INFLUENCE OF BIOCHAR ON RAPESEED AND MUSTARD AT VARIED PLANTING METHODS

MAHMUDA TASNEEM

DEPARTMENT OF AGRONOMY

SHER-E-BANGLA AGRICULTURAL UNIVERSITY

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INFLUENCE OF BIOCHAR ON RAPESEED AND MUSTARD AT VARIED PLANTING METHODS

By

MAHMUDA TASNEEM
Reg. No.: 12-04755

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APPROVED BY

(Prof. Dr. A.K.M. Ruhul Amin)
Supervisor

(Prof. Dr. Parimal Kanti Biswas)
Co-supervisor

(Prof. Dr. Md. Shahidul Islam)
Chairman
Examination Committee

DEPARTMENT OF AGRONOMY

Sher-e-Bangla Agricultural University
Sher-e-Bangla Nagar, Dhaka-1207

CERTIFICATE

This is to certify that the thesis entitled ***"INFLUENCE OF BIOCHAR ON RAPESEED AND MUSTARD AT VARIED PLANTING METHODS"*** *submitted to the Faculty of Agriculture, Sher-E-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of* ***MASTER OF SCIENCE (MS)*** *in* ***AGRONOMY,*** *embodies the results of a piece of bona fide research work carried out by* ***MAHMUDA TASNEEM,*** *Registration. No.* ***12-04755*** *under my supervision and guidance. No part of this thesis has been submitted for any other degree or diploma.*

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

Dated:

Dhaka, Bangladesh

(Prof. Dr. A. K. M. Ruhul Amin)
Supervisor

DEDICATED

TO

MY BELOVED PARENTS

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The Author

INFLUENCE OF BIOCHAR ON RAPESEED AND MUSTARD AT VARIED PLANTING METHODS

ABSTRACT

An experiment was conducted at the Agronomy field, Sher-e-Bangla Agricultural University, Dhaka during from Rabi, 2017-18 to investigate the yield performance of mustard and rapeseed varieties as influenced by different planting methods and different levels of biochar. The experiment was laid out in three factors Randomized Complete Block Design (RCBD) with three replications. There were 12 treatments (2 variety × 2 planting method x 3 levels of biochar). The varieties treatments were V_1= BARI Sarisha-11 and V_2= BARI Sarisha-14. Planting methods were P_1= Line Sowing and P_2= System of Mustard Intensification (SMI) at 30 x 30 cm (transplanting). Biochar treatments were B_0 = Control (No biochar application), B_1= application of biochar 5.00 t ha^{-1} and B_2= application of biochar 10.00 t ha^{-1}. Results revealed that highest plant height (137.60 cm) was achieved at the combination of BARI Sarisha-11 with SMI method and 10 t ha^{-1} of biochar. Highest number of siliquae $plant^{-1}$ (440.3) was achieved at the BARI Sarisha-11 with SMI method and 10 t ha^{-1} of biochar. Maximum siliqua length (5.74) and seeds $siliqua^{-1}$ (33.57) was achieved with the combination of BARI Sarisha-14 with SMI method and 10 t ha^{-1} of biochar. Highest weight of 1000-seed (3.49 g) was found at the combination of BARI Sarisha-11 with SMI method and 10 t ha^{-1} of biochar. Highest grain yield (2.75 t ha^{-1}) were obtained by the combination of BARI Sarisha-11 with SMI method and 10 t ha^{-1} of biochar. Maximum harvest index (30.18%) was obtained at the combination of BARI Sarisha-14 with SMI method and 10 t ha^{-1} of biochar.

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LIST OF ACRONYMS

Acronyms	Full word
AEZ	Agro Ecological Zone
BARC	Bangladesh Agricultural Research Council
BARI	Bangladesh Agricultural Research Institute
BBS	Bangladesh Bureau of Statistics
Cm	Centimeter
CV	Coefficient of Variation
DAS	Days After Sowing
et al.	And others (*et alibi*)
FAO	Food and Agriculture Organization
Gm	Gram
ha	Hectare
HI	Harvest Index
Kg	Kilogram
kg ha^{-1}	kg per hectare
LSD	Least Significance Difference
m^2	Square Meter
MS	Master of Science
no.	Number
NS	Non-Significant
%	Percent
P^H	Hydrogen ion concentration
$plant^{-1}$	per plant
SAU	Sher-e- Bangla Agricultural University
SMI	System of mustard intensification
SRDI	Soil Resources and Development Institute
t ha^{-1}	Ton per hectare
UNDP	United Nations Development Programme

CHAPTER I

INTRODUCTION

Rapeseed (*Brassica campestris* L.) belongs to family Cruciferae. Familiar species of rapeseed are *Brassica carinatea, Brassica nigra, Brassica campestris and Brassica oleracea* L. (Khan, 2015). Rapeseed is a source of the edible oil. Rapeseed and mustard being used for traditional and conventional oil seed crop of Bangladeshi peoples. The mustard oil is also used in preparing vegetable ghee, hair oil, medicines, soaps, lubricating oil and in tanning industries. The oil content in mustard seeds varies from 37-49 % (Bhowmik et al., 2014). Bangladesh occupying 0.532 million ha of land and the production was 0.596 million MT (metric ton) with the yield of 1.12 MT ha-1 of rapeseed in 2013-14 (AIS, 2015). Bangladesh has been facing acute shortage of edible oil for the last several decades. Our internal production can meet only about 21% of our consumption. The rest 79% is met from the import (Begum *et al*., 2012). Increased oilseed production is needed not only to meet the demand of the increased population but also to reduce import of edible oil to save foreign currencies. Major mustard growing districts of Bangladesh are Cumilla, Tangail, Jessore, Sirajgong, Sylhet, Faridpur, Pabna, Madaripur, Jamalpur, Rajshahi, Dinajpur, Kushtia, Kishoregonj, Rangpur and Dhaka (BBS, 2010). Rapeseed and mustard are covering about 80% of the total oilseed area and contributing to more than 60% of the total oilseed production in Bangladesh. It is a cold loving crop which is grown during Rabi season. The total area and production of mustard is 276.11 thousand hectare and 262.00 thousand tons. The present mustard yield (0.95 t ha-1) is very low as compared to other oilseeds growing countries in the world. The main reasons of lower yield are lack of good quality seed and inadequate adoption of improved production technologies (Mamun *et al*., 2014). Therefore, attempts must be made to increase the per unit production by using HYV and by adopting better management practices such as appropriate sowing method and adoption of improved cultural practices like adding biochar.

BARI has developed several high yielding varieties of mustard. Among them BARI Sharisa-11 is a composite variety which average yield 2.2-3 t ha^{-1}. Another variety BARI Sharisa-14 is a composite rapeseed variety which average yield 1.4-1.6 t ha^{-1} and crop duration 75-80 days.

In Bangladesh, for rapeseed and mustard cultivation, generally two main methods of sowing are followed. They are broadcasting and line sowing. Optimum plant population in per unit area can ensure through line sowing. On the other hand plants are sown haphazardly in case of broadcasting. So, desired plant population can not be maintained in broadcasting. A suitable technique of sowing is to find out for higher yield of mustard. The planting method affected significantly for the siliqua length, number of siliquae $plant^{-1}$, number of seed $siliqua^{-1}$, stover yield, biological yield and harvest index but statistically unaffected for 1000-seed weight and seed yield (Roy, 2015). Growth, development and final yield are mainly affected by the space available to plants; however, the precise and exact response will be species and cultivar specific. So, it is imperative to adjust plant population through planting method which may help in avoiding excessive crowding and thereby enabling the plants to utilize these resources more effectively and efficiently resulting in increased production. Higher plant population per unit area beyond an optimum limit results in competition among the plants for natural resources, resulting weaker plant and may cause severe lodging (Kumar *et al*., 2004). While, low density population produce more branches that carry fertile pods, thus prolonging the seed development phase. Plant density in mustard governs the components of yield and thus the yield of individual plants. A uniform distribution of plants per unit area is a prerequisite for yield stability (Diepenbrock, 2000). It was found that SMI produced 2.28% higher seed yield compared to conventional method (Roy, 2015). Ridge and furrow sowing was superior to conventional flat sowing for growth parameters and yield of *Brassica juncea* (Khan and Agarwal, 1985). Mustard yield can be increased by following system of mustard intensification techniques suggested by many researchers (Aziz, 2014). Transplanting of mustard has also been reported thereby saving time, and sresources. Transplanting reduces days to maturity and results in higher seed yield. Ridge transplanting reduced water applied by 30% for each furrow as compared to 45 cm row spacing in flat method without any loss in seed yield. The corresponding increase in water use efficiency (WUE) was 27%. In bed planting, there was a 35% saving in water resulting in 32% increase in WUE. Uniform distribution of crop plants over an area results in efficient use of nutrients, moisture, and suppression of weeds leading to high yield. In wider row spacing, solar radiation falling within the rows gets wasted particularly during the early stages of crop growth whereas in closer row spacing upper part of the crop canopy may be well above the light saturation capacity but the lower leaves remain starved of light and contribute negatively towards yield. An increase in rows up to 30 cm correspondingly prolonged maturity days followed by optimum 45cm and wider rows 60 cm spacing. The plants receiving narrow row spacing increased vegetative growth. Due to shade and competition for nutrients and moisture the crop matures later by increasing developmental phases. Taller plants were observed in the plots where crop was planted in rows of 60 cm apart followed by 45 cm and 30 cm row spacing due to sufficient space resulting in plants grown well and showed greater height (Sierts and Geister, 1987). The regression coefficient indicated that each increase in row spacing up to 60cm resulted in increased crop maturity by 0.54 days, plant height by 0.44cm, number of branches would increase by 0.11, pods per plant by 1.96, seeds per pod by 0.04, seed weight per plant by 0.45, seed index by 0.152g, oil content by 0.8% and increase in seed yield by 10.32kg ha^{-1}.

Bangladesh developing the more mustard varieties but soil condition is declining day by day by the application of more inorganic and synthetic fertilizers in the crop field. As a result, even the newly developed variety does not fit for changing soil conditions as well. On the other hand, the increasing of atmospheric carbon threatens the future agriculture due to more carbon emission. At such condition the biochar may be the best option. The application of biochar may reduce the amount the atm. carbon by sequestrating more carbon-dioxide from air into its porous particle. Biochar is also a fine-grained charcoal that is rich in organic carbon, produced by pyrolysis or by heating biomass in a low oxygen environment and has been used worldwide as a soil amendment to increase soil fertility (Schomberg *et al*., 2012). Biochar is the carbon-rich residue obtained by combustion of *fibrous* biomass (hemicellulose, cellulose and lignin) in *oxygen*-restricted condition which is utilized for soil amendment and for long term carbon sequestration (Winsley, 2007). Biochar has been reported to boost soil fertility and improve soil quality by raising soil pH, increasing moisture holding capacity, attracting more beneficial fungi and microbes, improving cation exchange capacity (CEC), and retaining nutrients in the soil (Lehmann *et al*., 2006). Biochar is often regarded as a soil conditioner because its application rapidly increases the soil fertility and plant growth by supplying and retaining nutrients while simultaneously improving the physical and biological properties of the soil (Glaser *et al*., 2002; Laird *et al*., 2010 and Uzoma *et al*., 2011). The application of biochar to soil is considered to have the potential for long-term soil carbon sequestration, as well as for improving plant growth and suppressing soil pathogens. Reibe *et al*. (2015) observed that plant growth and development of wheat were affected by the type of char and rates of application. Anders *et al*. (2013) stated that the change in the structure of the microbial community by biochar application is an indirect effect and depends on soil nutrient status.

Biochar (BC) enhanced significantly seed yield of rapeseed. Biochar is the most important major elements required for the growth and development of rapeseed and to evaluate the production potential or biological crop potential of rapeseed which deserve particular attention (Ahmed *et al.*,1994). With conceiving the above thinking in mind, the present research work has been undertaken in order to fulfilling the following objectives:

1. To study the effect of biochar on growth and yield of rapeseed and mustard,
2. To study the performance of rapeseed and mustard variety under different planting method and
3. To find out the best combination of rapeseed and mustard variety with biochar at varied planting method.

CHAPTER II

REVIEW OF LITERATURE

Plant growth has been found to be affected by two types of factors, viz. genetical and environmental. Though varietal difference arises usually due to the genetical factor but more precisely it is due to the interaction between genetical and environmental factors. Constituently varieties may differ markedly as well as in their yielding ability under different agro climatic conditions and agronomical practices such as planting method, planting geometry and adding soil amendment like biochar. A short review of the pertaining to the work done in Bangladesh and foreign countries with reference to the effect of varieties, planting techniques and biochar application on growth and yield of mustard and rapeseed with special reference is being given below.

2.1 Effect of varieties on growth and yield of mustard and rapeseed

High yield potential of a variety is the prerequisite for increasing the production of a crop. In the recent years, Bangladesh Agricultural Research Institute (BARI) and BINA has developed a number of high yielding varieties of mustard with yield potential up to 2.5 t ha^{-1}. The present national average yield of mustard is only 0.79 t ha^{-1} (BBS, 2006). Genotypes play an important role in crop production and the potential yield of a genotype within the genetic limit is determined by its environment (Iraddi, 2008).

Ahmed *et al.* (2017) conducted a varietal trial of mustard to find out the suitable mustard variety/varieties. A total of five varieties viz. BADC-1, SAU Sarisha-3, BARI Sarisha-11, BARI Sarisha-14 and BARI Sarisha-15 were tested in the farmer's field. Significant differences were found among the mustard varieties for number of branches $plant^{-1}$, number of capsules $plant^{-1}$, capsule length, 1000-seed weight and seed yield. The mustard var. BARI Sarisha-11 produced the highest number of branches $plant^{-1}$, number of capsules $plant^{-1}$, 1000-seed weight resulting the highest seed yield (1.64 t ha-1), followed by BARI Sarisha-15 (1.47 t ha-1). The seed yield of BARI Sarisha-11 and BARI Sarisha-15 was not differed significantly, but the growth duration of BARI Sarisha-15 was shorter than the others.

Helal *et al*. (2016) carried out an experiment of rapeseed and mustard to identify the suitable short durable variety for utilizing the fallow land of Sylhet region that remain fallow after harvest of T. Aman rice. Eight varieties (Improved Tori, TS-72, BARI Sarisha-8, BARI Sarisha-9, BARI Sarisha-12, BARI Sarisha-14, BARI Sarisha-15, and Binasarisha-4) and four promising lines (BC-05115 Y, BC-05117 Y, BC-05118 Y and Nap-205) of rapeseed-mustard were evaluated. Results indicated that, growth as well as yield and yield attributes of rapeseed mustard were significantly differed. The variety Improved Tori, BARI Sharisa-8, BARI Sharisa-14 and BARI Sharisa-15 produced the highest seed yield and took minimum days to mature and their growth parameters were also highly significant and positive correlation was observed in seed yield with siliqua plant^{-1}, straw yield, biological yield, 1000 seed weight and harvest index.

Hossain *et al*. (2015) conducted an experiment and work was subjected to study the proximate composition of six rapeseed and mustard varieties which are released by BARI. From *Brassica campestris* were BARI Sarisha 9, BARI Sarisha 14, and BARI Sarisha 15. The *Brassica napus* varieties were BARI Sarisha 13. Varieties BARI Sarisha 11 and BARI Sarisha 16 were from the *Brassica juncea* group. The comparative evaluation of its physicochemical properties, seed weight, moisture, ash, carbohydrates, protein, fat, total energy and minerals; among these varieties, the highest grain weight was obtained from BARI Sarisha-13 (4.38 g) and lowest grain weight obtained from BARI Sarisha-9 (3.06 g). The oil content of different varieties of mustard and rapeseed varied from 38.75% to 42.25%. BARI Sarisha-14 (554.3 kcal g^{-1}) contained the highest amount of total energy.

Islam *et al*. (2013) conducted a field experiment to find out suitable mustard varieties for intercropping with sugarcane. Five rapeseed/mustard varieties viz., Improved Tori -7, BARI Sarisha-9, BARI Sarisha-11, BARI Sarisha-14 and BARI Sarisha-15 were intercropped with sugarcane. Results showed that different intercropping combinations significantly influenced yield and yield components of mustard. The mustard variety BARI Sarisha-11 produced the highest seed yield (2199 kg ha^{-1}).

Paul (2018) studied the performance of different weed management techniques affecting growth and yield of mustard varieties. The experiment comprised of two factors *viz*., (i) three mustard varieties *viz*., BARI Sarisha 14, BARI Sarisha 15 and BARI Sorisha 17 and (ii) Five weed managements. Results revealed that mustard varieties, weed managements techniques and their interaction significantly influenced most of the weed parameters and plant characters of mustard. Among the mustard varieties BARI Sarisha 17 performed superior than other varieties and it produced 1.61 t ha^{-1} grain which was 96.34% higher than BARI Sorisha 14 (0.82 t ha^{-1}).

Afroze *et al*. (2011) conducted an experiment with two varieties viz. BARI Sarisha-9 and BARI Sarisha-6; three sowing date and three seed rates. It was observed that the variety had significant influence on the yield and yield contributing characters except non-effective pods $plant^{-1}$, non-effective seeds pod^{-1} and 1000-seed weight. Higher seed yield (1.54 t ha^{-1}) obtained in BARI Sarisha-9 was due to higher branches $plant^{-1}$, pods $plant^{-1}$and effective pods $plant^{-1}$. But higher plant height, pod length, effective seeds $plant^{-1}$and total seeds pod^{-1} were found in BARI Sarisha-6.

Roy (2015) conducted a field experiment to evaluate the performance of varieties on different planting methods of mustard. The treatment comprised of two planting methods and six varieties. Six different varieties were BARI Sarisha-11, BARI Sarisha-13, BARI Sarisha-14, BARI Sarisha-15, BARI Sarisha-16 and Tori-7. The seed yield of mustard varied for different variety. BARI Sarisha-11 produced the highest seed yield (1386.50 kg ha^{-1}) whereas the lowest seed yield (733.10 kg ha^{-1}) was given BARI Sarisha-14.

Alam *et al*. (2014) conducted a field experiment to determine changes in crop phenology, growth and yield of mustard genotypes under late sown condition when the crop faced high temperature. Yield and yield attributes of different varieties varied significantly. Among the varieties, BARI Sarisha-16 of *Brassica juncea* gave significantly the highest seed yield (1495 and 1415 kg ha^{-1}), which was statistically identical to BJDH-11, BJDH-12, BJDH-05, BJDH-20, and BARI Sarisha-6 and significantly different from all other varieties. The highest seed yield (1758 and 1825 kg ha^{-1}) were recorded from BJDH-11 and BARI Sarisha-16 of *Brassica juncea* at 25 November planting and BJDH-11 produced the highest yield at 15 December. The highest oil content of seeds (44.4 % and 45.9%) were obtained from the seed of BARI Sarisha-6 and BARI Sarisha-14 at 25 November.

Aziz (2014) studied with the variety BARI Sarisha-11, BARI Sarisha-13, BARI Sarisha-15 and SAU Sarisha-2. Sowing technique treatments were broadcasting, line sowing, raised bed and System of Mustard Intensification (SMI). Result showed that plant height of mustard and rapeseed were significantly influenced by different varieties throughout the growing period. At harvest, maximum numbers of primary branches were recorded at BARI Sarisha-15 which was statistically similar with SAU Sarisha-2 and the minimum numbers of primary branches were recorded at BARI Sarisha-13 which was statistically similar with BARI Sarisha-11. Maximum number of siliquae $plant^{-1}$ was recorded at BARI Sarisha-11 and minimum number of siliquae $plant^{-1}$ was observed at BARI Sarisha-15. The biggest siliqua length was recorded at BARI Sarisha-13 and the smallest siliqua length was observed at BARI Sarisha11. The highest grain yield (3.74 t ha^{-1}) was obtained at BARI Sarisha-11 and the lowest grain yield (2.54 t ha^{-1}) was found at BARI Sarisha-15. The highest stover yield (6.95 t ha^{-1}) was obtained at BARI Sarisha-13 and the lowest stover yield (3.77 t ha^{-1}) was found at BARI Sarisha-15.

