 kg ha^{-1}) with application of FYM @ 15 t ha^{-1} + RDF (12.5 kg N and 20 kg P_2O_5 ha^{-1}), might be due to the better plant nutrition and soil environment. Although, this difference with respect to seeds pod^{-1} and test weight of lentil remains non-significant in different fertilizer treatments.

Zeidan (2007) reported that plant height, number of branches per plant, number of pods per plant, 1000-seed weight, seed yield per plant, seed yield/feddan and straw yield/feddan of lentil were significantly affected by organic manure application. Increasing rates of applied organic manure from 0 to 20 m^3 /feddan markedly increased all the characters.

Rajkhowa *et al*. (2003) reported that 25-50% saving of fertilizer with the addition of 2.5 t ha^{-1} vermicompost, its significant increased the yield of green gram, nutrient uptake and nodulation and overall improved the soil health.

2.4 Effect of biochar with other organic manure

Studies have shown that biochar can be applied effectively with organic or inorganic fertilizers, compost, vermicompost, animal manures, and poultry manure to improve soil structure, fertility, NUE, and crop yield (Agegnehu *et al*., 2016, Trupiano *et al*., 2017).

Doan *et al*. (2015) applied biochar with vermicompost to maize and observed significant increase in crop growth and yield compared to untreated plots with biochar (control). Addition of willow (*Salix alba* L.) derived biochar with compost along with synthetic fertilizer significantly enhanced the maize growth in Ferralsol soil (Agegnehu *et al*., 2016).

According to Joseph *et al*. (2018), combined application of biochar with manures, composts, or other organic material can improve NUE as a result of slower leaching rates. Zhang *et al*. (2020) mixed organic fertilizer with biochar (1%) and observed an increase in root and shoot growth of cotton due to improved physiological activity of roots. Similarly, Omara *et al*. (2020) applied N (50–150 kg ha^{-1}) and biochar (5–15 Mg ha^{-1}) together to maize grown on a sandy soil. Results showed that biochar along with N increased NUE and maize grain yield. Mixing poultry litter biochar with fertilizers and manure significantly increased growth and fruit yield of cucumber (*Cucumis sativa* L.) by improving soil fertility and WHC in a sandy soil (Solaiman *et al*., 2020).

Adekiya *et al*. (2020) applied biochar (25–50 Mg ha^{-1}) alone and also in a mix with poultry manure (2.5–5.0 Mg ha^{-1}) in radish (*Raphanus raphanistrum*). At the end of the first year, authors reported an increase in radish yield for the biochar + poultry manure combined, but not for the biochar alone treatments when compared with the un-amended soil (control). Ibrahim *et al*. (2020) reported higher N uptake by plants following application of a biochar–N fertilizer compared to either biochar or N fertilizer alone.

Seleiman *et al*. (2019) applied rice straw biochar (10 Mg ha^{-1}) to sunflower grown under water in three water deficit stress treatments (i.e., 50%, no deficit; 70%, moderate deficit; 90%, severe deficit). After 30 and 55 d from germination, Si (150 g ha^{-1}) was exogenously applied (Jaafar *et al*., 2015). Results showed that severe water stress reduced oil and oleic acid contents by 18 and 25.8% compared to no water stress deficit (Seleiman *et al*., 2019). When biochar and silicon combined treatment was applied, on the other hand, oil and oleic acid contents increased by 10.2 and 12.2%, respectively (Seleiman *et al*., 2019). Similarly, seed yield under moderate and severe water deficit increased by about 27% in both cases when the biochar + Si treatment was applied, compared with similar water deficit treatments without any amendment (Seleiman *et al*., 2019). Therefore, for soil fertility and NUE especially, the addition of biochar with either organic or inorganic soil amendment is an appropriate practice.

Plant growth depends on adequate concentration of nutrients available in the soil solution, which can easily be taken up by plants. Deficiency of nutrients can decrease the plant growth and yield. Studies have suggested that biochar can increase the availability of C, N, Ca, Mg, K, and P to plants because biochar itself is a source of nutrients (Rodríguez-Vila *et al*., 2016, Abbas *et al*., 2021). In addition, it can absorb nutrients and then release them in a slow manner, thereby improving nutrient use efficiency. Many studies have shown that biochar amendments significantly increased the growth and biomass in various plant species (Seleiman *et al*., 2019, Solaiman, *et al*., 2020).

Incorporation of poultry litter biochar along with manure and fertilizers significantly enhanced biomass and fruit yield of cucumber (*Cucumis sativa* L.) by increasing soil WHC and nutrient concentration (Solaiman, *et al*., 2020). Yield of field mustard (*Brassica rapa* L.) was increased by 49% after the application of biochar compared to untreated soil with biochar (Khan *et al*., 2017). Similarly, Rafique *et al*. (2020) observed that soil amended with biochar increased the fresh and dry weight of maize by 50–55%. Sunflower growth and oil yield were increased under moderate and severe water deficit conditions after combined application of rice straw biochar and foliar spray of silicon (Seleiman *et al*., 2019).

Agegnehu *et al*. (2016) and Omara *et al*. (2020) reported an increase in maize growth and yield after the biochar incorporation. Similarly, Zhang *et al*. (2020) observed higher physiological activities of cotton root in biochar-amended soil than those obtained from untreated soil with biochar.

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted at the Sher-e-Bangla Agricultural University farm, Dhaka, Bangladesh to study the response of different proportion of biochar and vermicompost on yield and seed quality of lentil. The details of the materials and methods have been presented below:

3.1 Experimental site and duration

The research work was conducted at the Agronomy Farm of Sher-e-Bangla Agricultural University, Dhaka-1207 to find out the lentil seed yield and quality as affected by variety and biochar + vermicompost during the period from October 2019 to February 2020. Experimental field was located at 90°22´E longitude and 23°41´N latitude and altitude of 8.2 m above the sea level. The experimental site is presented in Appendix I.

3.2 Climate

Experimental area belongs to subtropical climatic zone which is characterized by heavy rainfall, high temperature and relatively long day period during "Kharif-1" season (April-September) and scarce rainfall, low humidity, low temperature and short day period during "Rabi" season (October-March). This climate is also characterized by distinct season, *viz*. the monsoon extending from May to October, the winter or dry season from November to February and per-monsoon period or hot season from March to April (Edris *et al.,* 1979). The meteorological data in respect of temperature, rainfall, relative humidity, average sunshine and soil temperature for the entire experimental period have been shown in Appendix II.

3.3 Characteristics of soil

The soil of the experimental area belongs to the Modhupur Tract in Agroecological Zone (AEZ)-28 (UNDP, 1988). It was medium high land and the soil series was Tejgaon (FAO, 1988). The soil was having a texture of sandy loam with pH and CEC were 5.6 and 2.64 meq/100 g soil, respectively. The characteristics of the soil under the experimental plot were analyzed in the Soil Testing laboratory, SRDI, Khamarbari, Dhaka and details of the recorded soil characteristics were presented in Appendix III.

3.4 Planting materials

Two lentil varieties *viz*. BARI masur-6 and BARI masur-7 were used as plant materials. About BARI masur-6 and BARI masur-7 are described as below:

3.4.1 BARI masur-6

BARI Masur-6 was developed by Pulses Research Centre, Ishurdi, Pabna in the year of 2006. It is a semi erect and medium statured and bushy cultivar. Plant height is of 35-40 cm. The leaves are dark green, with broad leaflets without tendrils. Flowers are light blue, and the pods and leaves turn to straw color during maturity stage Seed coat color is deep brown and cotyledons are bright orange. It has a 1000 seed weight of 19.84 g. It is resistant to rust/STB and tolerant to foot rot, moderately resistant to aphid. Its duration is 110-115 days. Average yield is 2500 kg ha^{-1}. Best sowing time is mid October to mid November and harvesting time is mid February to mid March.

3.4.2 BARI masur-7

BARI Masur-7 was developed by Pulses Research Centre, Ishurdi, Pabna in the year of 2011. BARI masur-7 is an erect cultivar with intensive branching and podding. The leaves are light green with narrow leaflets and rudimentary tendril. The flower is bluish-purple, and the pods, leaves and stems turn a light straw color at maturity. This variety contains high micronutrient especially Iron and Zinc. Seed coat- dark grey and cotyledon is bright orange. Its duration is 115-120 days. Average yield is 2200 kg ha^{-1}. Small fruit size with brownish color. Best sowing time is 1st week of November and harvesting time is late February.

3.5 Experimental Treatment

A pot experiment included two factors was as follows:

Factor A: Variety - 2

1. V_1= BARI masur-6
2. V_2= BARI masur-7

Factor B: Combination of Biochar and vermicompost - 6

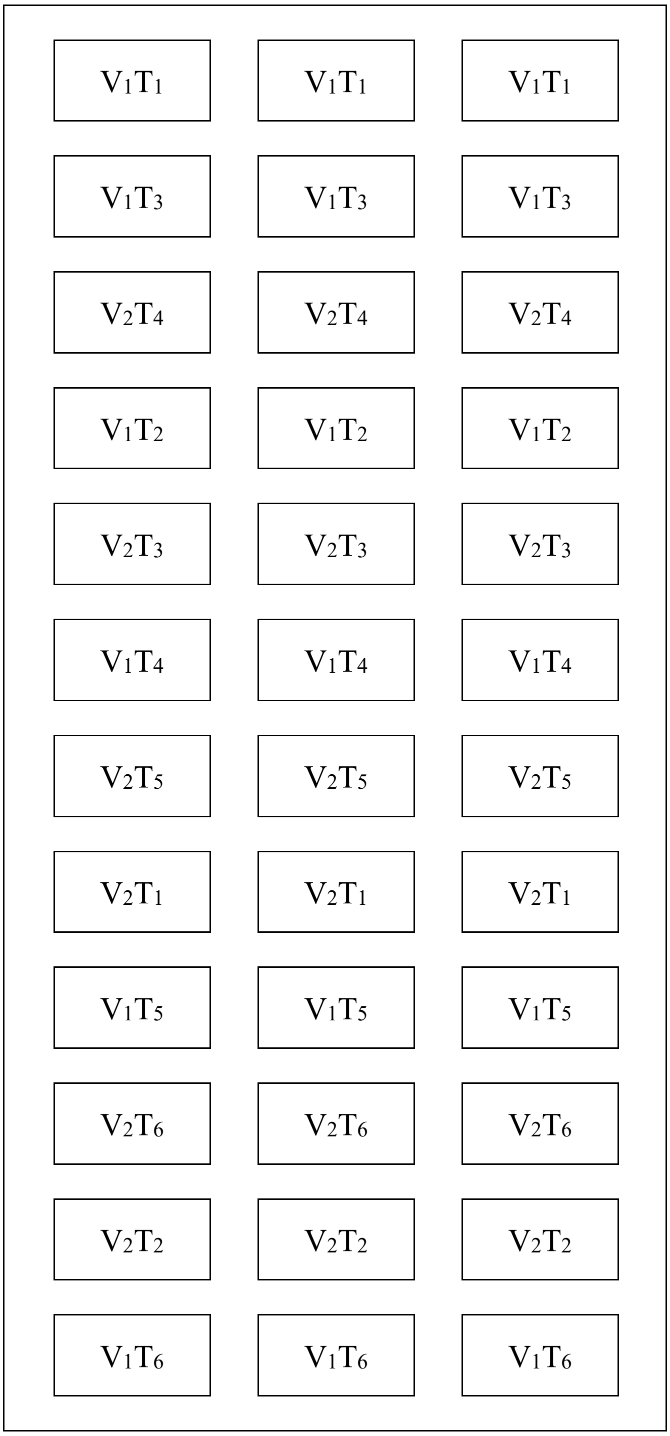
1. T_1 = 0 ton biochar ha^{-1} + 0 ton vermicompost ha^{-1}
2. T_2 = 5 ton biochar ha^{-1} + 0 ton vermicompost ha^{-1}
3. T_3 = 0 ton biochar ha^{-1} + 5 ton vermicompost ha^{-1}
4. T_4 = 1 ton biochar ha^{-1} + 4 ton vermicompost ha^{-1}
5. T_5 = 4 ton biochar ha^{-1} +1 ton vermicompost ha^{-1}
6. T_6 = 2.5 ton biochar ha^{-1} +2.5 ton vermicompost ha^{-1}

There were 12 (2×6) treatment combinations as given below:

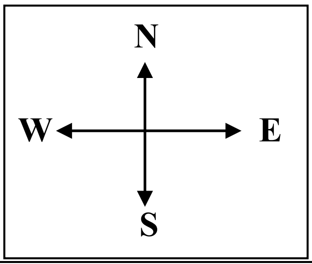
V_1T_1, V_1T_2, V_1T_3, V_1T_4, V_1T_5, V_1T_6, V_2T_1, V_2T_2, V_2T_3, V_2T_4, V_2T_5 and V_2T_6.