Basak *et al*. (2007) conducted a field experiment to find out the performance of three mustard varieties viz., i) BARI Sarisha-9, ii) BARI Sarisha-12 and iii) Tori-7 (Local) and three fertilizer doses. The variety BARI sarisha-9 produced the highest seed yield (892 $kgha^{-1}$).

Ferdous (2014) conducted a field experiment to evaluate the performance of varieties on different planting techniques of rapeseed and mustard. The treatment comprised of two planting techniques and five varieties. The two planting techniques were conventional method of sowing and sowing in puddle soil. Five different varieties were Improved Tori-7, BARI Sarisha-13, BARI Sarisha-15, BARI Sarisha-16 and SAU SR-03. Results indicated that the seed yield of mustard varied with varietal difference. Variety had significant influence on the growth and yield attributes. Results of the experiment showed that the plant height was significantly influenced by variety. However, the tallest plant 150.4 cm was recorded from the variety BARI Sarisha-16. At harvest highest number of branches plant^{-1} was recorded in SAU SR-03 (5.20). The highest number of siliquae plant^{-1} was obtained from the variety BARI Sarisha-16 which was statistically similar with the variety Improved Tori-7. Variety affected significantly on the length of siliqua, seeds siliqua^{-1}, 1000-seed weight, shelling percentage, grain yield, stover yield, biological yield and harvest index. The highest number of seeds siliqua^{-1} (22.34) was produced by the variety BARI Sarisha-15. BARI sarisha-13 and BARI Sarisha-16 produced the highest 1000-seed weight (4.07 g). Improved Tori-7 produced the highest seed yield (2.24 t ha^{-1}).

Yadav *et al*. (2014) conducted a field experiment comprised of three planting geometry and three varieties viz., Varuna, Vardan and NDR-8501. It is evident from the data that Varuna variety exhibited maximum initial plant population (12.4) followed by NDR-8501 (12.2). Varieties had significant variation on Plant height at all the stages except 30 DAS. It is quite evident from the data that higher plant height was obtained in NDR-8501 which was at par with Varuna at all the stages while significantly superior over Vardan variety. Data also showed that Vardan variety recorded smaller height of Plant at all the stages. Maximum Seed yield (1988.3) was recorded with NDR-8501 variety followed by Varuna (1840) and then Vardan.

2.2 Effect of planting methods on growth and yield of mustard

Alternative types of planting methods can alter seed placement and seedling growing conditions. These factor can affect establishment and seed yield of oilseed crop. Seedling with hoe drill (HD) resulted in the best emergence and stand ratings for seedling with a No-till drill (NT) were better than broadcast seedling (Aiken *et al.*, 2015).

Roy (2015) reported that planting method affected significantly for the siliqua length, number of siliquae plant^{-1}, number of seed siliqua^{-1}, stover yield, biological yield and harvest index but statistically unaffected for 1000-seed weight and seed yield. It was found that SMI produced 2.28% higher seed yield compared to conventional method.

Jangir *et al*. (2017) conducted a field experiment during rabi season of 2014-15 at College Farm, N. M. College of Agriculture, Navsari Agricultural University, Navsari with fifteen treatment combinations. Significantly higher values of plant height (171.63 cm), number of branches plant^{-1} (18.07), number of siliqua plant^{-1} (204.16), seed yield (1851 kg ha^{-1}) and stover yield (3808 kg ha^{-1}) were recorded with row spacing of 45 cm x 10 cm with normal planting followed by 60 cm x 10 cm with paired row planting.

Yadav *et al*. (2014) conducted a field experiment comprised of three planting geometry viz., 40×15cm, 40×20cm, 40×25cm and three varieties viz., Varuna, Vardan and NDR-8501. Results revealed that planting geometry of 40×15cm produced significantly higher growth yield. Taller plants were obtained at planting geometry of 40×15 cm which was significant over rest both of planting geometry. Shorter plants were recorded under wider planting geometry (40×25 cm.) sowing. Maximum Seed yield (2100) was recorded when crop was sown on 40×15 cm which was significantly superior over 40×20 cm and 40×25 cm planting geometry. The minimum Seed yield (1570) was recorded when sowing was done at 40×25 cm planting geometry. Maximum harvest index (22.4) was recorded when crop was sown on 40×20 cm which was equal to 40×25 cm and superior to 40×15 cm planting geometry. The minimum harvest index (21.8) was recorded when sowing was done at 40×15 cm planting geometry.

Pandey *et al*. (2017) conducted an experiment at Agronomy Research Farm of Narendra Deva University of Agriculture and Technology, Faizabad (Uttar Pradesh) during the Rabi season of 2008-09. The treatments were comprised of four levels of planting geometry (30x10 cm, 45x10 cm, 45x15 cm and 60x10 cm) and three varieties (NRCHB- 101, Rohini and Narendra Rye -8501,). Variety Narendra Rye

-8501, with planting geometry of 45x10 cm produced significantly higher plant height, primary and secondary branches plant^{-1}, number of leaves plant^{-1}, dry matte accumulation plant^{-1}. The maximum dry matte accumulation plant^{-1} was recorded with treatment combination Variety Narendra Rye -8501, with planting geometry of 45x15 cm.

Chaniyara *et al*. (2002) conducted an experiment to study the effect of inter and intra row spacing on yield of mustard during 1993-94 to 1996-97. They observed that grain yield was significantly highest when crop sown at 45 cm inter row spacing and 15 cm intra row spacing in all the individual years and in pooled results except in pooled results it was at par with 60 and 75 cm row spacing. Gross and net return was also higher in 45 cm row spacing and 15 cm plant to plant spacing. Interaction effect between inter and intra row spacing found significant and produced highest grain yield in 45 cm x 15 cm spacing.

Ching (2017) reported that small farmers around the world are dramatically boosting their productivity and yields by adapting a system called System of Crop Intensification (SCI). System of Crop Intensification is based on the system of Rice Intensification (SRI), which is characterized by simple modification to agricultural practices that synergize to promote healthy plant growth. This modification include improving soil conditions and greatly lowering plant density (crowding) without the use of synthetic pesticide or fertilizers. SCI methods are being adopted rapidly worldwide as they are low risk, do not require farmers to have access to unfamiliar technologies and save money on multiple inputs, while higher yield result in increased income.

Lathana (2012) reported that the adoption of SRI experiences and principles to other crops is being referred to generically on system of crop intensification (SCI), encompassing variants for wheat (SWI), maize (SMI), finger millet (SFMI), sugarcane (SSI), mustard, legumes such as pigeonpea, lentils, soybeans and vegetables such as tomato, chilies and eggplant.

Aziz (2014) reported that in terms of sowing technique, raised bed showed the tallest plant height 113.49 cm and System of Mustard Intensification (SMI) showed the shortest plant height 103.24 cm. At 75 DAS and at harvest SMI showed the tallest plant height (120.88 and 121.31 cm) and line sowing showed the shortest plant height (105.11 and 104.87 cm). At 30 DAS, maximum number of primary branches (3.17) were recorded at raised bed and minimum number of primary branches (2.25) were found at broadcasting. SMI technique scored the highest number of silquae plant^{-1} and broadcasting scored the lowest number of siliquae plant^{-1}. Highest grain yield (3.8 t ha^{-1}) was obtained at SMI and lowest grain yield (2.11 t ha^{-1}) was obtained at broadcasting. Maximum harvest index (32.45%) was recorded at line sowing and minimum harvest index (29.43%) was recorded at broadcasting. Maximum weight of 1000-seed (3.8 g) was found at raised bed and minimum weight of 1000-seed (3.52 g) was found at broadcasting.

Satpathy (2007) reported that System of Mustard Intensification or SMI, is an afterthought. Found out only recently that my system of transplanting mustard seedlings with wide spacing is similar to the System of Rice Intensification (SRI) developed in Madagascar some 25 years ago and now spreading in India. Both systems depend on low density of crops and seek to utilize the full potentiality of each plant, rather than on communities of plants as done with high-density planting. As explained earlier, by transplanting the full potentiality of individual plants can be realized.

Chauhan *et al*. (1992) conducted that row spacing of 30 cm in rape gave more grain and straw yields than other treatments grain and straw yields increasing by 5.9 and 5.2 percent over 40cm and 21.1 and 10.0 percent over 20 cm. Similar trend was observed for grain weight per plant and thousand seed weight. Number of branches were affected upto 40 cm spacing. The height of plant and number of primary branches were significantly increased by 30cm row spacing over 20 and 40. This may be more transformation and photosynthetase for reproductive part.

Sharma (1993) reported that row spacing 37.5cm produced markedly higher number of seeds siliquae^{-1}, 100 seed weight and seed yield (18.47 q ha^{-1}) then 45cm and 22.5 cm respectively.

Ghosh (1994) found that high plant density (3.33 lakh plant ha^{-1}) recorded the highest grain yield which was at per with medium plant density (2.22 lakh plant ha^{-1}) but significantly superior to plant density (1.67 lakh plant ha^{-1}). Similarly, high plant density resulted in highest stover yield which was significantly superior to both medium and low plant densities. The maximum yield was recorded at high plant density. Which was at per with medium and was significant with low plant density due to higher plants.

Singh (1994) conducted that growth yield attributes such as height of plant, Fresh and dry weight $plant^{-1}$, number of branches per plant, number of $siliquaeplant^{-1}$, weight of siliquae $plant^{-1}$ and seed weight $plant^{-1}$ were found significantly maximum in medium plant density (45x20 cm) over wider (60x20 cm) and lower (30x20 cm) plant densities due to optimum number of plants unit $area^{-1}$.

Singh (1995) suggested that growth characters such as height of main shoot, number of leaves $plant^{-1}$, fresh and dry weight $plant^{-1}$, Number of primary and secondary branches $plant^{-1}$ were recorded significantly maximum in row spacing 60 cm over 45 cm and 30 cm respectively.

Bhan *et al*. (1995) reported that plant spacing 15 cm was at par with 10 cm and 20 cm spacings and given 39.8 to 51.8 percent more seed yield than 26 cm and 30 cm row spacing respectively. The increase in seed yield in medium spcing was mainly due to optimum number of plant ha^{-1}. The plant spaced widely (30 cm) produced more siliqua $plant^{-1}$ than closer (no thinning) and medium plant spacing. No thinning treatment was not found favourable to yield attributes and yield. Though the plant stand, height of plant and maturity were observed higher under this treatment.

Kumar *et al*. (1995) has reviewed at plant nagar that wider planting geometry in Indian rape was increased pod bearing capacity and productivity of individual plants. The higher plant population compensated this effect and higher total seed and oil yield/ha was recorded at 222000 plant ha^{-1} (30x15 cm) .The lowest seed yield was recorded in crop sown in lines at 30 cm without thinning. The highest number of branches/plant in wider plant density the seed yield was maximum at 222000 plant ha^{-1} this may be justified as the improvement in yield attributes. At lower plant density failed to compensate yield for lower plant unit area^{-1}.

Ali *et al*. (1996) reported from Dhaka (Bangladesh) and found the effects of different levels of nitrogen, sulphur and plant density on yield attributes oil and protein content of rape seed. Nitrogen upto 120 kg ha^{-1} increased the yield component seed and stover yield harvet index progressively increased with the increase in level of sulphur. Lower plant density increased the number of siliquae m^{-2}, seed and stover yield ha^{-1} and harvest index.

Sharma *et al*. (1998) studied the effect of crop geometry and nitrogen levels on yield and its attributes of *Brassica* spp. The RH-819 and RH-30 Cv of indian mustard were at par but both gave significantly higher seed yield over Cv. TCH-2 of toria. The crop geometry had no significant effect on seed yield and its attributes.

Singh and Chauhan (2000) reported that plant spacing 40x15cm was found most suitable and economic in respect to seed production (q ha^{-1}) and net profit base over other plant spaces such as 30x15 cm and 60x15cm respectively. Though the growth characters as height of main shoot, dry matter production plant^{-1}, number of branches plant^{-1} and all the yield attributes were recorded maximum in wider plant space .i e. 60x15 cm due to more utilization of sunlight nutrients and paces. The seed yield (q ha^{-1}) and net profit (Rs ha^{-1}) were maximum in 45x15 cm plant space due to normal plant growth and optimum number of plant unit area^{-1}.

Mahan and Singh (2003) reported that plant density 60x16 cm produced significantly maximum growth characters such as height of main shoot, fresh and dry weight of plant^{-1} and number of branches plant^{-1}. The yield attributes were also maximum in respect plant density; i. e. 60x15 cm, followed by 50x15cm, 40x15cm and 30x15cm plant densities respectively. The biomass production and seed yield (q ha^{-1}) in 50x15 cm space produced 8.08, 8.15 and 23.9 also occurred Rs.1855.98 , Rs. 1867.16 and Rs. 5284.66 ha^{-1} as additional net income (Rs ha^{-1}), over 60x15 cm, 40x15cm and 30x15 cm spaces respectively.

Momoh *et al*. (2004) conducted an experiment to study yield and quality responses to plant densities of 17500 plant ha^{-1} (row spacing was 54.5cm) 97500 plant ha^{-1}, (row spacing 38cm) and 127500 plant ha^{-1}, row spacing of 29 cm to winter oil seed rape (*Brassica napus* L.) cultivar 'HD-605' at Zhejiang University Farm, China. Dry matter accumulation of plant decreased with increasing plant density, number of the primary secondary branches were also decreased with increasing plant density (18.2% and 38.7). Weight (3.33-3.52 mg), varied among in seed yield was respectively realised with increasing plant density from 67500 to 97500 plants/ha and from 97500 t0 1275oo plant ha^{-1};The seed oil content 42.26 to 44.91% was significantly more.

Kumar *et al*. (2004) studied that crop geometry of 30x10 cm significantly enhance the plant height, while 45x10 cm geometry for branches $plant^{-1}$ was significantly superior over 30x10 cm crop geometry. The result indicated that closer row spacing (30 cm) favoured more varietal growth of the plant, while wider row spacing 45cm was more favourable for total plant growth. Among the yield attributes only siliqua per plant were significantly higher in wider roe (45 cm) spacing with contributed towards realizing higher seed yield as compared to narrow row spacing (30 cm).

Singh and Ram (2005) suggested that all the growth characters such as height of main shoot, number of functional leaves $plant^{-1}$, fresh and dry weight per plant and number of branches per plant and yield contributing characters. As number of siliquae $plant^{-1}$, weight of siliquae $plant^{-1}$, number of seeds $plant^{-1}$ and weight of seeds $plant^{-1}$, weight of 1000 seeds were recorded maximum in wider row space i. e. 50 cm due to more space $plant^{-1}$ and more utilization of nutrient soil moisture and sun light over other closer spacing. The seed yield (q ha^{-1}) was recorded significantly maximum 45 cm row space over 50 cm, 40 cm and 30 cm row spaces respectively. The prescribed roe space i. e. 45cm produced maximum yield due to optimum paints unit $area^{-1}$ over wider space and in closer spaces, the plants were not survive properly due to dense plant population and would not cover seed yield unit $area^{-1}$.

2.3 Effect of biochar on growth and yield of mustard

As a result of biochar application both increase and decrease in crop yields have been reported so far. Several studies have found significant improvements in crop growth in a range of soil-biochar combinations (Spokas *et al*., 2012). Increase in plant nutrient availability or improvement in soil environment (CEC, pH, aeration) might be the reason behind such enhancements in plant growth (Steiner *et al*., 2007; Chan *et al*., 2008). Up to 96% yield increase in radish has been observed due to application of poultry litter biochar (up to 50 t ha^{-1}) in an Alfisol (Chan *et al*., 2008). In a cropping trial with *Vigna unguiculata* and *Oryza sativa* in an Anthrosol of Amazon, there was significant increase in P, Ca, Mg and Zn availability with a 38-45% increase in biomass of the two crops due to the addition of wood biochar (Lehmann *et al*., 2003). Despite the low nutrient status of some biochars, they generally increase nutrient availability through increased ion retention in soils (Liang *et al*., 2006).

Some indications exist from soils that are rich in bio-char that microbial community composition, species richness, and diversity change with greater bio-char concentrations (Pietikainen *et al*., 2000; Yin *et al*., 2000; Thies and Suzuki, 2003). Pietikainen *et al*. (2000) found a greater bacterial growth rate in layers of charcoal than in the underlying organic horizon in a temperate forest soil. Already small amounts of 7.9 t C ha^{-1} of bio-char in a highly weathered soil in the tropics significantly enhanced microbial growth rates when nutrients were supplied by fertilizer (Steiner, 2004). A greater microbial biomass was reported in forest soils in the presence of charcoal by Zackrisson *et al*. (1996), and higher microbial activity (CO_2 production as well as organic matter decomposition) was found in soils exposed to black carbon aerosols derived from charcoal making (Uvarov, 2000).

Pandit *et al*. (2018) reported that poor water and nutrient retention are the major soil fertility limitatios in the low productivity agricultural soil of Nepal. The addition of biochar to these soils is one way these hindrances can be overcome. In the present study, six biochar doses (control, 5 t ha^{-1}, 10 t ha^{-1}, 15 t ha^{-1}, 25 t ha^{-1} and 40 t ha^{-1}) were applied to a moderately acidic silty loam soil from Rasuwa, Nepal and the effects of soil physiochemical properties and maize and mustard over three years (i. e. six cropping seasons,) were investigated. Biochar addition did not show significant effects on maize and mustard grain yield in the first year, however significant positive effect ($p<0.01$) were observed during the second and third years. During the second year maize grain yield significantly increased by 50%, 47% and 93% and mustard grain yield by 96%, 128% and 134 % at 15 t ha^{-1}, 25 t ha^{-1} and 40 t ha^{-1} of biochar respectively. A similar significant increase in yield of both crops was observed in the third year.

Gonzaga *et al*. (2019) carried out a study was to evaluate the effect of different types and doses of biochars on the concentration and uptake of N and P in Indian mustard plants (*Brassica juncea* L.) grown in a Cu contaminated soil during three successive growth cycles. The greenhouse experiment was set up as randomized block design in a 3x3 factorial scheme, with 3 types of biochars (coconut shell, orange bagasse and sewage sludge) and three rates of application (0, 30 and 60t ha^{-1}), and 4 replicates. Biochar increased plant growth by approximately 30 to 224%; however, the orange bagasse biochar was the most effective. Biochar reduced plant N concentration in approximately 15-43%, regardless of the rate of application, indicating the need to carefully adjust N fertilization. In the last growth cycle, biochar from coconut shell and orange bagasse improved the N uptake efficiency suggesting a better amelioration effect with ageing in soil. Biochar did not affect P nutrition in Indian mustard to a great extent; however, it significantly decreased the N:P ratio in the plant. Application of biochar significantly ($P<0.05$) increased plant biomass in all growth cycles. However the effects varied with biochar type and rates of application. In the first and third growth cycles, biochar from coconut shell increased plant biomass by approximately 50 and 32%, regardless of the rate of application. In the second growth cycle, the increase was according to the rate of application, being 100% (30 t ha^{-1}) and 224% (60 t ha^{-1}). The OBB was more effective in increasing plant biomass in all growth cycles, varying from 168% (GC_1), 148-191% (GC_2, 30t ha^{-1} and 60t ha^{-1}, respectively) and 60% (GC_3). The effect of the SSB on plant biomass was only observed in the GC_2 (150%) and GC_3 (50% and

90%, for 30t ha^{-1} and 60t ha^{-1}, respectively), confirming the beneficial effect of this biochar as reported by Silva (2017).

Khan (2015) conducted an experiment was carried out in randomized complete block design (RCBD) having four replications. Four levels of biochar (0, 5.0, 7.5 and 10 tons ha^{-1}) and five levels of shoot cutting duration after date of sowing (ADS), (no cutting, 30 days ADS, 40 days ADS, 50 days ADS and 60 days ADS) were used in the experiment with the test cultivar Dunkled. From the results it is observed that rapeseed cultivar positively responded for days to flowering, days to maturity, number of branches $plant^{-1}$, H.I %, number of seeds pod^{-1}, thousand seed weight (g), biological yield (kg ha^{-1}), seed yield (kg ha^{-1}) and oil yield (kg ha^{-1}) to biochar levels and maximum seeds pod^{-1} (23 seeds), thousand seed weight (3.59 g), biological yield (10310 kg ha^{-1}), seed yield (1169 kg ha^{-1}) and oil yield (600 kg ha^{-1}) was observed in plot treated with 10 ton biochar ha^{-1}. Similarly highest seeds pod^{-1}(22), thousand seed weight (3.3 g), seed yield (1099 kg ha^{-1}) was noted in no shoot cutting plot followed by shoot cutting after 60 days of sowing ADS plots while promising biological yield (9025 kg ha^{-1}), and oil yield (568 kg ha^{-1}) was recorded in shoot cutting after 50 days ADS and after 60 days ADS of sowing. On the basis of the result it was concluded that shoot cutting with 10 ton biochar ha^{-1} produced highest seed and oil yield with green chop and recommended for higher seed, oil and biological yield in the agro- climatic condition of swat valley.

Sokchea *et al*. (2015) observed that increasing levels of biochar (0, 1.5, 3, 4.5 and 6 kg DM m^{-2}) derived from rice husk were applied to plots cultivated with Mustard Green vegetable for three successive crop cycles. The biochar was applied 15 days prior to transplanting the Mustard Green seedlings in the first cropping cycle only. Bio digester effluent or urea (100 kg N ha^{-1}) were applied during each cropping cycle. The initial application of biochar showed carry-over effects in soil amendment as measured by: (i) increases in pH and in water holding capacity of the soil in each of the three cycles; and (ii) higher biomass vegetable yield in each of the three cropping cycles. However, the relative increases in yield for the best biochar treatment over the control (zero biochar) decreased from the first to the third cropping cycle. Biomass yield for the three crop cycles showed increasing curvilinear trends according to the level of biochar applied in the first cycle. For the first two crop cycles the trend was for increasing response to biochar according to the level of biochar applied. However, for the third harvest cycle the relative response increase to the original application of biochar was for this to decrease with the quantity applied. Considering the responses in yield with harvest cycle (ie: residual effect of the biochar) then this showed a steady decline with cropping cycle. Biomass yields at each harvest were increased when urea was the fertilizer source compared with bio digester effluent.

Chhay *et al*. (2013) conducted an experiment involved 24 treatments arranged in a 6x4 factorial arrangement with 3 replications. The first factor was level of biochar (0, 1, 2, 3, 4 and 5 kg m^{-2}); the second factor was the type of vegetable (Water spinach, Chinese cabbage, Celery cabbage and Mustard green). Fertilization was with bio digester effluent (10kg N ha^{-1} applied to all treatments. The area of each plot was $1.6m^2$ (2.0 m length x 0.8 m width) with spacing between each plot of 0.5m. The experiment lasted 35 days. The biochar (pH 9.3; OM 29.4% in DM) was from a paddy rice drier (combustion temperature with rice husks as feedstock was about 500°C). Increasing the application of biochar from 0 to 5 kg m^{-2} led to linear increases in biomass DM yield of 39, 100, 300 and 350 % for Water spinach, Chinese cabbage, Celery cabbage and Mustard green, respectively. Soil quality was improved after the 35 day trial (pH 6.82-7.13; OM 22.6 - 25.7%). The chemical composition of the biomass DM showed average increases in crude protein from 13.7 to 18.1% for leaves and from 7.23 to 9.16 for stems. By contrast, crude fibre in leaves decreased from 14.5 to 9.27% in DM while in stems it fell from 15.6 to 10.7%.

Liu (2014) reported that two biochars were prepared at 40^0 c from peanut shell and Chinese medicine materials residue and their surface properties were measured by Scanning Electric Microscopy (SEM) and Electron Dispersive X-ray analysis (EDX).The two biochars were mixed at a ratio of 1:1, and then was applied to an acidic soil collected from a cropland in Huangdau districts of Qingdau, Shandhong province,China. The results of soil incubation and pot experiments showed that biochar application to the acidic soil (1% and 5%) increased p^H value from 5.8 to 6.1 and 6.7, improved Indian Mustard (*Brassica juncea*) seed germination rate by 10% and 15% respectively, and the shoot and root dry weight were significantly increased by 8.3% , 28.5%, 11.5% and 26.9%.

Zemanová *et al*. (2017) conducted a study to assess the effect of biochar on growth and metabolism of spinach (*Spinacia oleracea* L.) and mustard (*Sinapis alba* L.) planted in crop rotation: spinach (spring)-mustard-spinach (autumn). The impact of biochar soil application (5% per mass of soil) on the availability of Ca, Fe, K, Mg, Na and P to plants as well as the content of free proline and total amino acids contents were evaluated at degraded Chernozem soil. The results showed that biochar soil addition significantly increased spinach growth by 102% and 353% in spring and autumn, respectively. Biochar limited plant content of Ca, Mg and Na, however K content increased in all plants. Inconsistent effect was determined for Fe and P content in plants biomass. Total content of free amino acids was higher in plants harvested at amended treatments, except autumn spinach. Biochar increased proline content in all plants in comparison to control. The highest increase was obtained in mustard – by 186%. The results showed a more sensitive reaction of mustard to biochar application than spinach.

Lehmann and Joseph (2009) reported that increases in crop yield, BC has the potential to bring about indirect increases in agricultural production and farm income. Water is a scarce resource for which agriculture must compete. Urbanisation, soil sealing, climate change and salinization of arable land (which requires leaching with additional irrigation) are all contributing to decreased availability of water. Improved WHC and water use efficiency has been repeatedly demonstrated as a characteristic and significant feature of BC, which could help reduce water demand. By absorbing fluids and adsorbing particulate matter, BC filters water passing through it and reduces leaching, leading to greater efficiency of agrochemicals added to the soil. By improving drainage and aeration BC can also mitigate the harmful effects of waterlogging, such as acidification. The capacity of

BC to maintain soil C, stabilise SOM and improve soil structure and cohesion has the potential to prevent erosion and counteract compaction. In the developed world these factors could contribute to farm incomes but in much of the developing world, where many soils are degraded, they could be critical to subsistence.

Beck *et al*. (2011) and Chen *et al*. (2010) reported that converting biomass into BC, especially if done close to its point of use, could be a highly efficient and valuable form of waste reuse. BC provides an inconspicuous service which accrues from its other benefits, namely a reduced demand for fossil fuel, by improving the efficiency of fertilizers, reducing the demand for water, improving water quality conserving soil and improving its workability, and consuming waste.

2.4 Interaction effect of variety and planting method

Roy (2015) reported that BARI Sarisha-11 in SMI method resulted the highest seed yield (1830.70 kg ha^{-1}) that might be due to higher number of siliquae (483.47) $plant^{-1}$. BARI Sarisha-14 in SMI showed the lowest seed yield (429.80 kg ha^{-1}). Thus it may be concluded that SMI was not effective for all varieties i.e the variety BARI Sarisha-11 performed better in SMI method.

Mamun (2013) concluded that (BARI Sarisha-16 × 10 plants m^{-2}) gave the tallest plant (170.90 cm) but the highest leaf length (29.79 cm), leaf breadth (9.16 cm), length of siliqua (7.94 cm), seeds $siliqua^{-1}$ (26.03), 1000 seed weight (4.10 g), seed yield (1.60 t ha^{-1}) and harvest index (41.02%) were found from (BARI Sarisha-13 × 70 plants m^{-2}) where the highest dry weight $plant^{-1}$ (22.70 g), branches $plant^{-1}$ (7.56) and siliquae $plant^{-1}$ (145.70) were found from (BARI Sarisha-13 × 10 plants m^{-2}). Again, the maximum stover yield (2.93 t ha^{-1}) and biological yield (4.06 t ha^{-1}) were found from (BARI Sarisha-16 × 70 plants m^{-2}) and (BARI Sarisha-13 × 100 plants m^{-2}) respectively. So, above all deliberation, the best result was achieved from the treatment combination of BARI Sarisha-13 × 70 plants m^{-2}.

Ferdous (2014) stated that variety BARI Sarisha-16 showed the highest yield response (2.39 t ha^{-1}) with conventional technique that statistically similar with the variety Improved Tori-7 (2.38 t ha^{-1}) with conventional well as puddled soil condition. The interaction effect of conventional technique with BARI Sarisha-16 gives 0.42% higher yield return than puddle soil sowing with Improved Tori-7. Thus, it is concluded that the variety Improved Tori-7 can be well suited with both techniques and BARI Sarisha-16 could be grown with conventional method of sowing for higher yield output.

Aziz (2014) observed that highest dry matter (39.93 g) was produced by the combination of BARI Sarisha-11 and SMI technique. Highest number of siliquae plant^{-1} (1179.67) was achieved at the BARI Sarisha-11 and SMI technique. Maximum siliqua length (8.99) and seeds siliqua^{-1} (30.33) was achieved with the combination of BARI Sarisha-13 and SMI technique. Highest grain yield (4.75 t ha-1) and biological yield (16.06 t ha-1) were obtained by the combination of BARI Sarisha-11 and SMI technique. Maximum harvest index (36.45%) was obtained at the combination of BARI Sarisha-15 and SMI technique. Highest weight of 1000-seed (4.26 g) was found at the combination of BARI Sarisha-11 and raised bed technique. Highest oil percentage (41.73%) was obtained from the plots with the combination of BARI Sarisha-15 and line sowing technique.

From the above review of different experimental evidences related to this study it was noticed that different varieties and planting techniques had influence on yield contributing characters of mustard. Therefore, results indicate that biochar based soil management strategies can enhance mustard production with the environmental benefits of global warming mitigation. This can contribute positively to the viability and benefits of agricultural production systems.

CHAPTER III

MATERIALS AND METHODS

A brief description about experimental site, climatic condition, planting materials, treatments, experimental design and layout, crop growing procedure, intercultural operations, data collection and statistical analysis were described in this chapter. The details of experimental materials and methods are described below:

3.1 Description of the experimental site

3.1.1 Location

The research was conducted at the Sher-e-Bangla Agricultural University farm, Dhaka-1207 during from November, 2017 to March, 2018.

3.1.2 Geographical and agro-ecological Region

Geographically the experimental field is located at 23°46' N latitude and 90° 22' E longitude at an elevation of 8.2 m above the sea level belonging to the Agro-ecological Zone "AEZ-28" of Madhupur Tract (BBS, 2011). The location of the experimental site has been shown in Appendix I.

3.1.3 Climate

The experimental area is situated in the sub-tropical climatic zone and characterized by heavy rainfall during the months of April to September (Kharif Season) and scanty rainfall during the rest period of the year. The Rabi season (October to March) is characterized by comparatively low temperature and plenty of sunshine from November to February (SRDI, 1991). The weather data during the study period at the experimental site including maximum and minimum temperature, total rainfall and relative humidity were shown in (Appendix-II).

3.1.4 Soil

The soil type of the research field was general and shallow red brown terrace soils. It is under Tejgaon series. The selected plot was above flood level and sufficient sunshine was available. Irrigation and drainage system was also available during the experimental period. The experimental plot was also high land. Top soil was characterized by silty clay in texture, olive- gray whitish with common fine to medium distinct dark whitish. Brown mottles was also seen on the top soil. The soil was also characterized by pH- 6.3 and organic carbon- 1.8%. The experimental area was flat and medium high topography with available easy irrigation and drainage system. The soil status was shown in (Appendix-III).

3.2.1 Plant materials

Two released varieties of mustard (*Brassica* spp.) and rapeseed namely BARI Sarisha-11, BARI Sarisha-14 were selected for the study. From *Brassica campestris* was BARI Sarisha 14. BARI Sarisha 11 was from the *Brassica juncea* group. The seeds of BARI Sarisha-11 and BARI Sarisha-14 were collected from the oilseeds Research centre of BARI, Gazipur.

3.2.2 Brief description of selected varieties

BARI Sarisha-11: This is a composite mustard variety evolved by the BARI. It was released in 2001. The average height is 120-130 cm, leaf light green, produced 75-150 siliquae plant^{-1}, 12-15 seeds siliqua^{-1}, seed colour light brownish, 1000 seed weight 3.5-4 g, life cycle 105-110 days and average yield is 2-2.5 t ha^{-1}. Yield is 20-25% greater than Dolot variety.

BARI Sorisha-14: This is a composite rapeseed variety evolved by BARI. It was released in 1997 crossing ‘Tori 7’ with ‘Sonali sorisha’ by hybridization technique and released as BARI Sorisha 14 variety in 2006 by National Seed Board. The average height is 75-85 cm, leaf light green, produced 80-100 siliquae plant^{-1}, 22-26 seeds siliqua^{-1}, yellow color seed, 1000 seed weight 3.5-3.8 g, life cycle 75-80 days and average yield is 1.40 - 1.60 t ha^{-1}. It can produce 25-30% more mustard than ‘Tori 7’.

3.3 Collection biochar

Biochar is a fine-grained charcoal that is rich in organic carbon, produced by pyrolysis or by heating biomass in a low oxygen environment and has been used worldwide as a soil amendment to increase soil fertility (Schomberg *et al*., 2012). Biochar was collected from CCDB (Christian Commission for Development in Bangladesh), Shivaloy, Manikgonj, Bangladesh.

3.4 Soil sample collection

Soil sample were collected from seven different treatment's plot for two times. At first before the application of biochar and finally after harvest. Sample were collected in order to measure the soil P^H and soil organic carbon percentage (OC %). Before the application biochar P^H of soil sample was 6.3 and organic carbon percentage (OC %) was 0.39 %. After harvesting, P^H of soil sample was (4.65, 4.6 and 4.8) for the biochar doses B_0, B_1 and B_2, respectively. After harvesting, organic carbon percentage (OC %) of soil sample was (0.42, 0.92 and 0.66 %) for the biochar doses B_0, B_1 and B_2, respectively.

Here, B_0 = 0 t ha^{-1} of biochar (control), B_1 = 5 t ha^{-1} of biochar, B_2 = 10 t ha^{-1} of biochar

3.5 Details of the experiment

3.5.1 Treatments

The experimental treatments are as follows:

A. Factor-1. Variety: 2

(i) V_1 = BARI Sarisha 11

(ii) V_2 = BARI Sarisha14

B. Factor-2. Planting Method: 2

(i) P_1 = Sowing in line

(ii) P_2 = SMI (30 cm x 30 cm) transplanting

C. Factor-3. Biochar Application: 3

(i) B_0 = 0.0 t ha^{-1} (control)

(ii) B_1 = 5.0 t ha^{-1}

(iii) B_2 = 10 t ha^{-1}

3.5.2 Experimental design

The three factors experiment was laid out in Randomized Complete Block Design (RCBD) three factors with three replications. The total numbers of unit plots were 36. The size of unit plot was 2 m × 1.5 m.

3.6 Land preparation

The land was first opened with the tractor drawn disc plough. Ploughed soil was then brought into desirable fine tilth by 4 operations of ploughing and harrowing with country plough and ladder. The stubbles and weeds were removed. The final land preparation were done on November 7, 2017, respectively. Whole experimental land was divided into unit plots following the design of experiment. The plots are spaded one day before planting.

3.7 Seedling raising in polybag

Seedlings were raised in polybag for transplanting in SMI plot. Three to four seeds were sown in each polybag. Two seedlings were kept in each polybag and the other were thinned out. Seedlings in polybag were kept for seventeen days.

3.8 Transplanting

Seedlings of seventeen days old were transplanted in the SMI bed with care, without injuring their roots. Just after this, light irrigation was applied in the every transplanted plants.

3.9 Fertilizer application

The fertilizers were applied as basal dose @ Urea 205 kg ha^{-1}, TSP 150 kg ha^{-1}, MOP 85 kg ha^{-1}, Gypsum 120 kg ha^{-1}, Zinc Sulphate 4 kg ha^{-1}, Boric acid 10 kg ha^{-1} and Cow dung 10 ton ha^{-1} during the day of seed sowing in 18 plot of line sowing and during the day of transplanting in 18 SMI plot except urea. Half of the urea was applied during sowing and transplanting, another half was applied as side dressing during flowering stage.

3.10 Preparation and application of biochar

Biochar was grinded followed by sieving for using in the field. Then biochar was added to the soil of each plot according to the recommended doses 10 days before sowing.

3.11 Sowing of seeds in the field

Seeds were sown in rows made by hand rake on November 17, 2017 for line sowing plots. The seeds were placed continuously within the rows at a depth of 2-3 cm from the soil surface. Row to row distance in line sowing is 30 cm. In SMI method, seeds were grown in polybag. 17 days old seedlings were transplanted in the main plot.

3.12 Intercultural operations

3.12.1 Thinning

Thinning operation was done first on December 2, 2017 (15 days after sowing) second on December 7, 2017 (20 days after sowing) and the final thinning was done on December 13, 2017 (24 days after sowing) with maintaining population density.

3.12.2 Irrigation and weeding

Two irrigations were given during the life cycle. The first irrigation was given at 20 DAS (days after sowing) on December 7, 2017 and the second was done at 40 DAS on 27 December, 2017. In total, three irrigations were applied at intervals of every 20 days at pre-flowering, at full bloom, and at pod-formation stages. The crop field was weeded twice, first weeding was done at 15 DAS on December 2, 2013 and second weeding was done at 26 DAS on December 13, 2017. Boundaries and drainage channels were also kept weed free.

3.12.3 Plant protection

At middle stage of growth, aphids attacked the crop. To control this pest, Sumithion 50 EC@ 20 ml liter-10 water was sprayed twice on January 1, 2018 (45 DAS) and January 17, 2018 (61 DAS).

3.13 Harvesting and sampling

BARI Sharisa-14 was harvested at 90 DAS and BARI Shorisa-11 was harvested at 103 DAS. The crop was harvested as plot wise when about 90% of the siliquae ripen. Five samples plants were collected for taking yield attributes data from different places of each plot leaving undisturbed plant in the center. For collecting yield data, plants of central 1 m^2 was harvested from each plots. The harvested crops were tied into bundles and carried to the threshing floor

3.14 Threshing

The crop was sun dried for three days by placing them on the open threshing floor. Seeds were separated from the plants by beating the bundles with bamboo sticks.

3.15 Drying, cleaning and weighing

The separated seeds were cleaned and dried in the sun for 5 consecutive days for achieving safe moisture level of seed. The dried seeds were cleaned and weighed. The stover were also dried in the sun and weighted plot wise.

3.16 Recording of data

The data were recorded on the following parameters

i. Growth parameters

a. Plant height (cm)

b. Leaf SPAD value

c. Number of primary branch plant^{-1}

ii. Yield contributing parameters

a. Number of siliqua plant^{-1}

b. Length of siliquae

c. Number of seeds siliqua^{-1}

d. 1000 seed weight (g)

e. Shelling percentage

iii. Yield parameters

a. Seed yield (t ha^{-1})

b. Stover yield (t ha^{-1})

c. Harvest index

3.17 Procedure of recording data

3.17.1 Growth parameters

3.17.1.1 Plant height (cm)

Five plants were selected randomly from each plot. The height of the plants were measured from the ground level to the tip of the plant at 30, 40, 50, 60 days after sowing (DAS) and harvest.