3.6 Experimental design and layout

The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. There were 12 treatment combinations. In total of 36 unit plastic pots were used for 12 treatment combination which were replicated thrice. The size of each unit pot was 40 cm in diameter and 30 cm in height with the depth of 25 cm. Four plants were grown per plastic pot. Layout of the experimented is presented in Figure 1.



Legend



Factor A: Variety - 2

1. V_1= BARI masur-6
2. V_2= BARI masur-7

Factor B: Biochar + vermicompost – 7 treatments

1. T_1 = 0 ton biochar ha^{-1} + 0 ton vermicompost ha^{-1}
2. T_2 = 5 ton biochar ha^{-1} + 0 ton vermicompost ha^{-1}
3. T_3 = 0 ton biochar ha^{-1} + 5 ton vermicompost ha^{-1}
4. T_4 = 1 ton biochar ha^{-1} + 4 ton vermicompost ha^{-1}
5. T_5 = 4 ton biochar ha^{-1} + 1 ton vermicompost ha^{-1}
6. T_6 = 2.5 ton biochar ha^{-1} + 2.5 ton vermicompost ha^{-1}

Figure 1. Layout of the experimental plot

3.7 Seed collection

The seeds of the test crop i.e., BARI masur-6 and BARI masur-7 were collected from Farm Division, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh.

3.8 Pot preparation

Before seed sowing, pots were prepared with soils according to treatments. Before pot preparation, soils were mixed with recommended chemical fertilizer doses according to Krishi Projukti Hat Boi (BARI, 2019). Urea, TSP and MoP were added at the rate of 40, 80 and 30 mg per 20 kg soil for each pot. Well, decomposed biochar and vermicompost were mixed with soil according to doses assigned of biochar and vermicompost regarding treatments of the study. Plastic pots were filled with 20 kg soil at 10 days before seed sowing. Soils were made completely stubbles and weed free. Pot preparation was completed on 18 October 2019.

3.9 Biochar and vermicompost application

Biochar and/or vermicompost were used according to the treatments in each pot. Regarding treatments, the doses of biochar and vermicompost were as follows:

1. 1 ton biochar ha^{-1} = 10 g biochar per pot
2. 1 ton vermicompost ha^{-1} = 10 g vermicompost per pot

Considering these rates of biochar and vermicompost, doses of other treatments were calculated and applied to the experimental pots.

3.10 Sowing of seeds

Seeds were sown in each pot to obtain 4 plants of lentil in each pot which was done on 20 November, 2019. Two seeds were sown in each hill dipping to 2-3 cm and covered with soil properly. Extra plantation was done in order to gap filling if needed.

3.11 Intercultural operation

Thinning operation was done to obtain optimum plant population at 15 days after sowing. Four plants were kept in each pot.

Two hand weddings were done; first weeding was given at 15 days after sowing followed by second weeding at 15 days after first weeding.

The young plants were irrigated by a watering can and at later stage irrigation was done at the same way in each pot whenever necessary.

The crop was infested by insects and diseases. Ripcord 10 EC @ 1 ml L^{-1} was applied twice at an interval of 1 week to control aphid. On the other hand Bavistin 250 WP @ 2 g L^{-1} was also applied twice at an interval of 1 week to control fungal disease. Both the pesticides were first applied on the appearance of the pest incidence.

3.12 Harvesting and Sampling

The crop was harvested at 115 DAS on 13 March 2020. The crop was harvested pot wise when about 80% of the pods became mature. Samples were collected from each pot. The harvested crops were tied into bundles and carried to the threshing floor. Harvesting was done in the morning to prevent shattering of seeds. Seeds were separated and data were recorded on seed and stover after sun drying.

3.13 Threshing, cleaning, drying and weighing

The crop was sun dried for three to five days by placing them on the open threshing floor. Seeds were separated from the plants by beating the bundles with bamboo sticks. The seeds thus collected were dried in the sun for reducing the moisture in the seeds to a constant level (8%).

The dried seeds and straw were cleaned and weighed. After putting the seeds in airtight polythene bags, these were kept in dry and cool place at room temperature for storing.

The seeds thus collected were dried in the sun for reducing the moisture in the seeds to a constant level. The dried seeds and straw were cleaned and weighed.

3.14 Seed Quality

Seeds obtained from the field experiment were taken separately as treatment wise. These seeds were used for taking quality determination in the laboratory. For this purpose standard germination test was conducted and other different quality attributed data were taken.

3.15 Collection of data

The data were recorded on the following parameters:

3.15.1 Growth parameters

1. Plant height (cm)
2. Number of leaves plant^{-1}
3. Number of branches plant^{-1}

3.15.2 Yield contributing parameters

1. Dry weight plant^{-1} (g)
2. Number of pods plant^{-1}
3. Number of seeds pod^{-1}
4. Pod length (cm)
5. Number of seeds plant^{-1}
6. 100 seed weight (g)

3.15.3 Yield parameters

1. Seed yield plant^{-1} (g)
2. Stover yield plant^{-1} (g)
3. Biological yield plant^{-1} (g)
4. Harvest index (%)

3.15.4 Seed quality parameters

1. Germination (%)
2. Shoot length (cm)
3. Root length (cm)
4. Seed Vigor index

3.16 Procedure of data

Data on the following characters were collected from experimental plots and selected plants.

3.16.1 Plant height

The height of the 4 plants of each replication of each treatment was measured from the ground level to the tip of the largest leaf at 20, 40, 60 DAS and at harvest. Mean highest was them calculated.

3. 16.2 Number of leaves plant^{-1}

Total number of leaves was counted from 4 plants of each replication of each treatment at 30, 60, 90 DAS and at harvest and the mean number of leaves was then taken.

3.16.3 Number of branches plant^{-1}

The number of branches plant^{-1} was counted from 4 plants of each replication of each treatment. It was done by counting total number of branches of all sampled plants then the average data were recorded.

3.16.4 Dry weight plant^{-1}

Dry weight plant^{-1} was measured after harvest. Selected plants after harvest (4 plants of each replication of each treatment) were taken and oven dried for 72 hours at 70°C and averaged and then dry weight plant^{-1} was determined.

3. 16.5 Number of pods plant^{-1}

Number of umbel plant^{-1} was counted from selected plant samples (4 plants of each replication of each treatment) and then the average pod number was calculated.

3.16.6 Number of seeds pod^{-1}

The Seeds pod^{-1} was counted from 20 selected pods of plants and then the average seed number was calculated.

3. 16.7 Pod length

The length of pod was measured by meter scale from 20 pods of plants and then the average pod length was calculated.

3. 16.8 Number of seeds plant^{-1}

Total seeds were counted from selected plants (4 plants of each replication of each treatment) and then the average seed number was calculated.

3. 16.9 Weight of 100 seeds

Randomly 100 seeds were counted from each replication of each treatment, which were weighed by an electrical balance and data were recorded in gram (g).

3. 16.10 Seed yield plant^{-1}

The selected plants (4 plants of each replication of each treatment) were harvested to take seed yield per plant. The seed were threshed, cleaned, dried, weighed and adjusted at 8% moisture content and then averaged in gram (g).

3. 16.11 Stover yield plant^{-1}

After harvest of selected plants (4 plants of each replication of each treatment), seed were separated by threshing and separated stover were dried, weighed and then averaged in gram (g).

3.16.12 Biological yield plant^{-1}

The summation of seed yield and above ground stover yield was the biological yield. Biological yield = Grain yield + Stover yield.

3. 16.13 Harvest index

Harvest index was calculated on dry basis with the help of following procedure

$$\text{Harvest index (HI\%)} = \frac{\text{Seed yield plant}^{-1}}{\text{Biological yield plant}^{-1}} \times 100$$

Here, Biological yield = Grain yield plant^{-1} + stover yield plant^{-1}

3. 16.14 Seed quality

3. 16.14.1 Percent seed germination (%)

Produced seeds from the present experiment, percent seed germination were tested in the Laboratory. After 15 days of harvest, germination test was conducted. Germination was calculated as the number of seeds which was germinated within 12 days as a proportion of number of seeds set for germination test in each treatment.

$$\text{Germination percentage} = \frac{\text{Number of germinated seeds}}{\text{Total number of seeds set for germination}} \times 100$$

3.16.14.2 Root length

The Root length of ten seedlings from each sample was recorded finally at 12 days of germination test. Measurement was done using a meter scale and unit was expressed in centimeter (cm).

3.16.14.3 Shoot length

The shoot length of ten seedlings from each sample was measured finally at 12 days of germination test. Measurement was done using the unit centimeter (cm) by a meter scale.

3.16.14.4 Seed vigor index

The vigor index (VI) of the seedlings can be estimated as suggested by Abdul-Baki and Anderson (1973):

$$VI = (RL + SL) \times GP$$

Where , RL = root length (cm)

SL = shoot length (cm) and

GP = germination percentage

3.17 Statistical analysis

The collected data were compiled and tabulated. Statistical analysis was done on various plant characters to find out the significance of variance resulting from the experimental treatments. Data were analyzed using analysis of variance (ANOVA) technique with the help of computer package programme MSTAT-C (software) and the mean differences were adjudged by least significant difference test (LSD) as laid out by Gomez and Gomez (1984).

CHAPTER IV

RESULTS AND DISCUSSION

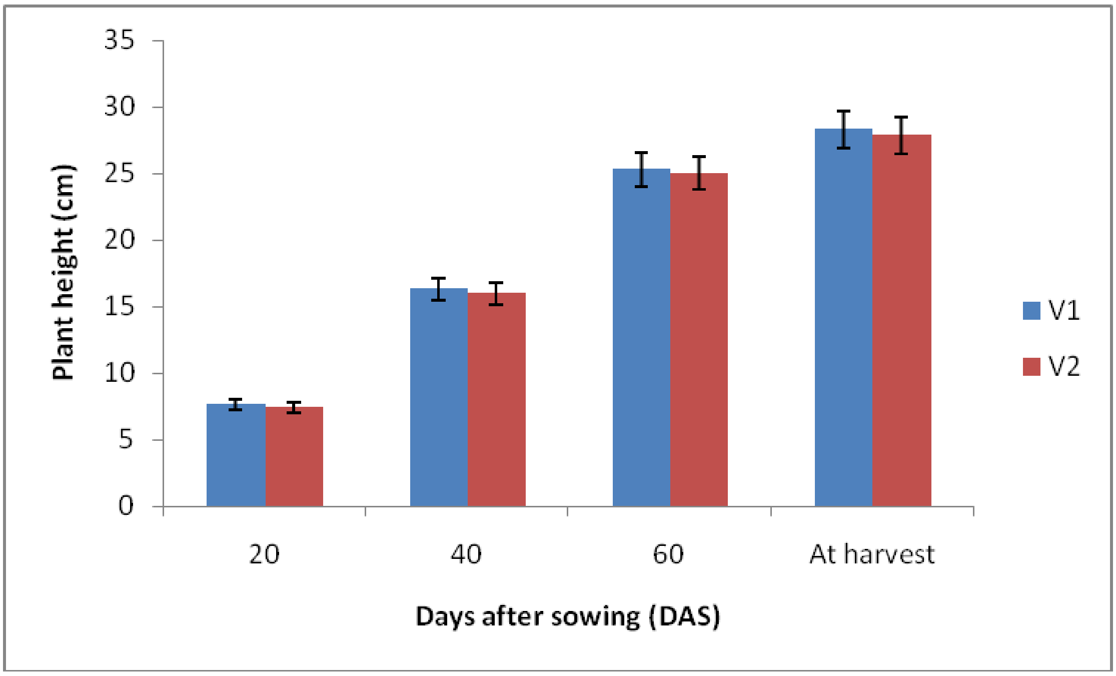
The study was carried out to find the response of different proportion of biochar and vermicompost on yield and seed quality of lentil. The results have been presented through Tables and Figures. Different parameters of the lentil cultivars influenced by variety and biochar and vermicompost have been presented and discussed under separate heads and sub–heads as follows:

4.1 Growth parameters

4.1.1 Plant height

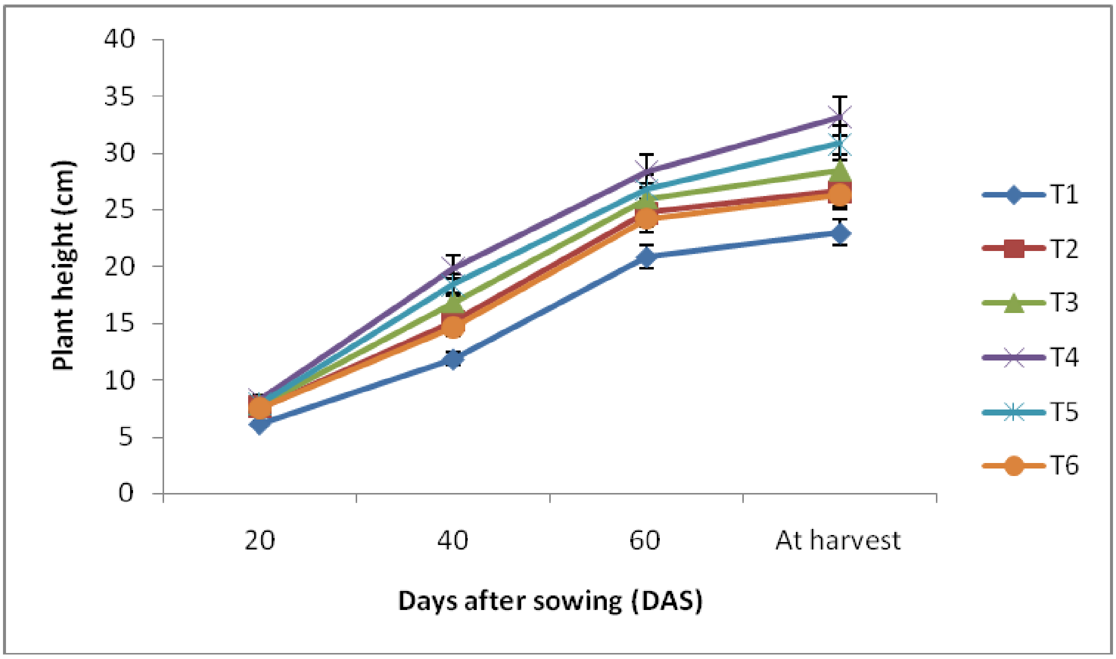
Plant height of lentil was not significantly influenced of different varieties at different growth stages (Figure 2 and Appendix IV). However, at 20, 40 and 60 DAS and at harvest, the maximum plant height (7.64, 16.29, 25.29 and 28.29 cm, respectively) was recorded from the variety V_1 (BARI masur-6) whereas the minimum plant height (7.40, 15.96, 25.00 and 27.84 cm, respectively) was found from the variety V_2 (BARI masur-7). Hasan *et al.* (2015) also found similar resut with the present study and found non-significant difference among plant height of BARI Masur-5, BARI Masur-6 and BARI Masur-7.

There was significant difference among the different treatments of biochar + vermicompost regarding plant height of lentil at different growth stages except at 20 DAS (Figure 3 and Appendix IV). Results indicated that at 20, 40 and 60 DAS and at harvest, the maximum plant height (8.28, 19.92, 28.40 and 33.22 cm, respectively) was recorded from the treatment T_4 (1 ton biochar ha^{-1} + 4 ton vermicompost ha^{-1}) which were followed by T_5 (4 ton biochar ha^{-1} +1 ton vermicompost ha^{-1}) whereas the minimum plant height (6.12, 11.85, 20.85 and 22.95 cm, respectively) was found from the control treatment T_1 (0 ton biochar ha^{-1} + 0 ton vermicompost ha^{-1}).



V_1= BARI masur-6, V_2= BARI masur-7

Figure 2. Plant height of lentil as influenced by different lentil varieties ($LSD_{0.05}$ = NS at all growth stages) (NS = Non-significant)



T_1 = 0 ton biochar ha^{-1} + 0 ton vermicompost ha^{-1}, T_2 = 5 ton biochar ha^{-1} + 0 ton vermicompost ha^{-1}, T_3 = 0 ton biochar ha^{-1} + 5 ton vermicompost ha^{-1}, T_4 = 1 ton biochar ha^{-1} + 4 ton vermicompost ha^{-1}, T_5 = 4 ton biochar ha^{-1} +1 ton vermicompost ha^{-1}, T_6 = 2.5 ton biochar ha^{-1} +2.5 ton vermicompost ha^{-1}

Figure 3. Plant height of lentil as influenced by different combinations of biochar and vermicompost ($LSD_{0.05}$ = 2.45^{NS}, 0.932, 0.938, 1.008 at 20, 40, 60 DAS and at harvest, respectively) (NS = Non-significant)

The treatment combinations of variety and biochar + vermicompost had significant effect on plant height of lentil at different growth stages except at 20 DAS (Table 1 and Appendix IV). Results showed that the maximum plant height (8.53, 20.10, 28.93 and 33.33 cm, respectively) was achieved by the treatment combination of V_1T_4 that was significantly similar to the treatment combination of V_2T_4 at all growth stages followed by V_2T_5. The minimum plant height (5.93, 11.73, 20.80 and 22.93 cm, respectively) was found from the treatment combination of V_2T_1 that was significantly similar to the treatment combination of V_1T_1 at all growth stages.

Table 1. Plant height of lentil varieties as influenced by different combination of biochar and vermicompost

Treatments	Plant height (cm)			
	20 DAS	40 DAS	60 DAS	Harvest
V_1T_1	6.30	11.97 g	20.90 f	22.97 e
V_1T_2	7.67	15.60 de	25.40 cd	27.03 d
V_1T_3	7.87	17.07 c	26.03 c	29.30 c
V_1T_4	8.53	20.10 a	28.93 a	33.33 a
V_1T_5	7.90	17.83 bc	26.07 c	30.63 bc
V_1T_6	7.57	15.17 ef	24.43 de	26.47 d
V_2T_1	5.93	11.73 g	20.80 f	22.93 e
V_2T_2	7.47	14.80 ef	24.03 e	26.23 d
V_2T_3	7.77	16.57 cd	25.90 c	27.63 d
V_2T_4	8.03	19.73 a	27.87 ab	33.10 a
V_2T_5	7.80	18.87 ab	27.47 b	31.03 b
V_2T_6	7.40	14.07 f	23.93 e	26.13 d
$LSD_{0.05}$	NS	1.329	1.316	1.504
CV(%)	13.8	9.87	9.41	7.16

V_1= BARI masur-6, V_2= BARI masur-7

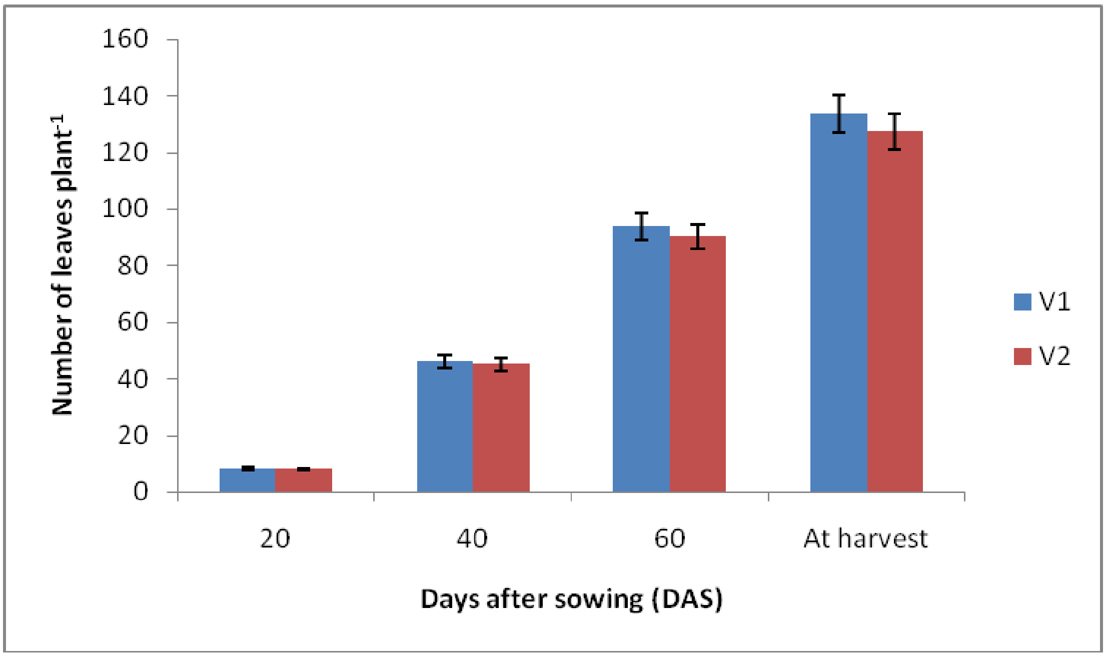
T_1 = 0 ton biochar ha^{-1} + 0 ton vermicompost ha^{-1}, T_2 = 5 ton biochar ha^{-1} + 0 ton vermicompost ha^{-1}, T_3 = 0 ton biochar ha^{-1} + 5 ton vermicompost ha^{-1}, T_4 = 1 ton biochar ha^{-1} + 4 ton vermicompost ha^{-1}, T_5 = 4 ton biochar ha^{-1} +1 ton vermicompost ha^{-1}, T_6 = 2.5 ton biochar ha^{-1} +2.5 ton vermicompost ha^{-1}

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

4.1.2 Number of leaves plant^{-1}

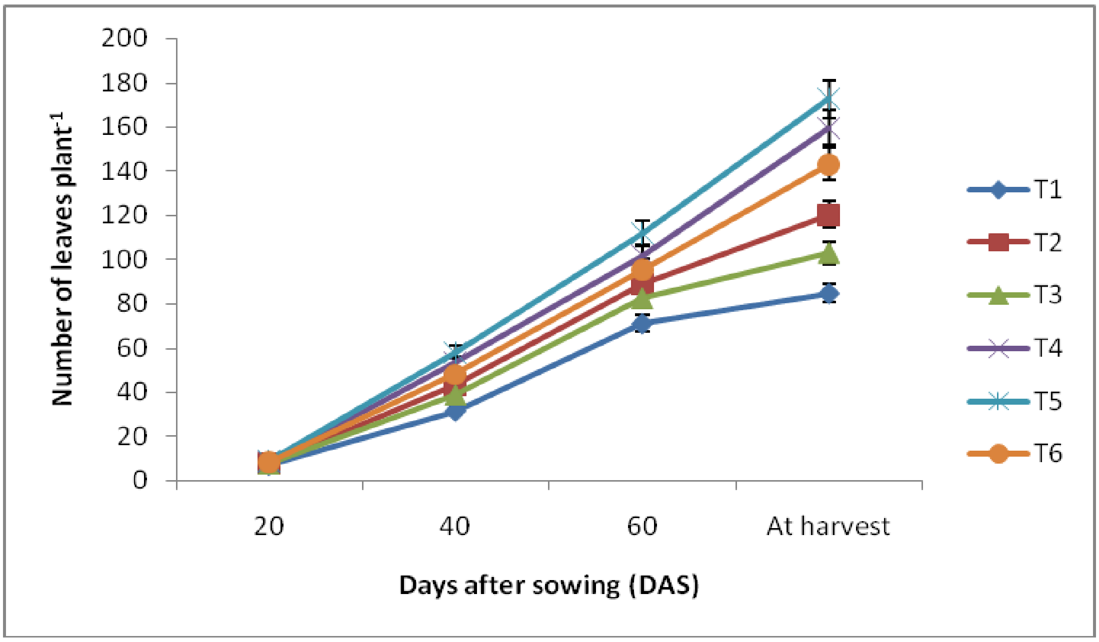
Different varieties of lentil at different growth stages showed significant variation on number of leaves plant^{-1} except at 20 and 40 DAS (Figure 4 and Appendix V). However, the highest number of leaves plant^{-1} (8.06, 46.00, 93.78 and 133.61 at 20, 40 and 60 DAS and at harvest, respectively) was recorded from the variety V_1 (BARI masur-6) whereas the lowest number of leaves plant^{-1}(7.89, 45.11, 90.22 and 127.50 at 20, 40 and 60 DAS and at harvest, respectively) was recorded from the variety V_2 (BARI masur-7). Similar result was also observed by the study of Biswas *et al*. (2018) and Mondal *et al*. (2013).

At 20 DAS, non-significant difference on number of leaves plant^{-1}of lentil was recorded but at 40 and 60 DAS and at harvest, number of leaves plant^{-1} was influenced significantly due to application of different doses of biochar + vermicompost (Figure 5 and Appendix V). Results indicated that the treatment T_5 (4 ton biochar ha^{-1} +1 ton vermicompost ha^{-1}) showed the highest number of leaves plant^{-1} (9.17, 58.00, 111.80 and 172.70 at 20, 40 and 60 DAS and at harvest, respectively) followed by T_4 (1 ton biochar ha^{-1} + 4 ton vermicompost ha^{-1}) whereas control treatment T_1 (0 ton biochar ha^{-1} + 0 ton vermicompost ha^{-1}) showed the lowest number of leaves plant^{-1}(7.17, 31.67, 71.17 and 84.83 at 20, 40 and 60 DAS and at harvest, respectively) that was significantly different from other treatments. This result suggested that variation on organic manure (biochar and vermicompost) doses showed significant variation on plant height of lentil that was supported by Glodowska *et al*. (2017) and Ceritoglu and Erman (2020); they found significant variation on plant height due to variation on different doses of biochar or vermicompost. Similar result was also observed by Ahmadpour and Hosseinzadeh (2017).