3.17.1.2 Leaf SPAD value

Five plants were selected randomly from each plot. Chlorophyll content is measured by SPAD value device (SPAD value meter). Three leaves from each plant were selected. SPAD value data were recorded from the three leaves and averaged the data. Data were recorded at 30, 40, 50 and 60 days after sowing (DAS).

3.17.1.3 Number of primary branches $plant^{-1}$

Five plants were selected randomly from each plot. Number of branch per plant was counted from each plant sample and then averaged at 40, 50 and 60 days after sowing (DAS).

3.17.2 Yield contributing parameters

3.17.2.1 Number of Siliquae $plant^{-1}$

Number of siliquae $plants^{-1}$ was counted from the 5 sample plant and then the average siliqua number was calculated.

3.17.2.2 Length of siliquae (cm)

Length of ten siliquae collected randomly from sampled plants the mean length was recorded.

3.17.2.3 Number of Seeds siliqua^{-1}

Number of seeds siliqua^{-1} was counted from 20 siliquae of sample plants and then the average seed number was calculated.

3.17.2.4 1000 seed weight (g)

1000-seeds were counted which were taken from the seeds sample of each plot separately, then weighed in an electrical balance and data were recorded.

3.17.2.5 Shelling percentage

The weight of 20 siliquae and the grains of 20 siliquae were taken from each treatment and the mean results were recorded. Shelling percentage was calculated by the following formulae:

$$\text{Shelling percentage (\%)} = \frac{Weight\ of\ seeds}{Weight\ of\ siliqua} \times 100$$

Here, weight of siliqua = seed weight + shell weight

3.17.3 Yield parameters

3.17.3.1 Grain yield (t ha^{-1})

Grain yield was recorded on the basis of harvested grain plot^{-1} (1 m^2) and was expressed in terms of yield (t ha^{-1}). Seed yield was adjusted to 10% moisture content.

3.17.3.2 Stover yield (t ha^{-1})

After separation of seeds from plant, the straw and shell of harvested area was sun dried and the weight was recorded and then converted to t ha^{-1}.

3.17.3.3 Harvest index

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

$$\text{HI (\%)} = \frac{Grain\ yield}{Biological\ yield} \times 100$$

Here, Biological yield = Grain yield + stover yield

3.18 Data analysis technique

The collected data were compiled and analysed statistically using the analysis of variance (ANOVA) technique with the help of MSTAT-C a computer package program and the mean differences were adjusted by Least Significance Difference (LSD) test at 5% level of probability (Gomez and Gomez, 1984).

CHAPTER IV

RESULTS AND DISCUSSION

The present experiment was conducted to observe the influence of biochar and planting method on the yield of mustard and oilseed varieties. Data on different growth and yield parameters of mustard were recorded. All the growth characters, yield attributing characters and yield data were statistically analyzed and the results are presented and discussed with the help of either table or graphs. In order to understand the effect of treatments, the data have also been presented in figures and tables.

4.1 Growth Parameters

4.1.1 Plant height

4.1.1.1 Effects of variety

Plant height recorded at 30, 40, 50, 60 DAS and at harvest of mustard plants have been presented in Figure 1 and Appendix IV. The figure shows that plant height increased straightly up to 60 DAS after that the rate of increase was much slower. The taller plants were recorded 40.66, 91.99, 115.77, 123.76 and 130.35cm at 30, 40, 50, 60 DAS and at harvest stage, respectively from BARI Sarisha 11. Whereas, the shorter plant height were recorded 32.84, 45.35, 51.42, 65.997 and 78.62 cm at 30, 40, 50, 60 DAS and at harvest stage, respectively from BARI Sarisha 14. The highest plant height in V_1 may perhaps the longer in this variety. Aziz (2014) also reported that BARI Sarisha 11 had higher plant height which confirms the present findings.

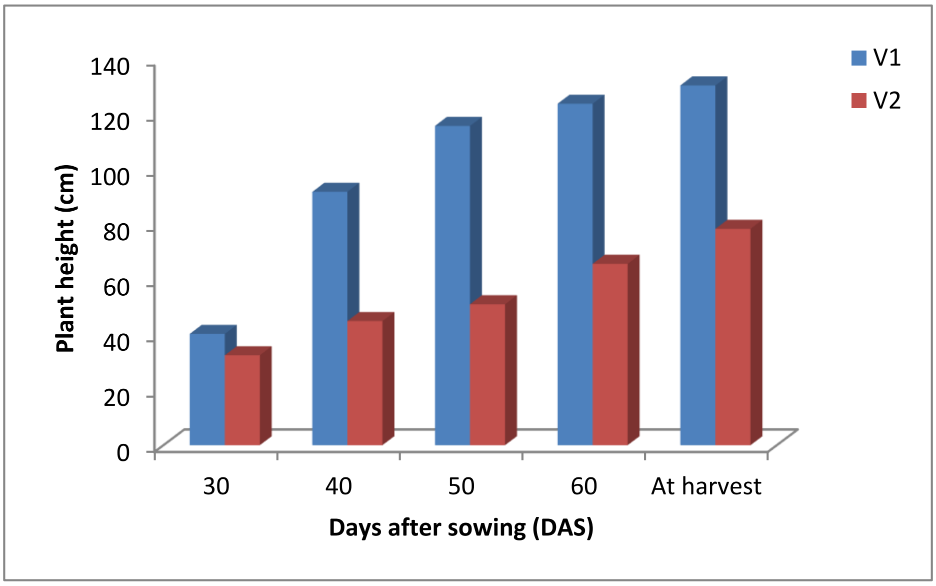


Figure 1. Plant height of rapeseed and mustard affected by variety ($LSD_{0.05}$ = 1.117, 2.385, 3.144, 3.267 and 4.289 at 30, 40, 50, 60 DAS and at harvest, respectively)

V_1 = BARI Sarisha-11, V_2 = BARI Sarisha-14

4.1.1.2 Effect of planting method

The plant height (cm) of mustard and rapeseed was significantly varied by different planting methods at 30, 40, 50, 60 DAS and at harvest (Appendix IV and Figure 2). The figure shows that plant height increased sharply up to at harvest and the rate of increase was highest from 30 to 40 DAS. The highest plant height were recorded 38.24, 69.45, 86.24, 98.07 and 107.66 cm at 30, 40, 50, 60 DAS and at harvest stage, respectively from P_2, whereas, the lowest plant height were recorded 35.26, 67.90, 80.95, 91.69 and 101.32 cm at 30, 40, 50, 60 DAS and at harvest stage, respectively from P_1. Khan *et al.* (2000) and Sarkees (2013) also found significant variation in plant height of rapes and mustard at different planting methods.

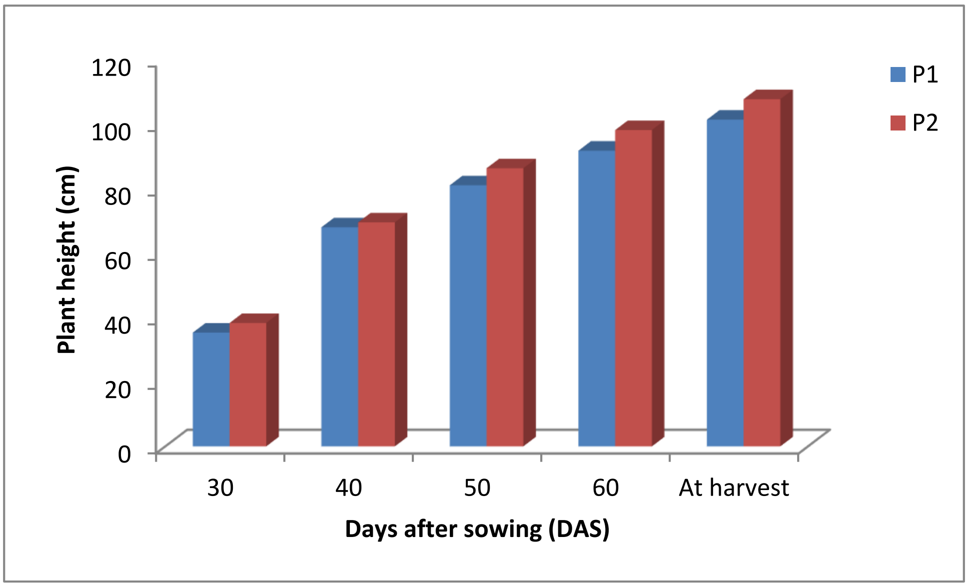


Figure 2. Plant height of rapeseed and mustard per plant affected by planting method ($LSD_{0.05}$ =1.022, 0.685, 2.173, 2.316 and 2.867 at 30, 40, 50, 60 DAS and at harvest, respectively)

P_1 = Sowing in line, P_2 = SMI 30x30cm transplanting

4.1.1.3 Effect of biochar

The plant height was significantly influenced by different level of biochar application at all growth stages of mustard shown in Appendix IV and Figure 3. At 30, 40, 50, 60 DAS and at harvest, the highest plant height 39.21, 72.10, 87.81, 99.07 and 108.10cm, respectively was recorded in B_2 (application of biochar 10 t ha^{-1}) where the lowest was measured at 30, 40, 50, 60 DAS and at harvest (33.03, 64.11, 79.04, 88.74 and 100.20 cm, respectively) in B_0 (no biochar application).And B_1 showed the plant height 37.74, 69.80, 83.83, 96.83 and 105.01cm at 30, 40, 50, 60 DAS and at harvest, respectively which is nearest to B_2. Van Zwieten *et al.* (2010) reported a nearly 30-40 per cent increase in wheat height when biochar produced from paper mill sludge was applied at a rate of 10 t ha^{-1} to an acidic soil. Gonzaga *et al*. (2019) also reported that Biochar increased the plant growth of mustard by approximately 30 to 224%.

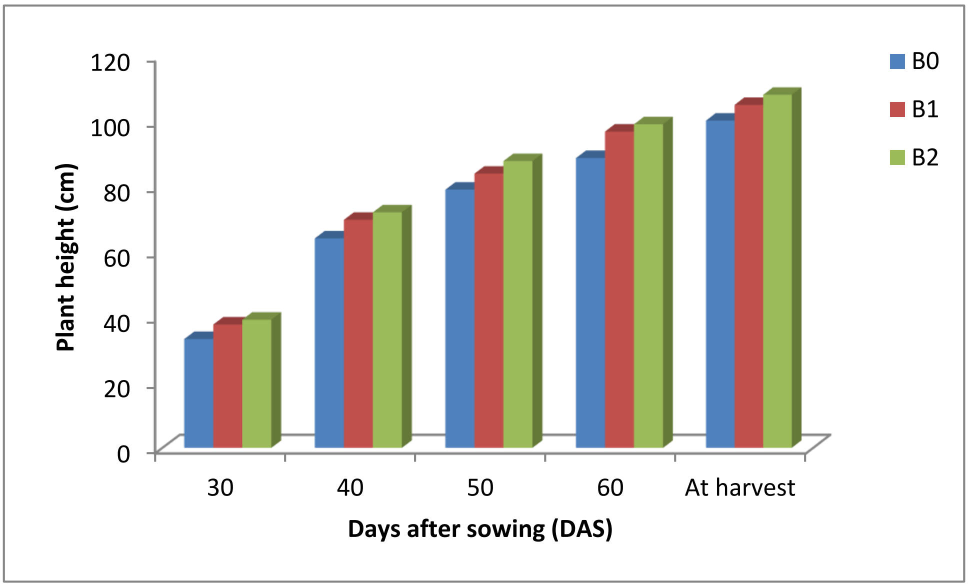


Figure 3. Plant height of rapeseed and mustard as affected by biochar doses ($LSD_{0.05}$ =1.120, 1.140, 1.023, 1.390 and 1.450 at 30, 40, 50, 60 DAS and at harvest, respectively)
B_0= Control (No biochar application), B_1= application of biochar 5 t ha^{-1},
B_2= application of biochar 10 t ha^{-1}

4.1.1.4 Combined effect of variety and planting method

Plant height (cm) was varied significantly due to interaction of variety and panting technique at all the growth stages and at harvest which is shown in and Appendix IV and Table 1. At 30 DAS, the tallest plant (41.41 cm) was recorded from the combination of BARI Sarisha-11 and SMI technique (V_1P_2) which was statistically similar with (V_1P_1). On the other hand, the shortest plant (30.61 cm) was obtained from the combination of BARI Sarisha-14 and line sowing technique (V_2P_1). Combination of BARI Sarisha-11 and line sowing method (V_1P_1) scored the tallest plant (92.60 cm) at 40 DAS which was statistically similar with V_1P_2. The shortest plant (43.19 cm) was recorded at the combination of BARI Sarisha-14 and line sowing method (V_2P_1). At 50 DAS, the tallest plant (117.9cm) was obtained from the combination of BARI Sarisha-11 and SMI method (V_1P_2). On the other hand, the shortest plant (48.29 cm) was observed from the combination of BARI Sarisha-14 and line sowing technique (V_2P_1). At 60 DAS and at harvest the tallest plant (127.60 and 133.90cm) were obtained from the combination of BARI Sarisha-11 and SMI method (V_1P_2). On the other hand the shortest plant (68.59 and 81.38 cm) was observed at the combination of BARI Sarisha-14 and line sowing technique (V_2P_1).

4.1.1.5 Combined effect of variety and biochar

Plant height (cm) was significantly affected by the interaction of variety and biochar at 30, 40, 50, 60 DAS and at harvest which is shown in Table 1 and Appendix IV. At 30 DAS, The tallest plant (43.19 cm) was recorded from the combination of BARI Sarisha-11 and biochar 10 t ha^{-1} (V_1B_2) which was statistically similar with (V_1B_1). On the other hand, the shortest plant (29.67 cm) was obtained from the combination of BARI Sarisha-14 and biochar 0 t ha^{-1} control (V_2B_0). Combination of BARI Sarisha-11 and 10 t ha^{-1} biochar (V_1B_2) scored the tallest plant (96.15 cm) at 40 DAS and the shortest plant (41.74 cm) was recorded at the combination of BARI Sarisha-14 and 0 t ha^{-1} biochar control (V_2B_0). At 50 DAS, tallest plant (120.4cm) was obtained from the combination of BARI Sarisha-11 and 10 t ha^{-1} biochar (V_1B_2). On the other hand, the shortest plant (46.81 cm) was observed from the combination of BARI Sarisha-14 and line sowing technique (V_2B_0). At 60 DAS and at harvest the tallest plant (129.00 and 134.50cm) were obtained from the combination of BARI Sarisha-11 and 10 t ha^{-1} biochar (V_1B_2). On the other hand, the shortest plant (61.69 and 74.90 cm) was observed at the combination of BARI Sarisha-14 and no biochar treatment (V_2B_0).

4.1.1.6 Combined effect of planting method and biochar

Plant height was affected significantly by the interaction of planting method and biochar at 30, 40, 50, 60 DAS and at harvest which is shown in Table 1 and Appendix IV. At 30 DAS, The tallest plant (40.31 cm) was recorded from the combination of SMI method and 10 t ha-1 of biochar (P_2B_2) which was statistically similar with P_1B_2 and P_2B_1. On the other hand, the shortest plant (31.45 cm) was obtained from the combination of sowing in line method and 10 t ha^{-1} of biochar (P_1B_0). Combination of SMI method and 10 t ha^{-1} of biochar (P_2B_2) scored the highest plant height (72.60cm) at 40 DAS which was statistically similar with P_1B_2 and P_2B_1. The shortest plant (63.45cm) was recorded at the combination of line sowing method and 0 t ha^{-1} of biochar control (P_1B_0) which is statistically similar with P_2B_0. At 50 DAS, highest plant height (90.17cm) was obtained from the combination of SMI method and 10 t ha^{-1} of biochar (P_2B_2). On the other hand, lowest plant height (76.78 cm) was observed from the combination of SMI method and 10 t ha^{-1} of biochar (P_2B_2). At 60 DAS and at highest plant height (101.20 and 111.00 cm) were obtained from the combination of SMI method and 10 t ha^{-1} of biochar (P_2B_2) which were similar with P_2B_1. On the other hand lowest plant height (83.79 and 97.07 cm) were observed at the combination of line sowing method and 0 t ha^{-1} of biochar control (P_1B_0). The result revealed that interaction of P_2B_2 showed the tallest plant for all sampling dates.

4.1.1.7 Combined effect of variety, planting method and biochar

There observed a significant variations in plant height of mustard and rapeseed due to interaction among variety, planting method and biochar doses at 30, 40, 50, 60 DAS and at harvest (Appendix IV and Table 2). At 30 DAS, the longest plant (43.26cm) was obtained from BARI Sarisha-11 with SMI method and 10 t ha^{-1} of biochar ($V_1P_2B_2$) which was statistically similar with $V_1P_2B_1$, $V_1P_1B_2$ and $V_1P_1B_1$. The shortest plant (27.42 cm) was obtained from BARI Sarisha-14 with line sowing method and 0 t ha^{-1} of biochar control ($V_2P_1B_0$). At 40 DAS, the longest plant (97.19cm) was obtained from BARI Sarisha-11 interaction with line sowing method and 10 t ha^{-1} of biochar $V_1P_1B_2$ that similar to $V_1P_2B_2$, $V_1P_1B_1$. The shortest plant (39.36 cm) was obtained from interaction of BARI Sarisha-14 with line sowing method and 0 t ha^{-1} of biochar control ($V_2P_1B_0$). At 50 and 60 DAS, the longest plant (121.40 and 130.40 cm) was obtained from BARI Sarisha-11 combined with SMI method and 10 t ha^{-1} of biochar ($V_1P_2B_2$) which was at par with $V_1P_1B_2$ and $V_1P_2B_1$. The shortest plant (44.35 and 59.02 cm) was obtained from BARI Sarisha-14 interact with line sowing method and o t ha^{-1} of biochar control ($V_2P_1B_0$). At harvest, the longest plant (137.60 cm) was obtained from BARI Sarisha-11 combined with SMI method and 10 t ha^{-1} of biochar ($V_1P_2B_2$) which was at par with $V_1P_2B_1$. The shortest plant (72.32 cm) was obtained from the interaction of BARI Sarisha-14 with line sowing method and 0 t ha^{-1} of biochar control ($V_2P_1B_0$).