V_1= BARI masur-6, V_2= BARI masur-7

Figure 4. Number of leaves plant^{-1} of lentil as influenced by different lentil varieties ($LSD_{0.05}$ = 1.11^{NS}, 1.213^{NS}, 1.024 and 2.366at 20, 40, 60 DAS and at harvest, respectively) (NS = Non-significant)



T_1 = 0 ton biochar ha^{-1} + 0 ton vermicompost ha^{-1}, T_2 = 5 ton biochar ha^{-1} + 0 ton vermicompost ha^{-1}, T_3 = 0 ton biochar ha^{-1} + 5 ton vermicompost ha^{-1}, T_4 = 1 ton biochar ha^{-1} + 4 ton vermicompost ha^{-1}, T_5 = 4 ton biochar ha^{-1} +1 ton vermicompost ha^{-1}, T_6 = 2.5 ton biochar ha^{-1} +2.5 ton vermicompost ha^{-1}

Figure 5. Number of leaves plant^{-1}of lentil as influenced by different combinations of biochar and vermicompost ($LSD_{0.05}$ = 2.06^{NS}, 2.131, 3.402 and3.533 at 20, 40, 60 DAS and at harvest, respectively) (NS = Non-significant)

Different combinations of variety and biochar + vermicompost gave statistically significant influence on number of leaves plant^{-1} of lentil at different growth stages except at 30 DAS (Table 2 and Appendix V). However, results indicated that the highest number of leaves plant^{-1}(9.33, 58.33, 112.70 and 173.70 at 20, 40 and 60 DAS and at harvest, respectively) was recorded from the treatment combination of V_1T_5 that was statistically same to the treatment combination of V_2T_5 at all growth stages followed by V_1T_4 and V_2T_4. On the other hand, the lowest number of leaves plant^{-1}(7.00, 31.33, 70.33 and 84.33 at 20, 40 and 60 DAS and at harvest, respectively) was found from the treatment combination of V_2T_1 that was statistically same to the treatment combination of V_1T_1.

Table 2. Number of leaves plant^{-1}of lentil varieties as influenced by different combination of biochar and vermicompost

Treatments	Number of leaves plant^{-1}			
	20 DAS	40 DAS	60 DAS	Harvest
V_1T_1	7.33	32.00 g	72.00 h	85.330 h
V_1T_2	7.67	44.67 de	91.67 e	128.30 e
V_1T_3	7.67	39.00 f	84.67 fg	104.00 g
V_1T_4	8.33	53.67 b	104.00 b	161.70 b
V_1T_5	9.33	58.33 a	112.70 a	173.70 a
V_1T_6	8.00	48.33 c	97.67 cd	148.70 c
V_2T_1	7.00	31.33 g	70.33 h	84.33 h
V_2T_2	7.67	42.33 e	86.67 f	112.00 f
V_2T_3	7.33	38.33 f	80.33 g	102.00 g
V_2T_4	8.00	53.33 b	99.67 bc	157.30 b
V_2T_5	9.00	57.67 a	111.00 a	171.70 a
V_2T_6	8.33	47.67 cd	93.33 de	137.70 d
$LSD_{0.05}$	NS	3.019	4.987	5.019
CV(%)	12.29	8.91	10.20	12.27

V_1= BARI masur-6, V_2= BARI masur-7

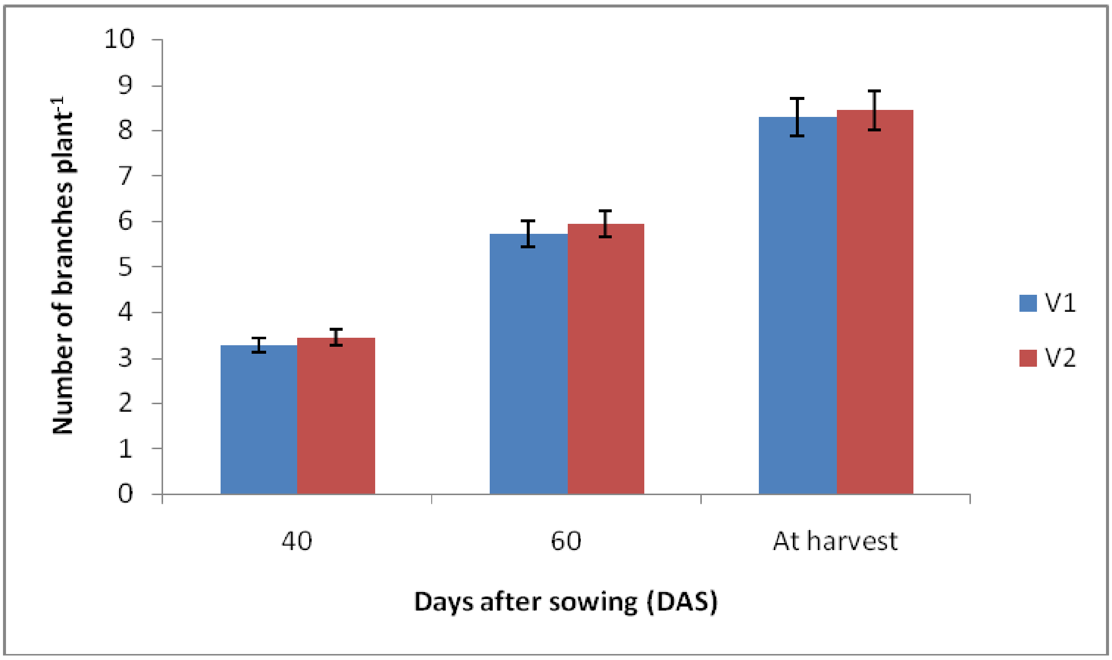
T_1 = 0 ton biochar ha^{-1} + 0 ton vermicompost ha^{-1}, T_2 = 5 ton biochar ha^{-1} + 0 ton vermicompost ha^{-1}, T_3 = 0 ton biochar ha^{-1} + 5 ton vermicompost ha^{-1}, T_4 = 1 ton biochar ha^{-1} + 4 ton vermicompost ha^{-1}, T_5 = 4 ton biochar ha^{-1} +1 ton vermicompost ha^{-1}, T_6 = 2.5 ton biochar ha^{-1} +2.5 ton vermicompost ha^{-1}

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

4.1.3 Number of branches plant^{-1}

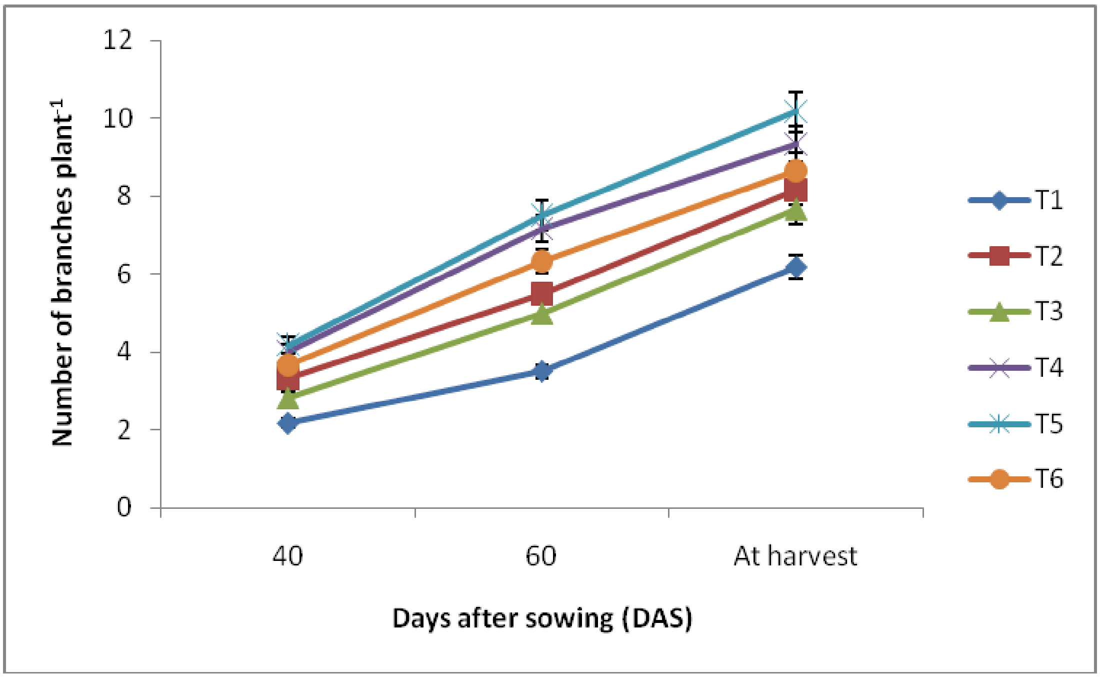
There was a non-significant variation on number of branches plant^{-1} at different growth stages influenced by different varieties of lentil (Figure 6 and Appendix VI). However, the highest number of branches plant^{-1} (3.44, 5.94 and 8.44 at 40 and 60 DAS and at harvest, respectively) was recorded from the variety V_2 (BARI masur-7) whereas the lowest number of branches plant^{-1} (3.28, 5.72 and 8.28 at 40 and 60 DAS and at harvest, respectively) was recorded from the variety V_1 (BARI masur-6). Singh *et al.* (2011) found similar result with the present study and obtained non-significant variation on number of branches plant^{-1} among different varieties of lentil.

Significant variation was observed on number of branches plant^{-1} of lentil at different growth stages influenced by different levels of biochar + vermicompost (Figure 7 and Appendix VI). It was observed that the treatment T_5 (4 ton biochar ha^{-1} +1 ton vermicompost ha^{-1}) gave the highest number of branches plant^{-1} (4.17, 7.50 and 10.17 at 40 and 60 DAS and at harvest, respectively) which was statistically identical with T_4 (1 ton biochar ha^{-1} + 4 ton vermicompost ha^{-1}) at all growth stages. Again, the control treatment T_1 (0 ton biochar ha^{-1} + 0 ton vermicompost ha^{-1}) showed the lowest number of branches plant^{-1} (2.17, 3.50 and 6.17 at 40 and 60 DAS and at harvest, respectively) that was significantly different from other treatments. Zeidan (2007) also reported similar result with the present study.



V_1= BARI masur-6, V_2= BARI masur-7

Figure 6. Number of branches plant^{-1} of lentil as influenced by different lentil varieties ($LSD_{0.05}$ = NS at all growth stages) (NS = Non-significant)



T_1 = 0 ton biochar ha^{-1} + 0 ton vermicompost ha^{-1}, T_2 = 5 ton biochar ha^{-1} + 0 ton vermicompost ha^{-1}, T_3 = 0 ton biochar ha^{-1} + 5 ton vermicompost ha^{-1}, T_4 = 1 ton biochar ha^{-1} + 4 ton vermicompost ha^{-1}, T_5 = 4 ton biochar ha^{-1} +1 ton vermicompost ha^{-1}, T_6 = 2.5 ton biochar ha^{-1} +2.5 ton vermicompost ha^{-1}

Figure 7. Number of branches plant^{-1} of lentil as influenced by different combination of biochar and vermicompost ($LSD_{0.05}$ = 0.227, 0.662 and 0.523 at 40, 60 DAS and at harvest, respectively)

Significant influence was found on number of branches plant^{-1} of lentil at different growth stages affected by treatment combinations of lentil variety and biochar + vermicompost (Table 3 and Appendix VI). It was exposed that the highest number of branches plant^{-1} (4.33, 7.67 and 10.33 at 40 and 60 DAS and at harvest, respectively) was recorded from the treatment combination of V_2T_5 which was statistically similar with the treatment combination of V_1T_5 at all growth stages followed by V_1T_4 and V_2T_4. On the other hand, the lowest number of branches plant^{-1} (2.00, 3.33 and 6.00 at 40 and 60 DAS and at harvest, respectively) was recorded from the treatment combination of V_1T_1 that was statistically similar to the treatment combination of V_2T_1 at all growth stages.

Table 3. Number of branches plant^{-1} of lentil varieties as influenced by different combination of biochar and vermicompost

Treatments	Number of branches plant^{-1}		
	40 DAS	60 DAS	Harvest
V_1T_1	2.00 g	3.33 e	6.00 f
V_1T_2	3.33 cd	5.33 cd	8.00 de
V_1T_3	2.67 ef	5.00 d	7.67 e
V_1T_4	4.00 ab	7.00 ab	9.33 bc
V_1T_5	4.00 ab	7.33 ab	10.00 ab
V_1T_6	3.67 bc	6.33 bc	8.67 cd
V_2T_1	2.33 fg	3.67 e	6.33 f
V_2T_2	3.33 cd	5.67 cd	8.33 de
V_2T_3	3.00 de	5.00 d	7.67 e
V_2T_4	4.00 ab	7.33 ab	9.33 bc
V_2T_5	4.33 a	7.67 a	10.33 a
V_2T_6	3.67 bc	6.33 bc	8.67 cd
$LSD_{0.05}$	0.541	1.052	0.74
CV(%)	9.37	10.66	11.29

V_1= BARI masur-6, V_2= BARI masur-7

T_1 = 0 ton biochar ha^{-1} + 0 ton vermicompost ha^{-1}, T_2 = 5 ton biochar ha^{-1} + 0 ton vermicompost ha^{-1}, T_3 = 0 ton biochar ha^{-1} + 5 ton vermicompost ha^{-1}, T_4 = 1 ton biochar ha^{-1} + 4 ton vermicompost ha^{-1}, T_5 = 4 ton biochar ha^{-1} +1 ton vermicompost ha^{-1}, T_6 = 2.5 ton biochar ha^{-1} +2.5 ton vermicompost ha^{-1}

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

4.2 Yield contributing parameters

4.2.1 Dry weight plant^{-1}

The effect of lentil variety on dry weight plant^{-1} had significant effect (Table 4 and Appendix VII). Results showed that the variety V_2 (BARI masur-7) gave the highest dry weight plant^{-1} (8.84 g) whereas the lowest dry weight plant^{-1} (7.81 g) was given by the variety V_1 (BARI masur-6). The result from the present study was in agreement with the findings of Baidya *et al*. (2018), Biswas *et al*. (2018) and Hasan *et al.* (2015).

Different biochar + vermicompost treatment had significant effect on dry weight plant^{-1} of lentil (Table 4 and Appendix VII). Treatment T_5 (4 ton biochar ha^{-1} +1 ton vermicompost ha^{-1}) registered the highest dry weight plant^{-1} (10.16 g) that was statistically same to T_4 (1 ton biochar ha^{-1} + 4 ton vermicompost ha^{-1}) followed by T_2 (5 ton biochar ha^{-1} + 0 ton vermicompost ha^{-1}) and T_6 (2.5 ton biochar ha^{-1} +2.5 ton vermicompost ha^{-1}) whereas control treatment T_1 (0 ton biochar ha^{-1} + 0 ton vermicompost ha^{-1}) gave the lowest dry weight plant^{-1} (6.25 g) that was significantly different to other treatments. Similar result was also reported by Glodowska *et al*. (2017) and Sharma *et al*. (2016).

Combined effect of different lentil variety and biochar + vermicompost treatment showed significant variation on dry weight plant^{-1} of lentil (Table 4 and Appendix VII). The highest dry weight plant^{-1} (10.24 g) was recorded from the treatment combination of V_2T_5 which was statistically similar to the treatment combination of V_1T_5 followed by V_1T_4 and V_2T_4 whereas the lowest dry weight plant^{-1} (6.22 g) was recorded from the treatment combination of V_1T_1 that was statistically same to V_2T_1.

4.2.2 Number of pods plant^{-1}

Number of pods plant^{-1} of lentil affected significantly due to varietal difference (Table 4 and Appendix VII). Results showed that the highest number of pods plant^{-1} (49.54) was recorded from the variety V_2 (BARI masur-7) whereas the lowest number of pods plant^{-1} (45.69) was recorded from variety V_1 (BARI masur-6). Awal and Roy (2015) and Datta *et al.* (2013) also found significant variation on number of pods plant^{-1} among different varieties of lentil which supported the present findings.

Application of different levels of biochar + vermicompost gave significant effect on number of pods plant^{-1} of lentil (Table 4 and Appendix VII). Results showed that the highest number of pods plant^{-1} (63.08) was recorded from the treatmentT_5 (4 ton biochar ha^{-1} +1 ton vermicompost ha^{-1}) that was significantly different to other treatments followed by T_4 (1 ton biochar ha^{-1} + 4 ton vermicompost ha^{-1}) whereas the lowest number of pods plant^{-1} (33.33) was recorded from the control treatment T_1 (0 ton biochar ha^{-1} + 0 ton vermicompost ha^{-1}) that was significantly different with other treatments. Supported result was also found from the findings of Mohammad *et al*. (2014), *et al*. (2016) and Ceritoglu and Erman (2020).

Number of pods plant^{-1} of lentil influenced significantly due to different combination of lentil variety and biochar + vermicompost treatments (Table 4 and Appendix VII). It was found that the highest number of pods plant^{-1} (63.40) was recorded from the treatment combination of V_2T_5 which was significantly same to V_1T_5 followed by V_1T_4. The lowest number of pods plant^{-1} (32.72) was recorded from the treatment combination of V_1T_1 which was significantly same to V_2T_1.

4.2.3 Number of seeds pod^{-1}

Non-significant variation was recorded on number of seeds pod^{-1} between two varieties of lentil (Table 4 and Appendix VII). However, the highest number of seeds pod^{-1} (1.64) was recorded from the variety V_2 (BARI masur-7)whereas the lowest number of seeds pod^{-1} (1.62) was recorded from the variety V_1 (BARI masur-6). The result obtained from the present study was supported by the findings of Hasan *et al.* (2015).

Significant variation was found on number of seeds pod^{-1} of lentil by the application of different biochar + vermicompost levels (Table 4 and Appendix

VII). The highest number of seeds pod^{-1} (1.79) was recorded from the treatmentT_5 (4 ton biochar ha^{-1} +1 ton vermicompost ha^{-1}) followed by T_4 (1 ton biochar ha^{-1} + 4 ton vermicompost ha^{-1}) whereas the lowest number of seeds pod^{-1} (1.49) was recorded from the control treatment T_1 (0 ton biochar ha^{-1} + 0 ton vermicompost ha^{-1}) that was significantly different to other treatments. Supported result was also found from the findings of Mohammad *et al*. (2014) and Sharma *et al*. (2016).

Number of seeds pod^{-1} of lentil varied significantly among the different combination of variety and biochar + vermicompost treatments (Table 4 and Appendix VII). The highest number of seeds pod^{-1} (1.80) was recorded from the treatment combination of V_2T_5 that was statistically same to the treatment combination of V_1T_5. The lowest number of seeds pod^{-1} (1.48) was recorded from the treatment combination of V_1T_1 which was statistically similar with the treatment combination of V_2T_1 and V_2T_3.

4.2.4 Pod length

Pod length of lentil showed non-significant variation due to varietal difference (Table 4 and Appendix VII). However, the highest pod length (0.89 cm) was recorded from the variety V_2 (BARI masur-7) whereas the lowest pod length (0.88 cm) was recorded from the variety V_1 (BARI masur-6)

Different combinations of biochar + vermicompost application gave non-significant difference on pod length of lentil (Table 4 and Appendix VII). However, the highest pod length (0.91 cm) was recorded from the treatmentT_5 (4 ton biochar ha^{-1} +1 ton vermicompost ha^{-1}) followed by T_4 (1 ton biochar ha^{-1} + 4 ton vermicompost ha^{-1}) whereas the lowest pod length (0.86 cm) was recorded from the control treatment T_1 (0 ton biochar ha^{-1} + 0 ton vermicompost ha^{-1}). Sharma *et al*. (2016) also found similar result with the present study who found significantly increased pod length with poultry biocher treatment @ 10% compared to urea in soybean.

Different treatment combination of variety and biochar + vermicompost showed significant variation on pod length of lentil (Table 4 and Appendix VII). However, treatment combination of V_2T_5 recorded the highest pod length (0.92 cm) followed by V_1T_4 and V_1T_5 whereas the lowest pod length (0.85 cm) was recorded from the treatment combination of V_1T_1.

4.2.5 Number of seeds plant^{-1}

Number of seeds plant^{-1} of lentil showed significant influence due to varietal performance (Table 4 and Appendix VII). The highest number of seeds plant^{-1} (82.61) was recorded from variety V_2 (BARI masur-7) whereas the lowest number of seeds plant^{-1} (75.67) was recorded from the variety V_1 (BARI masur-6). Supported result was also found from the findings of Datta *et al.* (2013) and observed significant variation on number of seeds plant^{-1} due to varietal difference.

Different levels of biochar + vermicompost application gave significant difference on number of seeds plant^{-1} of lentil (Table 4 and Appendix VII). The highest number of seeds plant^{-1} (113.50) was recorded from the treatmentT_5 (4 ton biochar ha^{-1} +1 ton vermicompost ha^{-1}) followed by T_4 (1 ton biochar ha^{-1} + 4 ton vermicompost ha^{-1}) whereas the lowest number of seeds plant^{-1} (50.17) was recorded from the control treatment T_1 (0 ton biochar ha^{-1} + 0 ton vermicompost ha^{-1}). Similar result was also found from the findings of Mohammad *et al*. (2014) and Sharma *et al*. (2016); they found significant variation on number of seeds plant^{-1} with different vermicompost and biochar application.

Different treatment combination of variety and biochar + vermicompost showed significant variation on number of seeds plant^{-1} of lentil (Table 4 and Appendix VII). The highest number of seeds plant^{-1} (114.70) was recorded from the treatment combination of V_2T_5 which was statistically identical with V_1T_5 followed by V_1T_4 and V_2T_4. The lowest number of seeds plant^{-1} (48.67) was recorded from the treatment combination of V_1T_1 which was statistically identical with V_2T_1.

4.2.6 Weight of 100 seeds

Non-significant variation was found on 100 seed weight of lentil as influenced by varietal performance (Table 4 and Appendix VII).However, the highest 100 seed weight (2.35 g) was recorded from the variety V_2 (BARI masur-7) whereas the lowest 100 seed weight (2.34 g) was recorded from the variety V_1 (BARI masur-6). Singh *et al.* (2011), Hasan *et al.* (2015) and Awal and Roy (2015) also found similar result with the present study.

Different effect of biochar + vermicompost application showed non-significant variation on 100 seed weight of lentil (Table 4 and Appendix VII). However, the treatment T_5 (4 ton biochar ha^{-1} + 1 ton vermicompost ha^{-1}) gave the highest 100 seed weight (2.45 g) whereas the control treatment T_1 (0 ton biochar ha^{-1} + 0 ton vermicompost ha^{-1}) showed the lowest 100 seed weight (2.22 g). Sharma *et al*. (2016) and Zeidan (2007) also observed similar result with the present study.

Significant influence was not found on 100 seed weight of lentil as influenced by combined effect of different variety and biochar + vermicompost treatment (Table 4 and Appendix VII). However, the highest 100 seed weight (2.47 g) was recorded from the treatment combination of V_2T_5 followed by V_1T_5 whereas the lowest 100 seed weight (2.21 g) was recorded from the treatment combination of V_1T_1.