Table 1. Combined effect of variety and planting method, variety and biochar, planting method and biochar on plant height of rapeseed and mustard at different days after sowing

Interaction	Plant height (cm) at different days after sowing				
	30	40	50	60	At harvest
Combined effect of variety and planting method					
V_1P_1	39.90 a	92.60 a	113.6 b	120.00 b	126.80 b
V_1P_2	41.41 a	91.38 a	117.9 a	127.60 a	133.90 a
V_2P_1	30.61 c	43.19 c	48.29 d	63.41 d	75.87 d
V_2P_2	35.06 b	47.51 b	54.55 c	68.59 c	81.38 c
$LSD_{(0.05)}$	**1.62**	**1.32**	**1.18**	**1.61**	**1.67**
Combined effect of variety and biochar					
V_1B_0	36.92 b	86.49 c	111.3 c	115.80 c	125.50 c
V_1B_1	41.87 a	93.33 b	115.6 b	126.50 b	131.10 b
V_1B_2	43.19 a	96.15 a	120.4 a	129.00 a	134.50 a
V_2B_0	29.67 d	41.74 e	46.81 f	61.69 e	74.90 f
V_2B_1	33.62 c	46.27 d	52.24 e	67.17 d	79.23 e
V_2B_2	35.22 bc	48.05 d	55.19 d	69.14 d	81.74 d
$LSD_{(0.05)}$	**1.99**	**2.01**	**1.88**	**2.30**	**2.37**
Combined effect of planting method and biochar					
P_1B_0	31.45 d	63.45 c	76.78 d	83.79 d	97.07 d
P_1B_1	36.23 bc	68.64 b	80.62 c	94.29 c	101.60 c
P_1B_2	38.10 ab	71.61 a	85.46 b	96.99 b	105.30 b
P_2B_0	35.14 c	64.76 c	81.29 c	93.68 c	103.30 bc
P_2B_1	39.26 a	70.97 a	87.24 b	99.37 a	108.70 a
P_2B_2	40.31 a	72.60 a	90.17 a	101.20 a	111.00 a
$LSD_{(0.05)}$	**2.26**	**2.01**	**1.88**	**2.30**	**2.37**
CV (%)	**7.33**	**6.12**	**8.63**	**7.86**	**9.51**

V_1 = BARI Sharisha 11, V_2 = BARI Sharisha 14, P_1= Sowing in line, P_2= SMI (30 cm × 30 cm spacing) planting, B_0 = 0.0 t ha^{-1} (Control), B_1 = 5.0 t ha^{-1}, B_2 = 10.0 t ha^{-1}

Table 2. Combined effect of variety, planting method and biochar on plant height of rapeseed and mustard at different days after sowing

Intraction	Plant height (cm) at different days after sowing				
	30	40	50	60	At harvest
$V_1P_1B_0$	35.48 c	87.55 c	109.20 c	108.60 c	121.80 d
$V_1P_1B_1$	41.11 a	93.07 b	112.20 bc	123.80 b	127.00 c
$V_1P_1B_2$	43.12 a	97.19 a	119.40 a	127.60 a	131.40 b
$V_1P_2B_0$	38.35 b	85.42 c	113.30 b	123.00 b	129.10 bc
$V_1P_2B_1$	42.63 a	93.60 b	119.00 a	129.20 a	135.10 a
$V_1P_2B_2$	43.26 a	95.12 ab	121.40 a	130.40 a	137.60 a
$V_2P_1B_0$	27.42 e	39.36 f	44.35 g	59.02 g	72.32 h
$V_2P_1B_1$	31.35 d	44.20 e	49.03 f	64.81 f	76.21 g
$V_2P_1B_2$	33.07 d	46.02 e	51.48 f	66.39 ef	79.07 fg
$V_2P_2B_0$	31.93 d	44.11 e	49.28 f	64.35 f	77.48 g
$V_2P_2B_1$	35.89 c	48.34 d	55.45 e	69.52 de	82.25 ef
$V_2P_2B_2$	37.37 bc	50.08 d	58.91 d	71.89 d	84.40 e
$LSD_{(0.05)}$	**2.241**	**2.280**	**3.239**	**3.256**	**3.353**
CV (%)	**7.33**	**6.12**	**8.63**	**7.86**	**9.51**

V_1 = BARI Sharisha 11, V_2 = BARI Sharisha 14, P_1= Sowing in line, P_2= SMI (30 cm × 30 cm spacing) planting, B_0 = 0.0 t ha^{-1} (Control), B_1 = 5.0 t ha^{-1}, B_2 = 10.0 t ha^{-1}

4.1.2 Number of primary branches plant^{-1}

4.1.2.1 Effect of variety

The number of primary branches plant^{-1} was significantly influenced by different varieties at 40, 50, and 60 DAS (Appendix V and Figure 4). The figure shows that the highest number of primary branches plant^{-1} (8.69, 9.48 and 10.39) were obtained from BARI Sarisha-14 (V_2) at 40, 50 and 60 DAS, respectively. On the other hand the lowest number of primary branches plant^{-1} (6.15, 7.15 and 7.78) were obtained from BARI Sarisha-11(V_1) at 40, 50 and 60 DAS, respectively. Ahmed and Kashem (2017) agreed with this result who reported that significant differences were found among the mustard varieties for number of branches plant^{-1}.

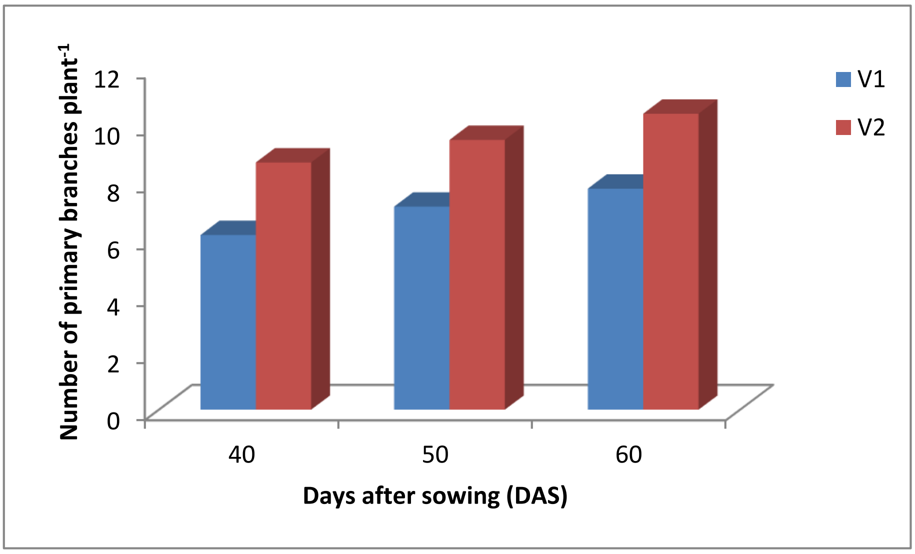


Figure 4. Effect of variety on primary branches number of rapeseed and mustard plant at different DAS ($LSD_{0.05}$= 0.208, 0.226 and 0.171at 40, 50 and 60 DAS, respectively)

V_1 = BARI Sarisha-11, V_2 = BARI Sarisha-14

4.1.2.2 Effect of planting method

Number of primary branches plant^{-1} was significantly affected by sowing technique at 40, 50 and 60 DAS (Appendix V and Figure 5).The highest number of primary branches plant^{-1} (9.12, 9.93 and 10.85) were recorded from SMI method (P_2) at 40, 50 and 60 DAS respectively. On the other hand the lowest number of primary branches plant^{-1} (5.72, 6.688 and 7.32) were recorded from line sowing method (P_1) at 40, 50 and 60 DAS respectively. Jangir *et al*. (2017) and Pandey *et al*. (2017) showed conformity with this result and reported that planting method and geometry showed significant variation of number of primary branches plant^{-1}.

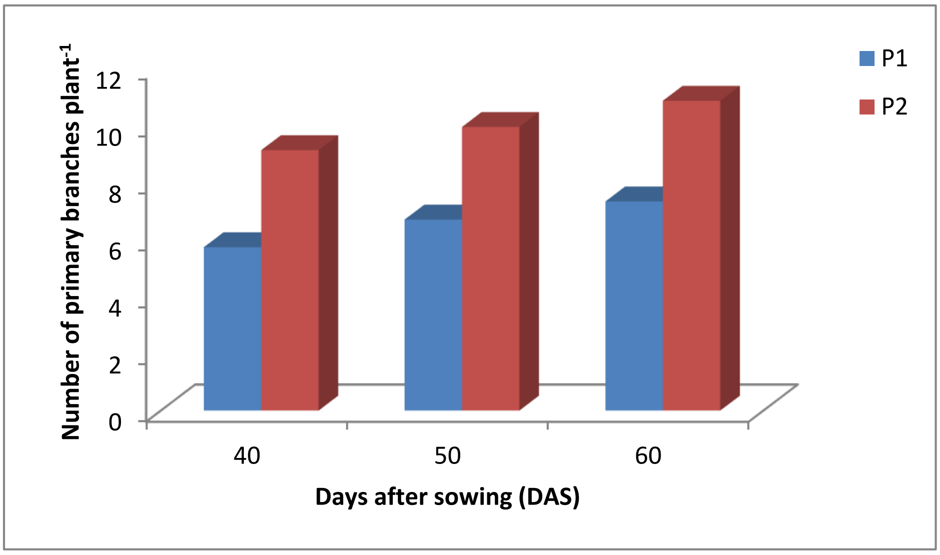


Figure 5. Number of primary branches per plant of rapeseed and mustard affected by planting method ($LSD_{0.05}$ = 0.259, 0.312 and 0.405 at 40, 50 and 60 DAS, respectively).

P_1 = Sowing in line, P_2 = SMI 30x30cm transplanting

4.1.2.3 Effect of biochar

Number of primary branches plant^{-1} was significantly influenced by different levels of biochar application at all growth stages of mustard (Figure 6 and Appendix V). The highest number of primary branches plant^{-1} (8.11, 9.17 and 10.09) were observed from 10 t ha^{-1} of biochar (B_2) at 40, 50 and 60 DAS respectively. Whereas the lowest number of primary branches plant^{-1} (6.38, 7.16 and 7.74) were observed from 0 t ha^{-1} of biochar control (B_0) at 40, 50 and 60 DAS respectively. Khan (2015) also reported that rapeseed cultivar positively responded at different biochar doses for number of branches plant^{-1}.

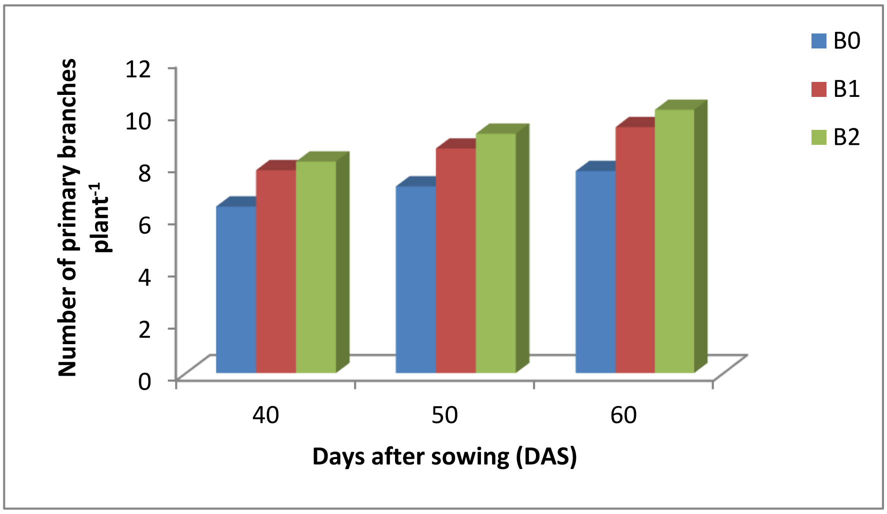


Figure 6. Number of primary branches plant^{-1} of rapeseed and mustard affected by biochar doses ($LSD_{0.05}$ =0.1312, 0.1949 and 0.1515 at 40, 50 and 60 DAS, respectively).

B_0= Control (No biochar application), B_1= application of biochar 5 t ha^{-1},

B_2= application of biochar 10 t ha^{-1}

4.1.2.4 Combined effect of variety and planting method

Number of primary branches was significantly affected by the different interaction of variety and sowing method at 40, 50 and 60 DAS Table 3 and Appendix V. The highest number of primary branches plant^{-1} (11.06, 11.68 and 12.72) were observed at 40, 50 and 60 DAS, respectively from the combination of BARI Sarisha-14 and SMI method (V_2P_2).On the other hand the lowest number of primary branches plant^{-1} (5.13, 6.11 and 6.58) were observed at 40, 50 and 60 DAS respectively from the combination of BARI Sarisha-11 and line sowing method (V_1P_1).

4.1.2.5 Combined effect of variety and biochar

Interaction effect between varieties and different levels of biochar exerted significant effect on number of primary branches plant^{-1} at 40, 50 and 60 DAS (Table 3 Appendix V). Maximum number of primary branches per plant 9.43, 10.34 and 11.37 were observed at 40, 50 and 60 DAS respectively from the variety BARI Sarisha-14 cultivated with application of biochar 10 t ha^{-1} (V_2B_2) which is statistically similar with V_2B_1. Minimum number of primary branches per plant

5.33, 6.12 and 6.83 were observed from the Variety BARI Sarisha-11 with no biochar application (V_1B_0) at 40, 50 and 60 DAS, respectively.

4.1.2.6 Combined effect of planting method and biochar

Interaction effect between planting method and different levels of biochar exerted significant effect on number of primary branches plant^{-1} at 40, 50 and 60 DAS (Table 3 and Appendix V). Maximum number of primary branches per plant (9.880, 10.95 and 12.00) were observed at 40, 50 and 60 DAS, respectively from the SMI method with application of biochar 10 t ha^{-1} (P_2B_2) which is statistically similar with P_2B_1. Minimum number of primary branches per plant 4.862, 5.975 and 6.495 were observed from the line sowing method with no biochar application (P_1B_0) at 40, 50 and 60 DAS, respectively.

4.1.2.7 Combined effect of variety, planting method and biochar

Interaction effect of variety with planting method and different level of biochar exerted significant effect on number of primary branches plant^{-1} at 40, 50 and 60 DAS (Table 4 and Appendix V). Maximum number of primary branches per plant (11.93, 12.93 and 14.07) were observed at 40, 50 and 60 DAS respectively from the variety BARI Sarisha-14 cultivated with SMI method and application of biochar 10 t ha^{-1} ($V_2P_2B_2$) which is statistically similar with $V_2P_2B_1$. Minimum number of primary branches per plant 4.39, 5.23 and 5.87 were observed from the Variety BARI Sarisha-11 with line sowing method and no biochar application ($V_1P_1B_0$) at 40, 50 and 60 DAS, respectively.

Table 3. Combined effect of variety and planting method, variety and biochar, planting method and biochar at different days after sowing for number of primary branches plant^{-1} of rapeseed and mustard at different DAS

Interaction	Number of primary branches plant^{-1} at different days after sowing		
	40	**50**	**60**
Combined effect of variety and planting method			
V_1P_1	5.13 d	6.11 d	6.58 d
V_1P_2	7.18 b	8.18 b	8.97 b
V_2P_1	6.31 c	7.27 c	8.06 c
V_2P_2	11.06 a	11.68 a	12.72 a
$LSD_{(0.05)}$	**0.34**	**0.38**	**0.36**
Combined effect of variety and biochar			
V_1B_0	5.33 e	6.12 d	6.83 d
V_1B_1	6.35 d	7.32 c	7.70 c
V_1B_2	6.78 c	8.01 b	8.80 b
V_2B_0	7.43 b	8.20 b	8.66 b
V_2B_1	9.20 a	9.89 a	11.15 a
V_2B_2	9.43 a	10.34 a	11.37 a
$LSD_{(0.05)}$	**0.42**	**0.47**	**0.44**
Combined effect of planting method and biochar			
P_1B_0	4.86 e	5.98 e	6.50 e
P_1B_1	5.97 d	6.70 d	7.30 d
P_1B_2	6.33 c	7.39 c	8.17 c
P_2B_0	7.90 b	8.34 b	8.99 b
P_2B_1	9.58 a	10.51 a	11.55 a
P_2B_2	9.88 a	10.95 a	12.00 a
$LSD_{(0.05)}$	**0.30**	**0.54**	**0.58**
CV (%)	**5.27**	**6.74**	**6.96**

V_1 = BARI Sarisha 11, V_2 = BARI Sarisha 14, P_1= Sowing in line, P_2= SMI (30 cm × 30 cm spacing) planting, B_0 = 0.0 t ha^{-1} (Control), B_1 = 5.0 t ha^{-1}, B_2 = 10.0 t ha^{-1}

Table 4. Combined effect of variety, planting method and biochar at different days after sowing for number of primary branches plant^{-1} of rapeseed and mustard

Intraction	Number of primary branches plant^{-1} at different days after sowing		
	40	**50**	**60**
$V_1P_1B_0$	4.39 h	5.23 h	5.87 g
$V_1P_1B_1$	5.27 g	6.07 gh	6.20 g
$V_1P_1B_2$	5.73 fg	7.03 ef	7.67 ef
$V_1P_2B_0$	6.27 ef	7.00 ef	7.78 ef
$V_1P_2B_1$	7.43 cd	8.57 cd	9.20 cd
$V_1P_2B_2$	7.83 c	8.98 bc	9.93 bc
$V_2P_1B_0$	5.33 g	6.72 fg	7.12 f
$V_2P_1B_1$	6.67 de	7.33 ef	8.40 de
$V_2P_1B_2$	6.93 de	7.75 de	8.67 d
$V_2P_2B_0$	9.53 b	9.67 b	10.20 b
$V_2P_2B_1$	11.73 a	12.45 a	13.90 a
$V_2P_2B_2$	11.93 a	12.93 a	14.07 a
$LSD_{0.05}$	**0.80**	**0.85**	**0.82**
CV (%)	**5.27**	**6.74**	**6.96**

V_1 = BARI Sarisha 11, V_2 = BARI Sarisha 14, P_1= Sowing in line, P_2= SMI (30 cm × 30 cm spacing) planting, B_0 = 0.0 t ha^{-1} (Control), B_1 = 5.0 t ha^{-1}, B_2 = 10.0 t ha^{-1}

4.1.3 Leaf SPAD value

4.1.3.1 Effect of variety

Leaf SPAD value is the chlorophyll content showed statistically non-significant difference due to different variety at 30 DAS but significant variation showed in 40, 50 and 60 DAS for rapeseed and mustard (Figure 7 and Appendix VI). On 30 DAS leaf SPAD value (52.45 and 53.12) were recorded from BARI Sarisha-11 (V_1) and BARI Sarisha-14 (V_2), respectively which are statistically non-significant. The highest leaf SPAD value (58.87, 60.93 and 62.25) were recorded at 40, 50 and 60 DAS, respectively from BARI Sarisha-14 (V_2) and the lowest leaf SPAD value (54.523, 58.601 and 59.853) were recorded at 40, 50 and 60 DAS, respectively from BARI Sarisha-11 (V_1).

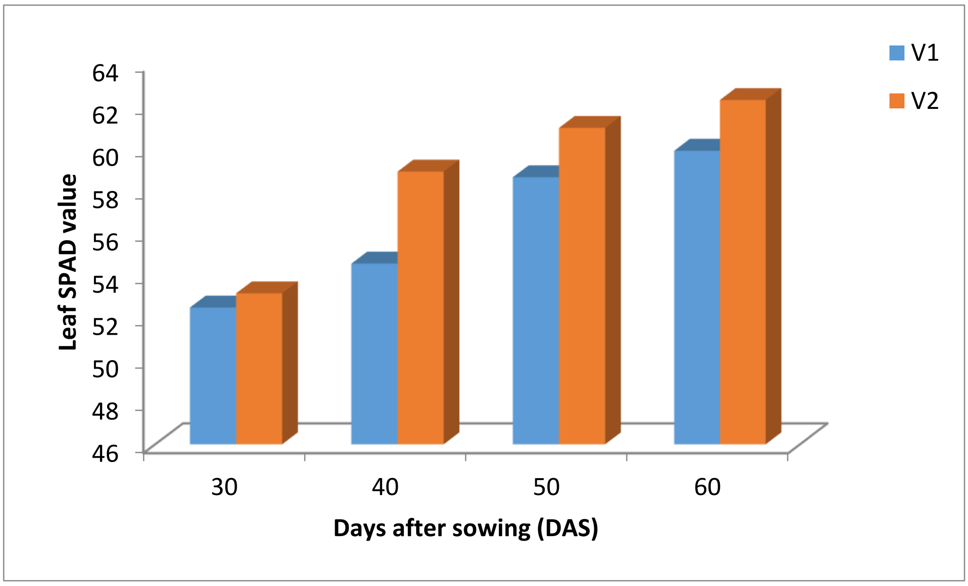


Figure 7. Leaf SPAD value of rapeseed and mustard plant affected by variety ($LSD_{0.05}$ =0.217, 0.206 and 0.243 at 40, 50 and 60 DAS, respectively).