Table 4. Yield contributing parameters of lentil varieties as influenced by different combination of biochar and vermicompost

Treatments	Yield contributing parameters					
	Dry weight $plant^{-1}$ (g)	Number of pods $plant^{-1}$	Number of seeds pod^{-1}	Pod length (cm)	Number of seeds $plant^{-1}$	100 seed weight (g)
Effect of variety						
V_1	7.81 b	45.69 b	1.62	0.88	75.67 b	2.34
V_2	8.84 a	49.54 a	1.64	0.89	82.61 a	2.35
$LSD_{0.05}$	0.407	2.032	NS	NS	4.703	NS
CV(%)	5.53	7.99	6.52	3.86	8.17	5.64
Effect of biochar + vermicompost						
T_1	6.25 d	33.33 f	1.49 d	0.86	50.17 f	2.22
T_2	9.00 b	47.76 d	1.60 c	0.88	77.00 d	2.32
T_3	8.33 c	44.83 e	1.54 d	0.87	69.50 e	2.27
T_4	9.84 a	56.64 b	1.71 b	0.90	97.17 b	2.41
T_5	10.16 a	63.08 a	1.79 a	0.91	113.50 a	2.45
T_6	9.38 b	52.06 c	1.64 c	0.89	85.50 c	2.38
$LSD_{0.05}$	0.382	2.365	0.054	NS	4.097	NS
CV(%)	5.53	7.99	6.52	3.86	8.17	5.64
Combined effect of variety and biochar + vermicompost						
V_1T_1	6.22 f	32.72 h	1.48 g	0.85	48.67 f	2.21
V_1T_2	8.88 d	44.72 f	1.58 de	0.88	71.00 d	2.30
V_1T_3	8.48 e	48.40 e	1.55 ef	0.87	75.33 d	2.28
V_1T_4	9.87 b	57.92 b	1.72 b	0.91	99.67 b	2.42
V_1T_5	10.08 ab	62.75 a	1.78 a	0.91	112.30 a	2.46
V_1T_6	9.32 c	51.64 de	1.60 de	0.88	83.00 c	2.35
V_2T_1	6.27 f	33.93 h	1.50 fg	0.86	51.67 f	2.22
V_2T_2	9.12 cd	50.80 de	1.62 cd	0.88	83.00 c	2.34
V_2T_3	8.18 e	41.27 g	1.52 fg	0.87	63.67 e	2.25
V_2T_4	9.80 b	55.36 bc	1.70 b	0.90	94.67 b	2.41
V_2T_5	10.24 a	63.40 a	1.80 a	0.92	114.70 a	2.47
V_2T_6	9.44 c	52.48 cd	1.67 bc	0.90	88.00 c	2.40
$LSD_{0.05}$	0.347	3.353	0.053	NS	5.804	NS
CV(%)	5.53	7.99	6.52	3.86	8.17	5.64

V_1= BARI masur-6, V_2= BARI masur-7

T_1 = 0 ton biochar ha^{-1} + 0 ton vermicompost ha^{-1}, T_2 = 5 ton biochar ha^{-1} + 0 ton vermicompost ha^{-1}, T_3 = 0 ton biochar ha^{-1} + 5 ton vermicompost ha^{-1}, T_4 = 1 ton biochar ha^{-1} + 4 ton vermicompost ha^{-1}, T_5 = 4 ton biochar ha^{-1} +1 ton vermicompost ha^{-1}, T_6 = 2.5 ton biochar ha^{-1} +2.5 ton vermicompost ha^{-1}

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

4.3 Yield parameters

4.3.1 Seed yield plant^{-1}

Seed yield plant^{-1} of lentil was not affected significantly due to varietal difference (Table 5 and Appendix VIII). However, the highest seed yield plant^{-1} (1.97 g) was recorded from the variety V_2 (BARI masur-7) whereas the lowest seed yield plant^{-1} (1.81 g) was recorded from the variety V_1 (BARI masur-6). This result was in agreement with the findings of Yadav *et al*. (2017), Hasan *et al.* (2015) and Awal and Roy (2015).

Application of different levels of biochar + vermicompost gave significant effect on seed yield plant^{-1} of lentil (Table 5 and Appendix VIII). Results exhibited that the highest seed yield plant^{-1} (2.82 g) was recorded from the treatmentT_5 (4 ton biochar ha^{-1} +1 ton vermicompost ha^{-1}) followed by T_4 (1 ton biochar ha^{-1} + 4 ton vermicompost ha^{-1}) whereas the lowest seed yield plant^{-1} (1.12 g) was recorded from the control treatment T_1 (0 ton biochar ha^{-1} + 0 ton vermicompost ha^{-1}). Similar result was also observed by the findings of Hadiuzamman *et al.* (2015) and Agegnehu *et al*. (2015). Hadiuzamman *et al.* (2015) found more effectiveness on seed yield plant^{-1} compared to cowdung and vermicompost. Agegnehu *et al*. (2015) reported significantly increased seed and pod yield of peanut with the application of biochar @ 10 t ha^{-1} along with inorganic fertilizers.

Seed yield plant^{-1} of lentil influenced significantly due to different combination of variety and biochar + vermicompost (Table 5 and Appendix VIII). Results showed that the highest seed yield plant^{-1} (2.86 g) was recorded from the treatment combination of V_2T_5 which was statistically same with V_1T_5 followed by V_1T_4 and V_2T_4. The lowest seed yield plant^{-1} (1.09 g) was recorded from the treatment combination of V_1T_1 that was statistically same to V_2T_1.

4.3.2 Stover yield plant^{-1}

Different variety of lentil showed non-significant difference on stover yield plant^{-1} (Table 5 and Appendix VIII). However, the highest stover yield plant^{-1} (3.04 g) was recorded from the variety V_2 (BARI masur-7) whereas the lowest stover yield plant^{-1} (00 g) was recorded from the variety V_1 (BARI masur-6). Baidya *et al*. (2018) reported significant variation on stover yield plant^{-1} due to varietal difference which was similar result with the present study.

Application of different levels of biochar + vermicompost had significant influence on stover yield plant^{-1} of lentil (Table 5 and Appendix VIII). The highest stover yield plant^{-1} (3.57 g) was recorded from the treatmentT_5 (4 ton biochar ha^{-1} +1 ton vermicompost ha^{-1}) followed by T_4 (1 ton biochar ha^{-1} + 4 ton vermicompost ha^{-1}) whereas the lowest stover yield plant^{-1} (2.42 g) was recorded from the control treatment T_1 (0 ton biochar ha^{-1} + 0 ton vermicompost ha^{-1}). Similar result was also observed by Islami *et al*. (2011); they observed increased stover yield using straw biochar in combination with farmyard manure in sunflower.

Different combinations of variety and biochar + vermicompost showed significant variation on stover yield plant^{-1} of lentil (Table 5 and Appendix VIII). Treatment combinations of V_2T_5 showed the highest stover yield plant^{-1} (3.59 g) which was statistically similar with V_1T_5 followed by V_1T_3, V_1T_4, V_2T_2 and V_2T_4. The lowest stover yield plant^{-1} (2.36 g) was recorded from the treatment combination of V_1T_1 that was statistically identical to V_2T_1.

Table 5. Yield parameters of lentil varieties as influenced by different combination of biochar and vermicompost

Treatments	Yield parameters			
	Seed yield plant^{-1} (g)	Stover yield plant^{-1} (g)	Biological yield plant^{-1} (g)	Harvest index (%)
Effect of variety				
V_1	1.81	3.01	4.96	37.62
V_2	1.97	3.04	4.99	38.71
$LSD_{0.05}$	NS	NS	NS	NS
CV(%)	4.32	7.14	5.68	3.12
Effect of biochar + vermicompost				
T_1	1.12 f	2.42 d	3.54 e	31.63 f
T_2	1.79 d	3.01 c	4.80 cd	37.28 d
T_3	1.59 e	2.95 c	4.53 d	34.99 e
T_4	2.36 b	3.20 b	5.56 b	42.56 b
T_5	2.82 a	3.57 a	6.38 a	44.17 a
T_6	2.03 c	3.01 c	5.04 c	40.35 c
$LSD_{0.05}$	0.131	0.137	0.341	1.445
CV(%)	4.32	7.14	5.68	3.12
Combined effect of variety and biochar + vermicompost				
V_1T_1	1.09 g	2.36 e	3.45 g	31.48 g
V_1T_2	1.64 e	2.81 cd	4.45 ef	36.92 ef
V_1T_3	1.72 e	3.19 b	4.91 de	35.04 f
V_1T_4	2.43 b	3.21 b	5.64 b	43.12 abc
V_1T_5	2.77 a	3.54 a	6.31 a	43.88 ab
V_1T_6	1.95 cd	3.02 bc	4.97 d	39.27 d
V_2T_1	1.15 g	2.47 e	3.62 g	31.78 g
V_2T_2	1.93 d	3.20 b	5.14 cd	37.64 de
V_2T_3	1.45 f	2.70 d	4.15 f	34.93 f
V_2T_4	2.30 b	3.18 b	5.48 bc	42.00 bc
V_2T_5	2.86 a	3.59 a	6.45 a	44.47 a
V_2T_6	2.12 c	2.99 bc	5.11 cd	41.44 c
$LSD_{0.05}$	0.1776	0.221	0.479	2.036
CV(%)	4.32	7.14	5.68	3.12

V_1= BARI masur-6, V_2= BARI masur-7

T_1 = 0 ton biochar ha^{-1} + 0 ton vermicompost ha^{-1}, T_2 = 5 ton biochar ha^{-1} + 0 ton vermicompost ha^{-1}, T_3 = 0 ton biochar ha^{-1} + 5 ton vermicompost ha^{-1}, T_4 = 1 ton biochar ha^{-1} + 4 ton vermicompost ha^{-1}, T_5 = 4 ton biochar ha^{-1} +1 ton vermicompost ha^{-1}, T_6 = 2.5 ton biochar ha^{-1} +2.5 ton vermicompost ha^{-1}

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

4.3.3 Biological yield plant^{-1}

Non-significant variation was found on biological yield plant^{-1} of lentil due to varietal difference (Table 5 and Appendix VIII). However, the highest biological yield plant^{-1} (4.99 g) was recorded from the variety V_2 (BARI masur-7) whereas the lowest biological yield plant^{-1} (4.96 g) was recorded from the variety V_1 (BARI masur-6).

Application of different levels of biochar + vermicompost gave significant effect on biological yield plant^{-1} of lentil (Table 5 and Appendix VIII). Results exhibited that the highest biological yield plant^{-1} (2.82 g) was recorded from the treatmentT_5 (4 ton biochar ha^{-1} +1 ton vermicompost ha^{-1}) followed by T_4 (1 ton biochar ha^{-1} + 4 ton vermicompost ha^{-1}) whereas the lowest biological yield plant^{-1} (3.54 g) was recorded from the control treatment T_1 (0 ton biochar ha^{-1} + 0 ton vermicompost ha^{-1}).

Biological yield plant^{-1} of lentil influenced significantly due to different combination of variety and biochar + vermicompost (Table 5 and Appendix VIII). Results showed that the highest biological yield plant^{-1} (6.45 g) was recorded from the treatment combination of V_2T_5 which was statistically same with V_1T_5 followed by V_1T_4. The lowest biological yield plant^{-1} (3.45 g) was recorded from the treatment combination of V_1T_1 that was statistically same to V_2T_1.

4.3.4 Harvest index

Different variety of lentil showed non-significant difference on harvest index (Table 5 and Appendix VIII). However, the highest harvest index (38.71%) was recorded from the variety V_2 (BARI masur-7) whereas the lowest harvest index (37.62%) was recorded from the variety V_1 (BARI masur-6). Awal and Roy (2015) and Singh *et al.* (2011) found similar result with the present study.

Application of different levels of biochar + vermicompost had significant influence on harvest index of lentil (Table 5 and Appendix VIII). The highest harvest index (44.17%) was recorded from the treatmentT_5 (4 ton biochar ha^{-1} +1 ton vermicompost ha^{-1}) followed by T_4 (1 ton biochar ha^{-1} + 4 ton vermicompost ha^{-1}) whereas the lowest harvest index (31.63%) was recorded from the control treatment T_1 (0 ton biochar ha^{-1} + 0 ton vermicompost ha^{-1}) that was significantly different to other treatments.

Different combination of variety and biochar + vermicompost showed significant variation on harvest index of lentil (Table 5 and Appendix VIII). Treatment combination of V_2T_5 showed the highest harvest index (44.47%) which was statistically similsr to V_1T_5 and V_1T_4. The lowest harvest index (31.48%) was recorded from the treatment combination of V_1T_1 that was statistically identical to V_2T_1.

4.4 Seed quality parameters

4.4.1 Germination

Non-significant variation was observed on seed germination as influenced by different variety of lentil (Table 6 and Appendix IX).However, the highest seed germination (84.33%) was given by the variety V_2 (BARI masur-7) whereas the lowest seed germination (83.67%) was found from seeds which was obtained from V_1 (BARI masur-6) variety.

Seeds of lentil obtained from different biochar + vermicompost levels showed significant variation on seed germination (Table 6 and Appendix IX). The highest seed germination (91.50%) was recorded from the seeds obtained from T_5 (4 ton biochar ha^{-1} +1 ton vermicompost ha^{-1}) treatment which was statistically same with T_4 (1 ton biochar ha^{-1} + 4 ton vermicompost ha^{-1}) followed by T_6 (2.5 ton biochar ha^{-1} +2.5 ton vermicompost ha^{-1}) whereas seeds obtained from control treatment T_1 (0 ton biochar ha^{-1} + 0 ton vermicompost ha^{-1}) gave the lowest seed germination (71.50%).

Lentil seeds obtained from the combination of different variety and biochar + vermicompost showed significant variation on seed germination (Table 6 and Appendix IX). Seeds obtained from V_2T_5 treatment combination showed highest seed germination (92.00%) which was significantly similar to the treatment combination of V_1T_5, V_1T_4 and V_2T_4. Reversely, seeds obtained from the treatment combination of V_1T_1 showed the lowest seed germination (71.00%) that was significantly same to V_2T_1.

4.4.2 Shoot length

Shoot length after germination at 12 days, different lentil variety showed non-significant variation (Table 6 and Appendix IX). However, the highest shoot length (84.66 cm) was given by the variety V_2 (BARI masur-7) whereas seeds of V_1 (BARI masur-6) variety showed the lowest shoot length (4.55 cm).

Shoot length after 12 days of germination, different treatments of biochar + vermicompost showed significant variation (Table 6 and Appendix IX). T_5 (4 ton biochar ha^{-1} +1 ton vermicompost ha^{-1}) treatment gave the highest shoot length (5.32 cm) that was statistically identical to T_4 (1 ton biochar ha^{-1} + 4 ton vermicompost ha^{-1}) followed by T_6 (2.5 ton biochar ha^{-1} +2.5 ton vermicompost ha^{-1}) whereas seeds of control treatment T_1 (0 ton biochar ha^{-1} + 0 ton vermicompost ha^{-1}) gave the lowest shoot length (3.78 cm).

Different treatment combinations of variety and biochar + vermicompost on shoot length of 12 days of germination of seeds showed significant variation (Table 6 and Appendix IX). Seeds obtained from the treatment combination of V_2T_5gave the highest shoot length (5.36 cm) which was significantly similar toV_1T_5 followed by V_1T_4 and V_2T_4 whereas seeds obtained from V_1T_1 gave the lowest shoot length (3.75 cm) which was significantly same to V_2T_1.

4.4.3 Root length

Produced seeds of different lentil varieties showed non-significant variation on root length at 12 days after seed germination (Table 6 and Appendix IX). However, the highest root length (4.15 cm) was given by T_2 (10th November) plantation seeds whereas the T_3 (20th November) plantation seeds showed the lowest root length (3.94 cm).

Root length at 12 days after germination of seed obtained from seeds of different treatments of biochar + vermicompostshowed significant variation (Table 6 and Appendix IX). Seeds obtained from N_1 (50% NPKS + 50% vermicompost) treatments gave the highest root length (4.44 cm) that was significantly same to N_0 (NPKS; standard dose) whereas seeds of N_3 (50% vermicompost + 50% spent mushroom compost) treatment gave the lowest root length (3.59 cm) that was significantly same to N_2 (50% NPKS + 50% spent mushroom compost).

Root length of 12 days after germination of seeds that were produced by different treatment combinations of variety and biochar + vermicompost showed significant variation (Table 6 and Appendix IX). Seeds obtained from the treatment combination of V_2T_5 gave the highest root length (3.26 cm) which was significantly similar toV_1T_4, V_1T_5, V_2T_4 and V_2T_6. On the other hand, seeds obtained from the treatment combination of V_1T_1 gave the lowest root length (2.20 cm) which was statistically similar with V_2T_1.

4.4.4 Seed vigor index

Seed vigour index of produced seeds of the present study was affected significantly due to different varietal performance (Table 6 and Appendix IX). Results indicated that the highest seed vigour index (637.83) was given by the variety V_2 (BARI masur-7) whereas the seeds of variety V_1 (BARI masur-6) showed the lowest seed vigour index (619.05).

Different levels of biochar + vermicompost showed significant variation on seed vigour index that were produced from the present study (Table 6 and Appendix IX). The highest seed vigour index (781.00) was recorded from the treatment T_5 (4 ton biochar ha^{-1} +1 ton vermicompost ha^{-1}) that was followed by T_4 (1 ton biochar ha^{-1} + 4 ton vermicompost ha^{-1}) whereas seeds from control treatment T_1 (0 ton biochar ha^{-1} + 0 ton vermicompost ha^{-1}) gave the lowest seed vigour index (428.70).

Table 6. Seed quality parameters of lentil varieties as influenced by different combination of biochar and vermicompost

Treatments	Seed quality parameters			
	Germination (%)	Shoot length (cm)	Root length (cm)	Seed vigor index
Effect of variety				
V_1	83.67	4.55	2.78	619.05 b
V_2	84.33	4.66	2.84	637.83 a
$LSD_{0.05}$	NS	NS	NS	8.147
CV(%)	8.51	6.98	5.17	9.50
Effect of biochar + vermicompost				
T_1	71.50 e	3.78 e	2.22 c	428.70 f
T_2	83.50 c	4.46 c	2.73 b	600.90 d
T_3	80.00 d	4.14 d	2.56 b	535.80 e
T_4	90.00 a	5.14 a	3.11 a	742.10 b
T_5	91.50 a	5.32 a	3.22 a	781.00 a
T_6	87.50 b	4.80 b	3.00 a	682.10 c
$LSD_{0.05}$	1.858	0.245	0.227	15.33
CV(%)	8.51	6.98	5.17	9.50
Combined effect of variety and biochar + vermicompost				
V_1T_1	71.00 g	3.75 g	2.20 f	422.50 i
V_1T_2	82.00 e	4.32 e	2.63 de	570.00 g
V_1T_3	81.00 ef	4.18 ef	2.60 de	549.00 g
V_1T_4	90.00 ab	5.12 b	3.10 ab	740.00 c
V_1T_5	91.00 a	5.27 ab	3.18 ab	769.10 b
V_1T_6	87.00 cd	4.67 d	2.96 bc	663.80 e
V_2T_1	72.00 g	3.80 g	2.24 f	434.90 i
V_2T_2	85.00 d	4.60 d	2.83 cd	631.80 f
V_2T_3	79.00 f	4.10 f	2.52 e	522.60 h
V_2T_4	90.00 ab	5.15 b	3.12 ab	744.20 c
V_2T_5	92.00 a	5.36 a	3.26 a	793.00 a
V_2T_6	88.00 bc	4.92 c	3.04 abc	700.40 d
$LSD_{0.05}$	2.649	0.152	0.245	22.97
CV(%)	8.51	6.98	5.17	9.50

V_1= BARI masur-6, V_2= BARI masur-7

T_1 = 0 ton biochar ha^{-1} + 0 ton vermicompost ha^{-1}, T_2 = 5 ton biochar ha^{-1} + 0 ton vermicompost ha^{-1}, T_3 = 0 ton biochar ha^{-1} + 5 ton vermicompost ha^{-1}, T_4 = 1 ton biochar ha^{-1} + 4 ton vermicompost ha^{-1}, T_5 = 4 ton biochar ha^{-1} +1 ton vermicompost ha^{-1}, T_6 = 2.5 ton biochar ha^{-1} +2.5 ton vermicompost ha^{-1}

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

Significant influence was observed on seed vigour index of produced seeds by combined effect of variety and biochar + vermicompost (Table 6 and Appendix IX). The seeds from the treatment combination of V_2T_5 registered the highest seed vigour index (793.00) followed by V_1T_5. Reversely, seeds from the treatment combination of V_1T_1 showed the lowest seed vigour index (422.50).

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was carried out during the period of October 2019 to February 2020 at the farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka-1207 to study the response of different proportion of biochar and vermicompost on yield and seed quality of lentil. The experiment consisted of two factors: Factor A: two lentil varieties *viz*. V_1 = BARI masur-6 and V_2= BARI masur-7and Factor B: Biochar + vermicompost (6 levels) *viz*. T_1 = 0 ton biochar ha^{-1} + 0 ton vermicompost ha^{-1}, T_2 = 5 ton biochar ha^{-1} + 0 ton vermicompost ha^{-1}, T_3 = 0 ton biochar ha^{-1} + 5 ton vermicompost ha^{-1}, T_4 = 1 ton biochar ha^{-1} + 4 ton vermicompost ha^{-1}, T_5 = 4 ton biochar ha^{-1} +1 ton vermicompost ha^{-1} and T_6 = 2.5 ton biochar ha^{-1} +2.5 ton vermicompost ha^{-1}. The experiment was laid out in randomized complete block design (RCBD) with three replications. Data on different growth, yield contributing parameters, yield and seed quality of lentil were recorded and analyzed statistically.

Regarding growth parameters, different varieties of lentil showed non-significant variation on plant height and number of branches plant^{-1} but number of leaves plant^{-1} varied significantly at 60 DAS and at harvest. However, at 20, 40 and 60 DAS and at harvest, the variety V_1 (BARI masur-6) showed the maximum plant height (7.64, 16.29, 25.29 and 28.29 cm, respectively) and number of leaves plant^{-1}(8.06, 46.00, 93.78 and 133.61, respectively) whereas V_2 (BARI masur-7) showed the minimum plant height (7.40, 15.96, 25.00 and 27.84 cm, respectively) and number of leaves plant^{-1}(7.89, 45.11, 90.22 and 127.50 at 20, 40 and 60 DAS and at harvest, respectively) was recorded from the variety V_2 (BARI masur-7). But at 40 and 60 DAS and at harvest, the highest number of branches plant^{-1} (3.44, 5.94 and 8.44, respectively) was recorded from the variety V_2 (BARI masur-7) whereas the lowest number of branches plant^{-1} (3.28, 5.72 and 8.28, respectively) was recorded from the variety V_1 (BARI masur-6). Regarding yield contributing parameters, different variety also showed non-significant variation on number of seeds pod^{-1}, pod length and 100 seed weight however, the highest (1.64, 0.89 cm and 2.35 g, respectively) was given by the variety V_2 (BARI masur-7) whereas the lowest (1.62, 0.88 cm and 2.34 g, respectively) was recorded from the variety V_1 (BARI masur-6). Similarly, variety V_2 (BARI masur-7) showed significantly highest dry weight plant^{-1}, number of pods plant^{-1} and number of seeds plant^{-1} (8.84 g, 49.54 and 82.61, respectively) compared to V_1 (BARI masur-6) (7.81 g, 45.69 and 75.67, respectively). Seed yield and seed quality parameters were not affected significantly between two varieties of lentil except vigor index. However, V_2 (BARI masur-7) showed the highest seed yield plant^{-1} (1.97g), stover yield plant^{-1} (3.04g), biological yield plant^{-1} (4.99g), harvest index (38.71%), seed germination (84.33%), shoot length (4.66 cm) and root length (2.84 cm) of seedlings after 12 days of germination and seed vigor index (637.83) whereas V_1 (BARI masur-6) gave the lowest seed yield plant^{-1} (1.81g), stover yield plant^{-1} (3.01g), biological yield plant^{-1} 4.96g), harvest index (37.62%), seed germination (83.67%), shoot length (4.55 cm) and root length (2.78 cm) of seedlings after 12 days of germination and seed vigor index (619.05).

Different biochar + vermicompost treatment showed significant variation on most of the growth, yield contributing parameters, seed yield and quality parameters of lentil. Treatment T_4 (1 ton biochar ha^{-1} + 4 ton vermicompost ha^{-1}) gave the maximum plant height (8.28, 19.92, 28.40 and 33.22 cm at 20, 40 and 60 DAS and at harvest, respectively) but the highest number of leaves plant^{-1} (9.17, 58.00, 111.80 and 172.70 at 20, 40 and 60 DAS and at harvest, respectively) and number of branches plant^{-1} (4.17, 7.50 and 10.17 at 40 and 60 DAS and at harvest, respectively) were recorded from T_5 (4 ton biochar ha^{-1} +1 ton vermicompost ha^{-1}) treatment whereasminimum plant height (6.12, 11.85, 20.85 and 22.95 cm at 20, 40 and 60 DAS and at harvest, respectively), number of leaves plant^{-1}(7.17, 31.67, 71.17 and 84.83 at 20, 40 and 60 DAS and at harvest, respectively) and number of branches plant^{-1} (2.17, 3.50 and 6.17 at 40 and 60 DAS and at harvest, respectively) were found from the control treatment T_1 (0 ton biochar ha^{-1} + 0 ton vermicompost ha^{-1}). Considering Yield contributing parameters and yield of lentil, T_5 (4 ton biochar ha^{-1} +1 ton vermicompost ha^{-1}) also showed the highest dry weight $plant^{-1}$ (10.16 g), number of pods $plant^{-1}$ (63.08), number of seeds pod^{-1} (1.79), pod length (0.91 cm), number of seeds $plant^{-1}$ (113.50), 100 seed weight (2.45 g), seed yield $plant^{-1}$ (2.82 g), stover yield $plant^{-1}$ (3.57 g), biological yield $plant^{-1}$ (6.38 g) and harvest index (44.17%) whereas control treatment T_1 (0 ton biochar ha^{-1} + 0 ton vermicompost ha^{-1}) showed the lowest dry weight $plant^{-1}$ (6.25 g), number of pods $plant^{-1}$ (33.33), number of seeds pod^{-1} (1.49), pod length (0.86 cm), number of seeds $plant^{-1}$ (50.17), 100 seed weight (2.22 g), seed yield $plant^{-1}$ (1.12 g), stover yield $plant^{-1}$ 2.42 g), biological yield $plant^{-1}$ (3.54 g) and harvest index (31.63%). Regarding seed quality parameters, the highest seed germination (91.50%), shoot length (5.32 cm) and root length (3.22 cm) of seedlings after 12 days of germination and seed vigor index (781.00) were registered from T_5 (4 ton biochar ha^{-1} +1 ton vermicompost ha^{-1}) whereas the lowest seed germination (71.50%), shoot length (3.78 cm) and root length (2.22 cm) of seedlings after 12 days of germination and seed vigor index (428.70) were found from T_1 (0 ton biochar ha^{-1} + 0 ton vermicompost ha^{-1}) treatment.