V_1 = BARI Sarisha-11, V_2 = BARI Sarisha-14

4.1.3.2 Effect of planting method

A critical analysis of mean data (Appendix VI and Figure 8) revealed that different planting method had no significant influence on SPAD value at 30, 40 50 and 60 DAS. At 30, 40, 50 and 60 DAS leaf SPAD value (52.92, 56.46, 59.90 and 60.43) were recorded respectively from line sowing method (P_1) and leaf SPAD value (52.647, 56.933, 60.637 and 61.674) were recorded at 30, 40, 50 and 60 DAS, respectively from SMI method (P_2) which were statistically non-significant.

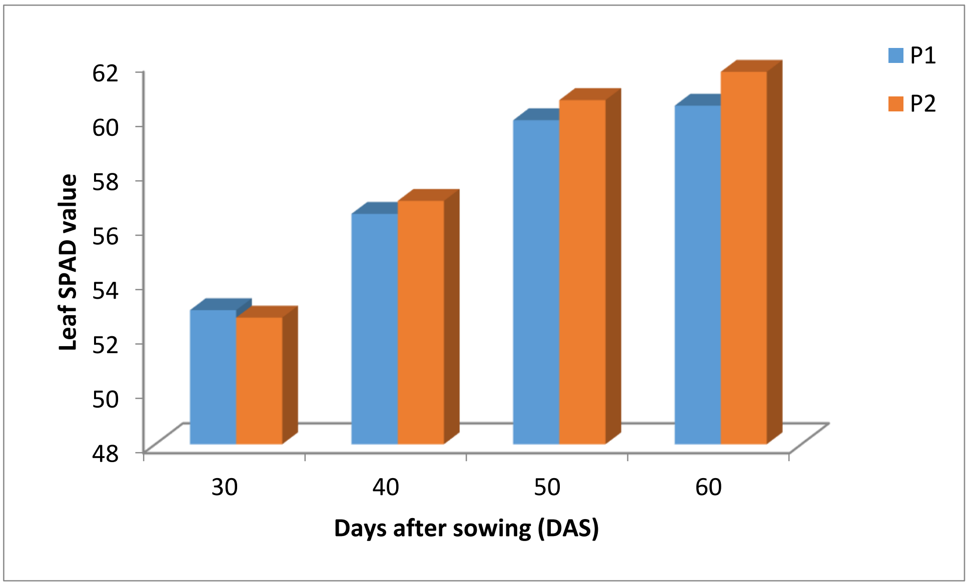


Figure 8. Leaf SPAD value data of rapeseed and mustard plant d affected by planting method respectively.

P_1 = Sowing in line, P_2 = SMI 30x30cm transplanting

4.1.3.3 Effect of biochar

A critical analysis of mean data (Appendix VI and Figure 9) revealed that different biochar levels had non-significant influence on SPAD value at 30 DAS but had significant influence at 40, 50 and 60 DAS. SPAD value increased with the increase of biochar level at all sampling dates (Figure 9). At 30 DAS leaf SPAD value (52.14, 52.83, 53.38) were recorded from 0, 5 and 10 t ha-1 of biochar respectively which were statistically non-significant. At 40, 50 and 60 DAS, maximum SPAD value (58.23, 62.31 and 63.14, respectively) was recorded from 10 t ha-1 of biochar followed by 5 t ha-1 of biochar (56.60, 59.65 and 61.23, respectively). Minimum SPAD value (55.26, 58.84 and 58.78, respectively) was recorded at no biochar application.

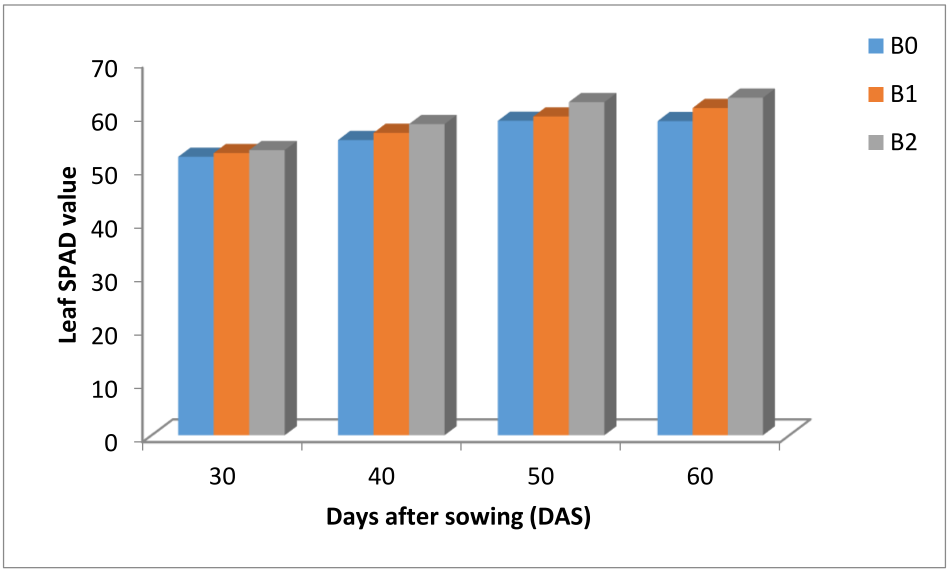


Figure 9. Leaf SPAD value of rapeseed and mustard plant affected by different biochar doses ($LSD_{0.05}$ = 0.5667, 0.5526 and 0.6656 at 40, 50 and 60 DAS respectively).

B_0 = Control (No biochar application), B_1= application of biochar 5 t ha^{-1},

B_2= application of biochar 10 t ha^{-1}

4.1.3.4 Combined effect of variety and planting method

A perusal of data (Table 5 and Appendix VI) revealed that the combined effect of variety and planting method significantly affected the SPAD value at 40, 50 and 60 DAS but not at 30 DAS. The highest SPAD value (58.97) was recorded from BARI Sarisha-14 when combine with SMI method (V_2P_2) at 40 DAS was statistically similar with V_2P_1 (58.77) and lowest SPAD value (54.15) was recorded from BARI Sarisha-11 when combine with line sowing method (V_1P_1).At 50 and 60 DAS, maximum SPAD value (61.57 and 62.75, respectively) were obtained from V_2B_2 . At 50 DAS the lowest SPAD value (59.49) was recorded from V_1P_1 which was statistically similar with V_1P_2, V_2P_1. At 60 DAS the lowest SPAD value (59.11) was recorded from V_1P_1.

4.1.3.5 Combined effect of variety and biochar

Combined effect between variety and different level of biochar exerted significant effect on SPAD value (Table 5 Appendix VI) at 40, 50 and 60 DAS but not at 30 DAS. At 40 DAS the highest SPAD value (60.31) was observed from BARI Sarisha-

14 when combine with 10t ha^{-1} of biochar (V_2B_2) which was statistically similar with V_2B_1 (59.06) and the lowest SPAD value (53.28) was observed from the combination of BARI Sarisha-11 and no application of biochar (V_1B_0) which is statistically similar with V_1B_1(54.15). At 50 DAS the highest SPAD value (62.69) was observed from BARI Sarisha-14 when combine with 10t ha-1 of biochar (V_2B_2) was statistically similar with V_1B_2 (61.94) and the lowest SPAD value (57.99) was observed from the combination of BARI Sarisha-11 and no application of biochar (V_1B_0) which is statistically similar with V_1B_1(58.88). The highest SPAD value (64.17) was observed from BARI Sarisha-14 when combine with 10t ha^{-1} of biochar (V_2B_2) at 60 DAS and the lowest SPAD value (57.49) was observed from the combination of BARI Sarisha-11 and no application of biochar (V_1B_0).

4.1.3.6 Combined effect of planting method and biochar

Combined effect between planting method and different levels of biochar exerted significant effect on SPAD value (Table 5 and Appendix VI) at 40, 50 and 60 DAS but not at 30 DAS. At 40 DAS the highest SPAD value (58.32) was observed from line sowing method when combine with 10t ha^{-1} of biochar (P_1B_2) which was statistically similar with P_2B_2 (58.14) and the lowest SPAD value (54.41) was observed from the combination of line sowing method and no application of biochar (V_1B_0). At 50 DAS the highest SPAD value (62.39) was observed from line sowing method when combine with 10t ha^{-1} of biochar (P_1B_2) was statistically similar with P_2B_2 (62.24) and the lowest SPAD value (58.19) was observed from the combination of line sowing method and no application of biochar (V_1B_0) which is statistically similar with V_1B_1(59.11). The highest SPAD value (63.73) was observed from SMI method when combine with 10t ha^{-1} of biochar (P_2B_2) at 60 DAS which was statistically similar with P_1B_2 (62.55) and the lowest SPAD value (58.25) was observed from the combination of BARI Sarisha-11 and no application of biochar (V_1B_0) which was statistically similar with P_2B_0.

Table 5. Combined effect of variety and planting method, variety and biochar, planting method and biochar at different days after sowing for leaf SPAD value of rapeseed and mustard

Interaction	Leaf SPAD value at different days after sowing			
	30	40	50	60
Combined effect of variety and planting method				
V_1P_1	52.27	54.15 b	59.49 b	59.11 d
V_1P_2	52.63	54.90 b	59.71 b	60.59 c
V_2P_1	53.57	58.77 a	60.30 b	61.75 b
V_2P_2	52.66	58.97 a	61.57 a	62.75 a
$LSD_{(0.05)}$	**NS**	**1.18**	**0.99**	**0.99**
Combined effect of variety and biochar				
V_1B_0	52.20	53.28 c	57.99 d	57.49 d
V_1B_1	52.46	54.15 c	58.88 cd	59.97 c
V_1B_2	52.69	56.15 b	61.94 a	62.10 b
V_2B_0	52.08	57.24 b	59.70 bc	60.08 c
V_2B_1	53.20	59.06 a	60.41 b	62.50 b
V_2B_2	54.08	60.31 a	62.69 a	64.17 a
$LSD_{(0.05)}$	**NS**	**1.44**	**1.34**	**1.52**
Combined effect of planting method and biochar				
P_1B_0	52.09	54.41 c	58.19 c	58.25 d
P_1B_1	53.21	56.65 b	59.11 bc	60.49 c
P_1B_2	53.46	58.32 a	62.39 a	62.55 ab
P_2B_0	52.19	56.10 b	59.49 b	59.32 cd
P_2B_1	52.45	56.56 b	60.18 b	61.97 b
P_2B_2	53.31	58.14 a	62.24 a	63.73 a
$LSD_{(0.05)}$	**NS**	**1.44**	**1.27**	**1.21**
CV (%)	**5.36**	**5.18**	**6.30**	**8.72**

V_1 = BARI Sharisha 11, V_2 = BARI Sharisha 14, P_1= Sowing in line, P_2= SMI (30 cm × 30 cm spacing) planting, B_0 = 0.0 t ha^{-1} (Control), B_1 = 5.0 t ha^{-1}, B_2 = 10 t ha^{-1}

4.1.3.7 Combined effect of variety, planting method and biochar

Combined effect between variety, planting method and different level of biochar exerted significant effect on SPAD value (Table 6 and Appendix VI) at 40, 50 and 60 DAS but not at 30 DAS. At 30 DAS, the highest SPAD value (54.42) was observed from BARI Sarisha-14 when combine with line sowing method and 10t ha-1 of biochar ($V_2P_1B_2$) which was statistically similar with $V_2P_1B_1$ (53.95) and $V_2P_2B_2$ (53.74). On the other hand the lowest SPAD value (51.83) was observed from the combination of BARI Sarisha-11 with line sowing method and no application of biochar ($V_1P_1B_0$) which was statistically similar with $V_1P_1B_1$ (52.47),

$V_1P_1B_2$ (52.50), $V_1P_2B_0$(52.57), $V_1P_2B_1$(52.45) and $V_2P_1B_0$ (52.35). At 40 DAS, the highest SPAD value (60.88) was observed from BARI Sarisha-14 when combine with line sowing method and10t ha^{-1} of biochar ($V_2P_1B_2$) and the lowest SPAD value (52.63) was observed from the combination of BARI Sarisha-11 with line sowing method and no application of biochar ($V_1P_1B_0$). At 50 DAS the highest SPAD value (63.67) was observed from BARI Sarisha-14 when combine with SMI method and 10t ha^{-1} of biochar ($V_2P_2B_2$) was statistically similar with $V_1P_1B_2$ (63.06) and the lowest SPAD value (56.98) was observed from the combination of BARI Sarisha-11 with line sowing method and no application of biochar ($V_1P_1B_0$). The highest SPAD value (64.65) was observed from BARI Sarisha-14 when combine with SMI method and 10t ha-1 of biochar ($V_2P_2B_2$) at 60 DAS and the lowest SPAD value (56.75) was observed from the combination of BARI Sarisha-11 with line sowing method and no application of biochar ($V_1P_1B_0$).

Table 6. Combined effect of variety, planting method and biochar at different days after sowing for leaf SPAD value of rapeseed and mustard

Treatments	Leaf SPAD value at different days after sowing			
	30	40	50	60
$V_1P_1B_0$	51.83 c	52.63 f	56.98 g	56.75 i
$V_1P_1B_1$	52.47 bc	54.06 e	58.44 f	59.18 gh
$V_1P_1B_2$	52.50 bc	55.76 d	63.06 a	61.41 cd
$V_1P_2B_0$	52.57 bc	53.92 e	58.99 ef	58.23 h
$V_1P_2B_1$	52.45 bc	54.24 e	59.32 d-f	60.75 de
$V_1P_2B_2$	52.87 b	56.53 d	60.81 bc	62.80 b
$V_2P_1B_0$	52.35 bc	56.19 d	59.41 de	59.75 fg
$V_2P_1B_1$	53.95 a	59.23 bc	59.78 de	61.80 c
$V_2P_1B_2$	54.42 a	60.88 a	61.71 b	63.69 b
$V_2P_2B_0$	51.80 c	58.28 c	59.99 cd	60.41 ef
$V_2P_2B_1$	52.45 bc	58.89 bc	61.04 b	63.20 b
$V_2P_2B_2$	53.74 a	59.74 b	63.67 a	64.65 a
$LSD_{(0.05)}$	**0.85**	**1.13**	**0.97**	**0.96**
CV (%)	**5.36**	**5.18**	**6.30**	**8.72**

V_1 = BARI Sharisha 11, V_2 = BARI Sharisha 14, P_1= Sowing in line, P_2= SMI (30 cm × 30 cm spacing) planting, B_0 = 0.0 t ha^{-1} (Control), B_1 = 5.0 t ha^{-1}, B_2 = 10 t ha^{-1}

4.2 Yield contributing parameter

4.2.1 Number of siliqua plant^{-1}

4.2.1.1 Effect of variety

The number of siliquae plant^{-1} was significantly influenced by different varieties of mustard and rapeseed at harvest (Appendix VII and Table 7). This was due to the variation in genetic makeup of different varieties affecting number of siliquae plant^{-1}. The highest number of siliquae plant^{-1} (262.66) was obtained from BARI Sarisha-11and the lowest number of siliquae per plant (124.24) was obtained from BARI Sarisha-14. Akhter (2005), Roy (2008) and Mamun *et al.* (2014) were also found that different varieties significantly affected the number of siliquae plant^{-1} of mustard and rapeseed.

4.2.1.2 Effect of planting method

Number of siliquae plant^{-1} was significantly affected by sowing method of mustard and rapeseed (Appendix VII and Table 7). Maximum number of siliquae per plant (289.73) was recorded at SMI method and minimum number of siliquae plant^{-1} (97.17) was observed at line sowing method. The result corroborates with the findings of Aziz (2014) who stated that there was marked statistical variation in number of siliquae plant^{-1} at different sowing method.

4.2.1.3 Effect of biochar

Number of siliquae plant^{-1} was significantly influenced by different levels of biochar application of mustard and rapeseed (Table 7 and Appendix VI). It was remarked from the present study that the increasing rate of biochar significantly increased number of siliquae plant^{-1}. B_2 (application of biochar 10 t ha^{-1}) treatment produced maximum number of siliquae plant^{-1} (221.2) and the lowest number of capsules plant^{-1} (155.6) was achieved with B_0 (no biochar application). Khan (2015) reported that rapeseed plant responded significantly at different doses of biochar for number of siliquae plant^{-1} which corroborates the present findings.

4.2.1.4 Combined effect of variety and planting method

Number of siliquae plant^{-1} was significantly affected by the combination of variety and sowing method which is shown at Table 8 and Appendix VII. Combination of BARI Sarisha-11 and SMI method (V_1P_2) scored the maximum number of siliquae plant^{-1} (404.8) and minimum number of siliquae plant^{-1} (73.82) was recorded at the combination of BARI Sarisha-14 and line sowing method (V_2P_1).

4.2.1.5 Combined effect of variety and biochar

Combined effect between variety and different levels of biochar exerted significant effect on number of siliquae plant^{-1} (Table 8 and Appendix VII). The maximum number of siliquae plant^{-1} (301.5) was observed in the variety BARI Sarisha-11 cultivated with application of biochar 10 t ha^{-1} (V_1B_2) and the minimum number of siliquae per plant (100.4) was observed Variety BARI Sarisha-14 with no biochar application (V_2B_0).

4.2.1.6 Combined effect of planting method and biochar

Number of siliquae plant^{-1} significantly affected by the combination of planting method and different level of biochar which is shown at Table 8 and Appendix VII. Combination of SMI method and 10 t ha^{-1} of biochar (P_2B_2) scored the maximum number of siliquae plant^{-1} (318.2) and minimum number of siliquae plant^{-1} (65.18) was recorded at the combination of line sowing method and no application of biochar (P_1B_0).

4.2.1.7 Combined effect of variety, planting method and biochar

Number of siliqua plant^{-1} significantly affected by the interaction of variety with planting method and biochar which is shown at Table 9 and Appendix VII. The highest number of siliquae plant^{-1} (44.3) was recorded at the combination of BARI Sarisha-11 with SMI method and 10 t ha^{-1} of biochar ($V_1P_2B_2$) and the lowest number of siliquae plant^{-1} (60.13) was observed at the combination of BARI Sarisha-14 with line sowing method and no application of biochar ($V_2P_1B_0$).

4.2.2 Length of silqua

4.2.2.1 Effect of variety

The present study is remarked that length of siliqua (cm) of rapeseed and mustard plant was significantly affected by variety (Appendix VII and Table 7). Biggest siliqua length (5.15 cm) was recorded at BARI Sarisha-14 and minimum siliqua length (4.13 cm) was observed at BARI Sarisha-11. BARI (1999) and Hossain *et al.* (1996) also reported that rapeseed and mustard varieties showed significant variations in respect of length of siliquae.

4.2.2.2 Effect of planting method

Present study showed that planting methods of rapeseed-mustard was not affected significantly on the length of siliqua (Appendix VII and Table 7). The maximum length of siliqua (4.72 cm) was observed in the SMI method and the minimum length of siliqua (4.56 cm) was obtained from the line sowing method. The result was supported with the findings of Hossain *et al.* (2013) who pointed out that siliqua length was not significantly influenced by sowing method.

4.2.2.3 Effect of biochar

Length of siliqua was significantly influenced by different levels of biochar application of mustard and rapeseed (Table 7 and Appendix VII). It was revealed from the present study that the increasing rate of biochar significantly increased the length of siliqua. B_2 (application of biochar 10 t ha^{-1}) treatment produced the highest length of siliqua (4.99 cm) which was nearest to B_1 (application of biochar 5 t ha^{-1}). The lowest number of length of siliqua (4.33 cm) was achieved with B_0 (no biochar application). Khan *et al*. (2015) reported that rapeseed plant responded significantly at different doses of biochar for length of siliqua which was similar with the present findings.

4.2.2.4 Combined effect of variety and planting method

Length of siliqua was significantly affected by the interaction of variety and planting method which is shown at Table 8 and Appendix VII. The largest siliqua (5.19 cm) was recorded at the combination of BARI Sarisha-14 and SMI method (V_2P_1) which was statistically similar with V_2P_2 and the shortest siliqua (3.92 cm) was observed at the combination of BARI Sarisha-11 and line sowing method (V_1P_1).

4.2.2.5 Combined effect of variety and biochar

Combined effect between variety and different level of biochar exerted significant effect on the length of siliqua (Table 8 and Appendix VII). The highest length of siliqua (5.60 cm) was observed in the variety BARI Sarisha-14 cultivated with application of biochar 10 t ha-1 (V_2B_2). The lowest length of siliqua (3.905 cm) was observed Variety BARI Sarisha-11 with no biochar application (V_1B_0) which was statistically similar with $V_1B_{1.}$

4.2.2.6 Combined effect of planting method and biochar

Combined effect between planting method and different levels of biochar exerted significant effect on the length of siliqua (Table 8 and Appendix VII). The highest length of siliqua (5.155 cm) was observed in the SMI method with application of biochar 10 t ha^{-1} (P_2B_2). The lowest length of siliqua (4.295 cm) was observed from line sowing method with no biochar application (V_1B_0).

4.2.2.7 Combined effect of variety, planting method and biochar

Length of Siliqua was significantly affected by the interaction of variety with planting method and biochar which is shown at Table 9 and Appendix VII. Maximum length of siliqua (5.74 cm) was recorded at the combination of BARI Sarisha-14 with SMI method and 10 t ha^{-1} of biochar ($V_2P_2B_2$) which was statistically similar with $V_2P_1B_2$ (5.46) and minimum length of siliqua (3.74 cm) was observed at the combination of BARI Sarisha-11 with line sowing method and no application of biochar ($V_1P_1B_0$) which was statistically at par with $V_1P_1B_1$ (3.83) and $V_1P_2B_0$ (4.07).

4.2.3 Number of seeds siliqua^{-1}

4.2.3.1 Effect of variety

Number of seeds siliqua^{-1} of rapeseed and mustard plant was significantly affected by variety (Appendix VII and Table 7). Maximum number of seeds siliqua^{-1} (28.552) was recorded at BARI Sarisha-14 and minimum number of seeds siliqua^{-1} (13.297) was observed at BARI Sarisha-11. Hossain *et al.* (1996) reported similar result that there was significant difference among the varieties with respect to number of seeds siliqua^{-1}.

4.2.3.2 Effect of planting method

Significant variation of number of seed siliqua^{-1} was found due to planting method of rapeseed and mustard (Appendix VII and Table 7). Among two planting method, higher number of seeds siliqua^{-1} (23.13) was observed from SMI method and lower number of seeds siliqua^{-1} (18.72) was obtained from the line sowing method. Similar finding was also reported by Hossain *et al.* (2013), who reported that changes of planting technique significantly influenced the number of seeds siliqua^{-1}.

4.2.3.3 Effect of biochar

Results presented in Table 7 and Appendix VII on number of seeds siliqua^{-1} influenced by different levels of biochar application were statistically significant. It the result revealed that the highest number of seeds siliqua^{-1} (22.71) was recorded in B_2 (application of biochar 10 t ha^{-1}) and the lowest number of seeds siliqua^{-1} (18.74) was achieved by B_0 (no biochar application). The results from B_1 on number of seeds siliqua^{-1} were intermediate compared to highest and lowest number of seeds siliqua^{-1}. Similar result was also reported by Khan *et al*. (2015) who observed that rapeseed plant responded significantly at different doses of biochar for length of siliqua. Khan *et al*. (2015) also reported that rapeseed plant responded significantly at different doses of biochar for number of seeds siliqua^{-1}.

4.2.3.4 Combined effect of variety and planting method

Number of seeds siliqua^{-1} was significantly affected by the interaction of variety and planting method which is shown at Table 8 and Appendix VII. Maximum number of seeds siliqua^{-1} (32.04) was recorded at the combination of BARI Sarisha-14 and SMI method (V_2P_2) and minimum number of seeds siliqua^{-1} (12.37) was observed at the combination of BARI Sarisha-11 and line sowing method (V_1P_1).

4.2.3.5 Combined effect of variety and biochar

Combined effect between varieties and different levels of biochar showed significant effect on number of seeds siliqua^{-1} at harvest (Table 8 and Appendix VII). The highest number of seeds siliqua^{-1} (30.65) was observed in the variety BARI Sarisha-14 cultivated with application of biochar 10 t ha^{-1} (V_2B_2). The lowest number of seeds siliqua^{-1} (11.27) was observed variety BARI Sarisha-11 with no biochar application (V_1B_0).

4.2.3.6 Combined effect of planting method and biochar

Number of seeds siliqua^{-1} was significantly affected by the interaction of planting method and different levels of biochar which is shown at Table 8 and Appendix VII. Maximum number of seeds siliqua^{-1} (24.62) was recorded at the combination of SMI method with application of biochar 10 t ha^{-1} (P_2B_2) which was statistically similar with P_2B_1 (23.70) and minimum number of seeds siliqua^{-1} (16.42) was observed at the combination of BARI Sarisha-11 and line sowing method (P_1B_0).

4.2.3.7 Combined effect of variety, planting method and biochar

Number of seeds siliqua^{-1} was significantly affected by the interaction of variety with planting method and biochar which is shown at Table 9 and Appendix VII. Maximum number of seeds siliqua^{-1} (33.57) was recorded at the combination of BARI Sarisha-14 with SMI method and 10 t ha^{-1} of biochar ($V_2P_2B_2$) which was statistically similar with $V_2P_2B_1$ (32.67) and minimum number of seeds siliqua^{-1} (10.27) was observed at the combination of BARI Sarisha-11 with line sowing method and no application of biochar ($V_1P_1B_0$).

4.2.4 Weight of 1000 seeds

4.2.4.1 Effect of variety

Thousand seed weight (g) was significantly affected by different variety (Table 7 and Appendix VII). Higher weight of thousand seeds (3.277 g) were obtained at BARI Sarisha-11. Lower weight of thousand seeds (2.958 g) were recorded at BARI Sarisha-14.The result agreed with Ahmed *et al*. (2017) who found that weight of 1000 seeds of rapeseed and mustard varied from variety to variety and species to species.

4.2.4.2 Effect of planting method

Significant variation on to the weight of thousand seeds was found due to planting methods of rapeseed and mustard (Appendix VII and Table 7). The SMI method produced the higher weight of thousand seeds (3.293 g) and the lower number (2.942 g) weight of 1000 seeds obtained from the line sowing method. This result has contradiction with the findings of Hossain *et al*. (2013) who reported that 1000 seed weight did not show any significant variation due to sowing method. But the result has similarity with the findings of Khan *et al.* (2000) who stated that changes of planting technique significantly influenced the 1000 seed weight of canola.

4.2.4.3 Effect of biochar

Results showed that weight of 1000 seeds influenced significantly by different levels of biochar application in rapeseed and mustard (Table 7 and Appendix VII). It can be mentioned from the present study that the highest weight of 1000 seeds (3.26 g) was recorded in B_2 (application of biochar 10 t ha^{-1}) which was statistically similar with B_1 (application of biochar 5 t ha^{-1}) whereas the lowest weight of 1000 seeds was achieved by B_0 (no biochar application) (2.915 g). Wacal *et al.* (2016) found that 1000-seed weight was significantly influenced by biochar application in mustard.

4.2.4.4 Combined effect of variety and planting method

Weight of 1000-seed was significantly influenced by the interaction between variety and planting method (Appendix VII and Table 8). The highest 1000-seed weight (3.437g) was obtained from BARI Sarisha-11 with SMI method (V_1P_2) combination. The lowest number of 1000-seed weight (2.767 g) was produced by the interaction of BARI Sarisha-14 with line sowing method (V_2P_1).

4.2.4.5 Combined effect of variety and biochar

Combined effect between varieties and different levels of biochar showed non-significant effect on weight of 1000 seeds at harvest (Table 8 and Appendix VII). The highest weight of 1000 seeds (3.46 g) was observed in the BARI Sarisha-11 cultivated with application of biochar 10 t ha^{-1} (V_1B_2) which was statistically similar with V_1B_1 (3.38g). The lowest weight of 1000 seeds (2.84 g) was observed variety BARI Sarisha-14 with no biochar application (V_2B_0) which was statistically similar with V_1B_0 (2.99), V_2B_1 (2.975), V_2B_2 (3.06).

4.2.4.6 Combined effect of planting method and biochar

Weight of 1000-seed was significantly influenced by interaction between planting method and different level of biochar (Appendix VII and Table 8). The highest 1000-seed weight (3.38g) was obtained from SMI method with application of biochar 10 t ha-1 (P_2B_2). The lowest number of 1000-seed weight (2.62 g) was produced by the interaction of line sowing method with no biochar application (P_1B_0).

4.2.4.7 Combined effect of variety, planting method and biochar

Weight of 1000 seeds was significantly influenced by interaction of variety with planting method and different level of biochar (Appendix VII and Table 9). The highest 1000-seed weight (4.35g) was obtained from BARI Sarisha-11 with SMI method and application of biochar 10 t ha^{-1} ($V_1P_2B_2$), which was statistically similar with $V_1P_2B_1$ (3.42), $V_1P_2B_0$ (3.4) and $V_1P_1B_2$ (3.43) . The lowest 1000-seed weight (2.58 g) was produced by the interaction of BARI Sarisha-11 with line sowing method and no biochar application ($V_1P_1B_0$) which was statistically similar with $V_2P_1B_0$ (2.66).

4.2.5 Shelling percentage (%)

4.2.5.1 Effect of Variety

Variety significantly affected the shelling percentage of mustard (Appendix VII and Table 7). BARI Sarisha-11 produced higher shelling percentage (50.21%). Lower shelling percentage was produced by BARI Sarisha-14 (46.15%). The result was in conformity with Akhter (2005) who observed significant variations for shelling percentage for different varieties.

4.2.5.2 Effect of planting method

Significant variation was found to the shelling percentage due to planting methods of mustard and rapeseed (Appendix VII and Table 7). The line sowing produced the higher shelling percentage (48.46%) and the lower shelling percentage (47.90%) was observed in SMI method.

4.2.5.3 Effect of biochar

Application of different level of biochar showed significant variation for shelling percentage (%) shown in Table 7 and Appendix VII. No application of biochar showed the highest shelling percentage (50.06%) and the lowest shelling percentage (46.52%) observed due to application of biochar 10 t ha^{-1}.

4.2.5.4 Combined effect of variety and planting method

Shelling percentage was significantly influenced by interaction between variety and planting method (Appendix VII and Table 8). The highest shelling percentage (50.94%) was obtained from BARI Sarisha-11 with line sowing method (V_1P_1). The lowest shelling percentage (45.98%) was produced by the interaction of BARI Sarisha-14 with line sowing method (V_2P_1) which was statistically similar with V_2P_2 (46.32%)

4.2.5.5 Combined effect of variety and biochar

Combined effect between varieties and different levels of biochar showed non-significant effect on shelling percentage (Table 9 and Appendix VII). The highest shelling percentage (53.56%) was observed in the BARI Sarisha-11 with no application of biochar (V_1B_0).The lowest shelling percentage (45.69%) was observed variety BARI Sarisha-14 with 10 t ha^{-1} of biochar application (V_2B_2) which was statistically similar with V_2B_1 (46.21%) and V_2B_0 (46.55%).

4.2.5.6 Combined effect of planting method and biochar

Shelling percentage was not significantly influenced by interaction of planting methods and different levels of biochar (Appendix VII and Table 8). The highest shelling percentage (50.32%) was obtained from SMI method with no application of biochar (P_2B_0) which was statistically similar with P_1B_0 (49.80%). The lowest shelling percentage (46.29%) was produced by the interaction of SMI method with 10 t ha^{-1} of biochar application (P_2B_2) which was statistically similar with P_2B_1 (47.10%) and P_1B_2 (46.75%).

4.2.5.7 Combined effect of variety, planting method and biochar

Shelling percentage was affected significantly due to interaction of variety with planting method and different levels of biochar (Appendix VII and Table 9). The highest shelling percentage (53.41%) was obtained from BARI Sarisha-11 with line sowing method and no application of biochar ($V_1P_1B_0$) which was statistically similar with $V_1P_2B_0$ (53.72%). The lowest shelling percentage (45.57%) was produced by the interaction of BARI Sarisha-14 with SMI method and 10 t ha^{-1} biochar application ($V_2P_2B_2$) which was statistically similar with $V_2P_1B_2$ (45.82%), $V_2P_1B_1$ (45.94%), $V_2P_1B_0$ (46.19%) and $V_2P_2B_1$ (46.47%) .

Table 7. Yield contributing parameters of rapeseed and mustard as influenced by variety, planting method and biochar

Treatments	Length of siliqua (cm)	No. of siliqua/plant	No. of seeds/siliqua	1000 seed weight (g)	Shelling percentage
Effect of variety					
V_1	4.13 b	262.66 a	13.30 b	3.28 a	50.21 a
V_2	5.15 a	124.24 b	28.55 a	2.96 b	46.15 b
$LSD_{(0.05)}$	0.20	4.87	2.41	0.11	1.24
Effect of planting method					
P_1	4.56	97.17 b	18.72 b	2.94 b	48.46 b
P_2	4.72	289.7 a	23.13 a	3.29 a	47.90 a
$LSD_{(0.05)}$	NS	3.87	1.06	0.22	0.32
Effect of biochar					
B_0	4.33 c	155.6 c	18.74 c	2.92 b	50.06 a
B_1	4.59 b	203.6 b	21.32 b	3.18 a	47.97 b
B_2	4.99 a	221.2 a	22.71 a	3.26 a	46.52 c
$LSD_{(0.05)}$	0.05	2.995	0.75	0.13	0.55
CV (%)	3.43	9.88	4.25	4.91	8.34

V_1 = BARI Sharisha 11, V_2 = BARI Sharisha 14

P_1= Sowing in line, P_2= SMI (30 cm × 30 cm spacing) planting

B_0 = 0.0 t ha^{-1} (Control), B_1 = 5.0 t ha^{-1}, B_2 = 10.0 t ha^{-1}

Table 8. Combined effect of variety and planting method, variety and biochar, planting method and biochar for yield contributing parameters

Interaction	Length of siliqua (cm)	No. of siliqua/plant	No. of Seeds/siliqua	1000 seed weight (g)	Shelling percentage
Combined effect of variety and planting method					
V_1P_1	3.92 c	120.5 c	12.37 d	3.12 b	50.94 a
V_1P_2	4.33 b	404.8 a	14.22 c	3.44 a	49.49 b
V_2P_1	5.19 a	73.82 d	25.07 b	2.77 c	45.98 c
V_2P_2	5.10 a	174.7 b	32.04 a	3.15 b	46.32 c
$LSD_{(0.05)}$	**0.12**	**3.17**	**1.31**	**0.15**	**0.63**
Combined effect of variety and biochar					
V_1B_0	3.91 d	210.8 c	11.27 e	2.99 c	53.56 a
V_1B_1	4.10 cd	275.7 b	13.85 d	3.38 ab	49.72 b
V_1B_2	4.39 c	301.5 a	14.77 d	3.46 a	47.35 c
V_2B_0	4.76 b	100.4 f	26.22 c	2.84 c	46.55 cd
V_2B_1	5.09 b	131.4 e	28.78 b	2.98 c	46.21 cd
V_2B_2	5.60 a	140.9 d	30.65 a	3.060 bc	45.69 d
$LSD_{(0.05)}$	**0.35**	**4.06**	**1.60**	**0.38**	**1.42**
Combined effect of planting method and biochar					
P_1B_0	4.30 d	65.18 f	16.42 d	2.62 e	49.80 ab
P_1B_1	4.55 c	102.2 e	18.93 c	3.06 d	48.83 b
P_1B_2	4.83 b	124.2 d	20.80 b	3.15 c	46.75 c
P_2B_0	4.37 d	246.0 c	21.07 b	3.21 c	50.32 a
P_2B_1	4.63 c	305.0 b	23.70 a	3.30 b	47.10 c
P_2B_2	5.16 a	318.2 a	24.62 a	3.38 a	46.29 c
$LSD_{(0.05)}$	**0.14**	**4.56**	**1.60**	**0.076**	**1.26**
CV (%)	**5.28**	**9.88**	**7.48**	**7.62**	**8.34**

V_1 = BARI Sharisha 11, V_2 = BARI Sharisha 14

P_1= Sowing in line, P_2= SMI (30 cm × 30 cm spacing) planting

B_0 = 0.0 t ha^{-1} (Control), B_1 = 5.0 t ha^{-1}, B_2 = 10.0 t ha^{-1}

Table 9. Combined effect of variety, planting method and biochar for yield contributing parameters of rapeseed and mustard

Intraction	Length of siliqua (cm)	No. of Siliqua/plant	No. of Seeds/siliqua	1000 seed weight (g)	Shelling percentage
$V_1P_1B_0$	3.74 f	70.23 j	10.27 h	2.58 g	53.41 a
$V_1P_1B_1$	3.83 f	128.7 h	12.97 fg	3.34 bc	51.72 b
$V_1P_1B_2$	4.20 e	162.7 f	13.87 efg	3.43 ab	47.68 c
$V_1P_2B_0$	4.07 ef	351.3 c	12.27 gh	3.40 ab	53.72 a
$V_1P_2B_1$	4.36 de	422.8 b	14.73 ef	3.42 ab	47.73 c
$V_1P_2B_2$	4.57 cd	440.3 a	15.67 e	3.49 a	47.01 cd
$V_2P_1B_0$	4.85 c	60.13 k	22.57 d	2.66 g	46.19 de
$V_2P_1B_1$	5.27 b	75.67 j	24.90 c	2.78 f	45.94 e
$V_2P_1B_2$	5.46 ab	85.67 i	27.73 b	2.86 f	45.82 e
$V_2P_2B_0$	4.66 cd	140.7 g	29.87 b	3.02 e	46.91 cd
$V_2P_2B_1$	4.90 c	187.2 e	32.67 a	3.17 d	46.47 de
$V_2P_2B_2$	5.74 a	196.1 d	33.57 a	3.26 cd	45.57 e
$LSD_{(0.05)}$	**0.36**	**6.21**	**2.27**	**0.09**	**0.95**
CV (%)	**5.28**	**9.88**	**7.48**	**7.62**	**8.34**

V_1 = BARI Sharisha 11, V_2 = BARI Sharisha 14, P_1= Sowing in line, P_2= SMI (30 cm × 30 cm spacing) planting, B_0 = 0.0 t ha^{-1} (Control), B_1 = 5.0 t ha^{-1}, B_2 = 10.0 t ha^{-1}

4.3 Yield parameters

4.3.1 Seed yield

4.3.1.1 Effect of Variety

Varietal differences significantly affected on the seed yield of rapeseed and mustard (Appendix VIII and Table 10). BARI Sarisha-11 produced higher seed yield (2.11 t ha^{-1}) and lower seed yield was produced by BARI Sarisha-14 (1.56 t ha^{-1}). The result agreed with Rahman (2002) and BARI (2001) who reported that seed yield of rape and mustard were varied with different varieties. Yeasmin (2013) also found significant varietal effect on seed yield of mustard.

4.3.1.2 Effect of planting method

Seed yield (t ha^{-1}) of rapeseed and mustard plant was significantly affected by different sowing method (Appendix VIII and Table 10). Higher seed yield (2.115 t ha^{-1}) was obtained at SMI method and lower seed yield (1.560 t ha^{-1}) was found at line sowing method. Hossain *et al.* (2013) and Sarkees (2013) also reported that sowing method had significant influence on seed yield which supports the main result.