Treatment combination of variety and biochar + vermicompost showed significant variation on most of the studied parameters. The significantly maximum plant height (8.53, 20.10, 28.93 and 33.33 cm at 20, 40 and 60 DAS and at harvest, respectively) was achieved by the treatment combination of V_1T_4 but the highest number of leaves $plant^{-1}$(9.33, 58.33, 112.70 and 173.70 at 20, 40 and 60 DAS and at harvest, respectively) was recorded from V_1T_5 and the highest number of branches $plant^{-1}$ (4.33, 7.67 and 10.33 at 40 and 60 DAS and at harvest, respectively) was found from V_2T_5 whereas the minimum plant height (5.93, 11.73, 20.80 and 22.93 cm at 20, 40 and 60 DAS and at harvest, respectively) and number of leaves $plant^{-1}$(7.00, 31.33, 70.33 and 84.33 at 20, 40 and 60 DAS and at harvest, respectively) were found from V_2T_1 but the lowest number of branches $plant^{-1}$ (2.00, 3.33 and 6.00 at 40 and 60 DAS and at harvest, respectively) was recorded from V_1T_1. Again, treatment combination ofV_2T_5 registered the highest dry weight plant^{-1} (10.24 g), number of pods plant^{-1} (63.40), number of seeds pod^{-1} (1.80), pod length (0.92 cm), number of seeds plant^{-1} (114.70), 100 seed weight (2.47 g), seed yield plant^{-1} (2.86 g), stover yield plant^{-1} (3.59 g), biological yield plant^{-1} (6.6.45 g) and harvest index (44.47%) whereas V_1T_1 gave the lowest dry weight plant^{-1} (6.22 g), number of pods plant^{-1} (32.72), number of seeds pod^{-1} (1.48), pod length (0.85 cm), number of seeds plant^{-1} (48.67), 100 seed weight (2.21 g), seed yield plant^{-1} (1.09 g), stover yield plant^{-1} (2.36 g), biological yield plant^{-1} (3.45 g) and harvest index (31.48%). Regarding seed quality parameters, the highest seed germination (92.00%), shoot length (5.36 cm) and root length (3.26 cm) of seedlings after 12 days of germination and seed vigor index (793.00) were found from V_2T_5 whereas the lowest seed germination (71.00%), shoot length (3.75 cm) and root length (2.20 cm) of seedlings after 12 days of germination and seed vigor index (422.50) were found from V_1T_1.

Conclusion

From the present study, the following conclusion may be drawn –

1. The results on the most of the parameters between two varieties of lentil showed non-significant variation, however, V_2 (BARI masur-7) showed relatively better performance regarding yield contributing parameters, yield and seed quality.
2. Application of 4 ton biochar ha^{-1} and 1 ton vermicompost ha^{-1} showed best crop performance, highest seed yield and better quality seeds.
3. The variety BARI masur-7 in combination with 4 ton biochar ha^{-1} and 1 ton vermicompost ha^{-1} gave the best results in respect of maximum seed yield and better seed quality.
4. The lentil variety BARI masur-7 cultivation with 4 ton biochar ha^{-1} and 1 ton vermicompost ha^{-1} can be considered as best combination compared to other treatment combinations.

Recommendation

Further research works at different regions of the country are needed to be carried out for the confirmation of the present findings.

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APPENDICES

Appendix I. Agro-Ecological Zone of Bangladesh showing the experimental location

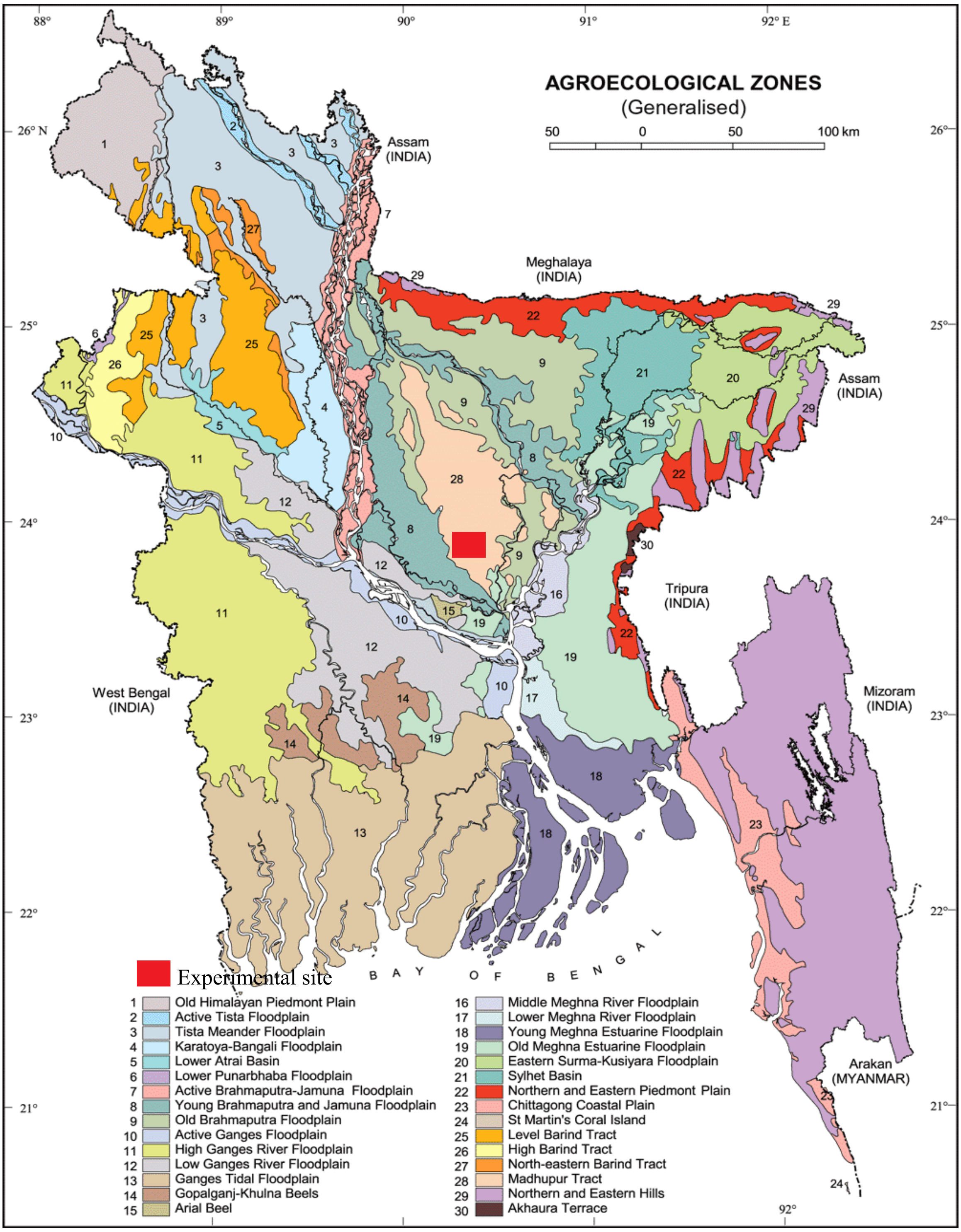

Figure 8. Experimental site

Appendix II. Monthly records of air temperature, relative humidity and rainfall during the period from October 2019 to February 2020.

Year	Month	Air temperature (°C)			Relative humidity (%)	Rainfall (mm)
		Max	*Min*	*Mean*		
2019	October	30.42	16.24	23.33	68.48	52.60
2019	November	28.60	8.52	18.56	56.75	14.40
2019	December	25.50	6.70	16.10	54.80	0.0
2020	January	23.80	11.70	17.75	46.20	0.0
2020	February	22.75	14.26	18.51	37.90	0.0

Source: Bangladesh Meteorological Department (Climate division), Agargaon, Dhaka-1212.

Appendix III. Characteristics of experimental soil analyzed at Soil Resources Development Institute (SRDI), Farmgate, Dhaka.

A. Morphological characteristics of the experimental field

Morphological features	**Characteristics**
Location	Agronomy Farm, SAU, Dhaka
AEZ	Modhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled
Flood level	Above flood level
Drainage	Well drained
Cropping pattern	Not Applicable

Source: Soil Resource Development Institute (SRDI)

B. Physical and chemical properties of the initial soil

Characteristics	**Value**
Partical size analysis % Sand	27
%Silt	43
% Clay	30
Textural class	Silty Clay Loam (ISSS)
pH	5.6
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total N (%)	0.03
Available P (ppm)	20
Exchangeable K (me/100 g soil)	0.1
Available S (ppm)	45

Source: Soil Resource Development Institute (SRDI)

Appendix IV. Mean square of plant height of lentil varieties as influenced by different combination of biochar and vermicompost

Sources of variation	Degrees of freedom	Mean square of plant height			
		20 DAS	40 DAS	60 DAS	At harvest
Replication	2	1.670	0.563	2.475	2.263
Factor A	1	0.514^{NS}	0.967**	0.780**	1.778*
Factor B	5	3.303^{NS}	49.45*	40.14*	78.83*
AB	5	0.039^{NS}	0.814**	1.417*	0.768**
Error	22	3.077	0.616	0.604	0.789

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix V. Mean square of number of leaves plant^{-1}of lentil varieties as influenced by different combination of biochar and vermicompost

Sources of variation	Degrees of freedom	Mean square of number of leaves plant^{-1}			
		20 DAS	40 DAS	60 DAS	At harvest
Replication	2	4.111	5.361	14.583	6.361
Factor A	1	0.250^{NS}	7.111*	113.78*	336.11*
Factor B	5	2.961^{NS}	562.2*	1241.5*	6873.5*
AB	5	0.117^{NS}	0.778**	3.311**	57.444*
Error	22	0.960	3.179	8.674	8.785

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix VI. Mean square of number of branches plant^{-1} of lentil varieties as influenced by different combination of biochar and vermicompost

Sources of variation	Degrees of freedom	Mean square of number of branches plant^{-1}		
		40 DAS	60 DAS	At harvest
Replication	2	0.111	0.750	0.194
Factor A	1	0.250^{NS}	0.444**	0.250**
Factor B	5	3.428^{NS}	13.27*	11.56*
AB	5	0.050^{NS}	0.044**	0.050**
Error	22	0.102	0.386	0.191

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix VII. Mean square of yield contributing parameters of lentil varieties as influenced by different combination of biochar and vermicompost

Sources of variation	Degrees of freedom	Mean square of yield contributing parameters					
		Dry weight plant^{-1}	Number of pods plant^{-1}	Number of seeds pod^{-1}	Pod length	Number of seeds plant^{-1}	100 seed weight
Replication	2	0.010	3.970	0.003	0.001	3.444	0.001
Factor A	1	0.010**	0.207**	0.003^{NS}	0.001^{NS}	8.028*	0.021^{NS}
Factor B	5	12.05*	633.78*	0.074**	0.003^{NS}	2914.8*	0.052^{NS}
AB	5	0.056**	29.043*	0.002**	0.000^{NS}	101.76*	0.018^{NS}
Error	22	0.042	3.922	0.001	0.001	11.747	0.103

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix VIII. Mean square of yield parameters of lentil varieties as influenced by different combination of biochar and vermicompost

Sources of variation	Degrees of freedom	Mean square of yield parameters			
		Seed yield plant^{-1}	Stover yield plant^{-1}	Biological yield plant^{-1}	Harvest index
Replication	2	0.002	0.112	0.143	5.475
Factor A	1	0.011^{NS}	0.003^{NS}	0.012^{NS}	1.626^{NS}
Factor B	5	2.132*	0.839**	5.551*	135.8*
AB	5	0.062**	0.123**	0.338**	1.754**
Error	22	0.011	0.017	0.080	1.446

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix IX. Mean square of seed quality parameters of lentil varieties as influenced by different combination of biochar and vermicompost

Sources of variation	Degrees of freedom	Mean square of seed quality parameters			
		Germination (%)	Shoot length (cm)	Root length (cm)	Seed Vigor index
Replication	2	9.083	0.002	0.013	322.323
Factor A	1	4.000^{NS}	0.096^{NS}	0.029^{NS}	3171.943*
Factor B	5	332.4*	2.097*	0.853**	105956.9*
AB	5	4.000*	0.028**	0.013**	1349.009*
Error	22	2.447*	0.008**	0.021**	183.969

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level