4.3.1.3 Effect of biochar

Seed yield of mustard and rapeseed influenced by application of different levels of biochar were statistically significant (Table 10 and Appendix VIII). The highest grain yield (2.165 t ha^{-1}) was recorded in B_2 (Application of biochar 10 t ha^{-1}) while the lowest grain yield (1.375 t ha^{-1}) was achieved by B_0 (no biochar application). Pandit *et al*. (2018) reported that mustard grain yield significantly increased by 96%, 128% and 134 % at 15 t ha^{-1}, 25 t ha^{-1} and 40 t ha^{-1} of biochar respectively.

4.3.1.4 Combined effect of variety and planting method

Seed yield was significantly affected by the interaction of variety and planting method which is shown at Table 11 and Appendix VIII. Highest seed yield (2.41 t ha^{-1}) was obtained at the combination of BARI Sarisha-11 and SMI method (V_1P_2) and lowest grain yield (1.31 t ha^{-1}) was found at the combination of BARI Sarisha-14 and line sowing method (V_2P_1).

4.3.1.5 Combined effect of variety and biochar

Interaction effect between varieties and different level of biochar showed significant effect on seed yield at harvest (Table 11 and and Appendix VIII). The highest seed yield (2.46 t ha^{-1}) was observed in the variety BARI Sarisha-11 cultivated with application of biochar 10 t ha^{-1} (V_1B_2). The lowest seed yield (1.11 t ha^{-1}) was observed variety BARI Sarisha-14 with no biochar application (V_2B_0).

4.3.1.6 Combined effect of planting method and biochar

Seed yield was significantly influenced by interaction among planting methods and different levels of biochar (Appendix VIII and Table 11). The highest seed yield (2.46 t ha^{-1}) was obtained from SMI method with application of biochar 10 t ha^{-1} (P_2B_2) which was statistically similar with P_2B_1 (2.29 t ha^{-1}) and the lowest seed yield (1.15 t ha^{-1}) was produced by the interaction of line sowing method with no application of biochar (P_1B_0).

4.3.1.7 Combined effect of variety, planting method and biochar

Seed yield was significantly influenced by the interaction of varieties with planting methods and different levels of biochar (Appendix VIII and Table 12). The highest seed yield (2.75 t ha^{-1}) was obtained from BARI Sarisha-11 with SMI method and application of 10 t ha^{-1} biochar ($V_1P_2B_2$). The lowest seed yield (0.970 t ha^{-1}) was produced by the interaction of BARI Sarisha-14 with line sowing method and no application of biochar ($V_2P_1B_0$).

4.3.2. Stover yield

4.3.2.1 Effect of variety

Stover yield was significantly influenced by the varieties (Appendix VIII and Table 10). BARI Sarisha-11 gave higher stover yield (5.91 t ha^{-1}) and lower stover yield (3.84 t ha^{-1}) was observed in BARI Sarisha-14. It has been reported that stover yields of rape and mustard are different in different varieties (BARI, 2001). This finding agreed with Akhter (2005) who found that variety affect significantly on stover yield.

4.3.2.2 Effect of planting method

Stover yield of rapeseed and mustard plant was significantly affected by different planting methods (Appendix VIII and Table 10). Higher stover yield (5.46 t ha^{-1}) was obtained at SMI method and lower stover yield (4.29 t ha^{-1}) was found at line sowing method. Aziz (2014) agreed with this finding and reported that Stover yield (t ha^{-1}) of mustard and rapeseed plant was significantly affected by different sowing techniques.

4.3.2.3 Effect of biochar

Stover yield of rapeseed and mustard varied significantly due to different levels of biochar application (Appendix VIII Table 10). The highest stover yield (5.52 t ha^{-1}) was observed from B_2 (application of Biochar 10 t ha^{-1}) which was nearest to B_1 (5.15) while the lowest stover yield (3.96 t ha^{-1}) from B_0 (no biochar application).

4.3.2.4 Combined effect of variety and planting method

Stover yield was significantly affected by the interaction of variety and planting method which is shown at Appendix VIII and Table 11. Highest stover yield (6.54 t ha^{-1}) was obtained at the combination of BARI Sarisha-11 and SMI method (V_1P_2). On the other hand, lowest stover yield (3.30 t ha^{-1}) was found at the combination of BARI Sarisha-14 and line sowing method (V_2P_1).

4.3.2.5 Combined effect of variety and biochar

Interaction effect between varieties and different levels of biochar showed significant effect on strove yield (t ha^{-1}) at harvest (Appendix VIII and Table 11). The highest strove yield (6.61 t ha^{-1}) was observed in the variety BARI Sarisha-11 cultivated with application of biochar 10 t ha^{-1} (V_1B_2). The lowest strove yield (2.99 t ha^{-1}) was observed variety BARI Sarisha-14 with no biochar application (V_2B_0).

4.3.2.6 Combined effect of planting method and biochar

Stover yield was not significantly influenced by interaction of planting methods and biochar (Appendix VIII and Table 11). The highest stover yield (6.05 t ha^{-1}) was produced by the interaction of SMI method with application of biochar 10 t ha^{-1} (P_2B_2) which was statistically similar with P_2B_1 (5.84) and the lowest stover yield (3.42 t ha^{-1}) was observed in the interaction of line sowing method with no biochar application P_1B_0 .

4.3.2.7 Combined effect of variety, planting method and biochar

Stover yield was significantly influenced by interaction of varieties with planting methods and different levels of biochar (Appendix VIII and Table 12). The highest stover yield (7.11 t ha^{-1}) was obtained from BARI Sarisha-11 with SMI method and application of 10 t ha^{-1} biochar ($V_1P_2B_2$) which was statistically similar with $V_1P_2B_1$ (6.82 t ha^{-1}). The lowest stover yield (2.69 t ha^{-1}) was produced by the interaction of BARI Sarisha-14 with line sowing method and no application of biochar ($V_2P_1B_0$).

4.3.3 Harvest Index

4.3.3.1 Effect of variety

Harvest Index of rapeseed and mustard plant was significantly affected by different variety (Appendix VIII and Table 10). Higher harvest index (28.65%) was observed at BARI Sarisha-14 and lower harvest index (26.31%) was obtained at BARI Sarisha-11. The result agreed with the findings of Islam *et al.* (1994) who reported that varieties had significant effect on harvest index (%) of mustard.

4.3.3.2 Effect of planting method

Significant difference was found due to the effect of planting method in rapeseed and mustard (Appendix VIII and Table 10). Higher harvest index (28.14%) was found in SMI method and lower (26.82%) was obtained from the line sowing method. This result was in agreement with the findings of Khan *et al.* (2000) and Hossain *et al.* (2013). They found significant variation due to sowing method of mustard.

4.3.3.3 Effect of biochar

Harvest index was significantly influenced by different levels of biochar application (Appendix VIII and Table 10). It can be stated from the present study that the highest harvest index (28.57 %) was recorded in B_2 (application of biochar 10 t ha^{-1}) which was statistically similar with B_1 and the lowest harvest index (25.97%) was achieved by B_0 (no biochar application). Khan (2015) reported that rapeseed plant responded significantly at different doses of biochar for harvest index which agreed the findings.

4.3.3.4 Combined effect of variety and planting method

Harvest Index was significantly affected by the combination of variety and planting method which was shown at Appendix VIII and Table 11. Highest harvest index (29.13%) was obtained at the combination of BARI Sarisha-14 and SMI method (V_2P_2) which was statistically similar with V_2P_1 (28.17%). On the other hand lowest harvest index (25.47%) was found at the combination of BARI Sarisha-11 and line sowing method (V_1P_1).

4.3.3.5 Combined effect of variety and biochar

Interaction effect between variety and different levels of biochar showed significant effect on harvest Index at harvest (Appendix VIII and Table 11). The highest harvest Index (29.61%) was observed in the variety BARI Sarisha-14 cultivated with application of biochar 10 t ha^{-1} (V_2B_2) which was statistically similar with V_2B_1. The lowest harvest index (24.93%) was observed variety BARI Sarisha-11 with no biochar application (V_1B_0).

4.3.3.6 Combined effect of planting method and biochar

Harvest index was significantly influenced by the interaction among planting methods and different levels of biochar (Appendix VIII and Table 11). The highest harvest index (29.53%) was produced by the interaction of SMI method with application of biochar 10 t ha^{-1} (P_2B_2) which was statistically similar with P_2B_1 (28.39%). The lowest harvest index (25.43%) was produced by the interaction of line sowing method with no biochar application (P_1B_0) which was statistically similar with P_2B_0 (26.51).

4.3.3.7 Combined effect of variety, planting method and biochar

Harvest index was significantly influenced by interaction of variety with planting methods and different levels of biochar (Appendix VIII and Table 12). The highest harvest index (30.18 t ha^{-1}) was obtained from BARI Sarisha-14 with SMI method and application of 10 t ha^{-1} biochar ($V_2P_2B_2$) which was statistically similar with $V_2P_2B_1$ (29.72 t ha^{-1}). The lowest harvest index (24.33t ha^{-1}) was produced by the interaction of BARI Sarisha-11 with line sowing method and no application of biochar ($V_1P_1B_0$).

Table 10. Yield parameters of rapeseed and mustard as influenced by variety, planting method and biochar

Treatments	Seed yield (t ha^{-1})	Stover yield (t ha^{-1})	Harvest index (%)
Effect of variety			
V_1	2.11 a	5.91 a	26.31 b
V_2	1.56 b	3.84 b	28.65 a
$LSD_{(0.05)}$	**0.16**	**0.15**	**0.75**
Effect of planting method			
P_1	1.56 b	4.29 b	26.82 b
P_2	2.12 a	5.46 a	28.14 a
$LSD_{(0.05)}$	**0.11**	**0.19**	**0.63**
Effect of biochar			
B_0	1.38 c	3.96 c	25.97 b
B_1	1.97 b	5.15 b	27.90 a
B_2	2.17 a	5.52 a	28.57 a
$LSD_{(0.05)}$	**0.14**	**0.16**	**1.00**
CV (%)	**6.13**	**8.77**	**8.30**

V_1 = BARI Sharisha 11, V_2 = BARI Sharisha 14, P_1= Sowing in line, P_2= SMI (30 cm × 30 cm spacing) planting, B_0 = 0.0 t ha^{-1} (Control), B_1 = 5.0 t ha^{-1}, B_2 = 10.0 t ha^{-1}

Table 11. Combined effect of variety and planting method, variety and biochar, planting method and biochar for yield parameters of rapeseed and mustard

Interaction	Seed yield ($t\ ha^{-1}$)	Stover yield ($t\ ha^{-1}$)	Harvest index (%)
Combined effect of variety and planting method			
V_1P_1	1.81 b	5.27 b	25.47 c
V_1P_2	2.41 a	6.54 a	27.15 b
V_2P_1	1.31 c	3.30 d	28.17 a
V_2P_2	1.82 b	4.38 c	29.13 a
$LSD_{(0.05)}$	**0.16**	**0.21**	**0.97**
Combined effect of variety and biochar			
V_1B_0	1.64 d	4.92 c	24.93 c
V_1B_1	2.24 b	6.20 b	26.49 b
V_1B_2	2.46 a	6.61 a	27.52 b
V_2B_0	1.11 e	2.995 f	27.01 b
V_2B_1	1.71 cd	4.10 e	29.32 a
V_2B_2	1.88 c	4.44 d	29.61 a
$LSD_{(0.05)}$	**0.18**	**0.22**	**1.37**
Combined effect of planting method and biochar			
P_1B_0	1.15 d	3.42 d	25.43 d
P_1B_1	1.66 c	4.46 c	27.42 bc
P_1B_2	1.88 b	4.99 b	27.60 bc
P_2B_0	1.60 c	4.50 c	26.51 cd
P_2B_1	2.30 a	5.84 a	28.39 ab
P_2B_2	2.46 a	6.05 a	29.53 a
$LSD_{(0.05)}$	**0.20**	**0.23**	**1.37**
CV (%)	**6.13**	**8.77**	**8.30**

V_1 = BARI Sharisha 11, V_2 = BARI Sharisha 14, P_1= Sowing in line, P_2= SMI (30 cm × 30 cm spacing) planting, B_0 = 0.0 t ha^{-1} (Control), B_1 = 5.0 t ha^{-1}, B_2 = 10.0 t ha^{-1}

Table 12. Combined effect of variety, planting method and biochar for yield parameters of rapeseed and mustard

Treatments	Seed yield (t ha^{-1})	Stover yield (t ha^{-1})	Harvest index (%)
$V_1P_1B_0$	1.33 f	4.14 e	24.33 f
$V_1P_1B_1$	1.95 d	5.57 c	25.92 e
$V_1P_1B_2$	2.16 c	6.10 b	26.16 de
$V_1P_2B_0$	1.95 d	5.69 c	25.53 e
$V_1P_2B_1$	2.53 b	6.82 a	27.05 cd
$V_1P_2B_2$	2.75 a	7.11 a	28.88 b
$V_2P_1B_0$	0.97 g	2.69 g	26.53 c-e
$V_2P_1B_1$	1.36 f	3.34 f	28.92 b
$V_2P_1B_2$	1.59 e	3.88 e	29.05 b
$V_2P_2B_0$	1.25 f	3.30 f	27.49 c
$V_2P_2B_1$	2.05cd	4.85 d	29.72 ab
$V_2P_2B_2$	2.16 c	4.99 d	30.18 a
$LSD_{(0.05)}$	**0.20**	**0.36**	**1.07**
CV (%)	**6.13**	**8.77**	**8.30**

V_1 = BARI Sharisha 11, V_2 = BARI Sharisha 14, P_1= Sowing in line, P_2= SMI (30 cm × 30 cm spacing) planting, B_0 = 0.0 t ha^{-1} (Control), B_1 = 5.0 t ha^{-1}, B_2 = 10.0 t ha^{-1}

CHAPTER V

SUMMARY AND CONCLUSION

The present work was done at the research farm of Sher-e-Bangla Agricultural University, Dhaka during 2017-18, rabi season to investigate the yield performance of mustard and rapeseed varieties as influenced by different planting methods and different levels of biochar application.

The experiment was laid out in three factors Randomized Complete Block Design (RCBD) with three replications. The size of unit plot was 2 m x 1.5 m and total number of plot was 36. There were 12 treatments (2 Variety x 2 Planting methods x 3 doses of biochar). The variety treatments were V_1= BARI Sarisha-11, V_2= BARI Sarisha-14; planting method treatments were P_1= Line Sowing, P_2= SMI (30cmx 30 cm) transplanting and the biochar application treatments were B_0 = no application of biochar (control), B_1 = 5 t ha^{-1}, B_2 = 10 t ha^{-1}.

The data on crop growth parameters like plant height,Number of primary branches $plant^{-1}$ and leaf SPAD value data were recorded at different growth stages. Yield and yield attributes parameters like number of siliquae $plant^{-1}$, siliqua length, seeds $siliqua^{-1}$, 1000-grains weight, stover yield, shell yield and grain yield were recorded after harvest. Data were analyzed using the M-STAT C computer package program developed by IRRI. The mean differences among the treatments were compared by 5% level of significance.

Results showed that, BARI Sarisha-11 showed taller plant 40.66, 91.99, 115.77, 123.76 and 130.35 cm at 30, 40, 50, 60 DAS and at harvest. On the other hand, BARI Sarisha-14 showed shorter plant 32.84, 45.35, 51.42, 65.997 and 78.62 cm at 30, 40, 50, 60 DAS and at harvest, respectively. At 40, 50 and 60 DAS, maximum number of primary branches 8.69, 9.48 and 10.39, respectively was achieved by V_2. V_1 scored minimum number of primary branches 6.15, 7.15 and 7.78 at 40, 50 and 60 DAS, respectively. V_2 achieved higher leaf SPAD value 53.12, 58.87, 60.93 and

62.25 at 30, 40, 50 and 60 DAS respectively and V_1 achieved lower leaf SPAD value 52.45, 54.52, 58.60 and 59.85 at 30, 40, 50 and 60 DAS, respectively.

V_1 scored higher number (26.66) of silquae plant^{-1} and V_2 scored lower number (12.24) of siliquae plant^{-1}. Maximum siliqua length (5.15 cm) was scored at V_2 and minimum siliqua length (4.13 cm) was recorded at V_1. Maximum number of seeds siliqua^{-1} (28.55) was recorded at V_2 and minimum number of seeds siliqua^{-1} (13.30) was recorded at V_1. V_1 scored the higher shelling percentage (50.21 %) and V_2 scored the lower shelling (46.15 %). V_1 scored the higher stover yield (5.905 t ha^{-1}) and V_2 scored the lower stover yield (3.84 t ha^{-1}). Higher grain yield (2.11 t ha^{-1}) was obtained at V_1 and lowest grain yield (1.56 t ha^{-1}) was obtained at V_2. Maximum harvest index (28.65 %) was recorded at V_2 and minimum harvest index (26.31 %) was recorded at V_1. Maximum weight of 1000-seed (3.28 g) was found at V_1 and minimum weight of 1000-seed (2.96 g) was found at V_2.

In terms of planting method, at 30, 40, 50, 60 DAS and at harvest P_2 showed the taller plant 38.24, 69.45, 86.24, 98.07 and 107.66 cm and P_1 showed the shorter plant 35.26, 67.90, 80.96, 91.69 and 101.32 cm. At 40, 50 and 60 DAS maximum number of primary branches 9.12, 9.94 and 10.85 were recorded at P_2 and minimum number of primary branches 5.72, 6.69 and 7.32 were found at P_1. Leaf SPAD value not significantly affected by the planting method.

P_2 scored higher number of silquae plant^{-1} (289.73) and P_1 scored lower number of siliquae plant^{-1} (97.17). Siliqua length was not significantly affected by planting method. Maximum number of seeds siliqua^{-1} (23.13) was recorded at P_2 and minimum number of seeds siliqua^{-1} (18.72) was recorded at P_1. P_1 scored higher shelling percentage (48.46 %) and P_2 scored lower shelling percentage (47.90%). P_2 scored higher stover yield (5.46 t ha^{-1}) and P_1 scored lower stover yield (4.29 t ha^{-1}). Higher grain yield (2.12 t ha^{-1}) was obtained at P_2 and lower grain yield (1.56 t ha^{-1}) was obtained at P_1. Maximum harvest index (28.14%) was recorded at P_2 and minimum harvest index (26.82%) was recorded at P_1. Maximum weight of 1000-seed (3.29 g) was found at P_2 and minimum weight of 1000-seed (2.94 g) was found at P_1.

In terms of biochar application, at 30, 40, 50, 60 DAS and at harvest B_2 showed the tallest plant 39.21, 72.10, 87.81, 99.07 and 108.10 cm and B_0 showed the shortest plant 33.30, 64.11, 79.04, 88.74 and 100.20 cm. At 40, 50 and 60 DAS maximum number of primary branches 8.12, 9.17 and 10.09 were recorded at B_2 and minimum number of primary branches 6.38, 7.16 and 7.74 were found at B_0. At 30 DAS leaf SPAD value not significantly affected by the biochar application. At 40, 50 and 60 DAS highest leaf SPAD value 58.23, 62.31 and 63.14 were observed for B_2 and B_0 showed the lowest leaf SPAD value 55.26, 58.84 and 58.78 at 40, 50 and 60 DAS, respectively.

Considering biochar, B_2 scored higher number of silquae plant^{-1} (221.2) and B_0 scored lower number of siliquae plant^{-1} (155.6). B_2 showed the highest siliqua length (4.99) and B_0 showed the lowest siliqua length (4.33). Maximum number of seeds siliqua^{-1} (22.71) was recorded at B_2 and minimum number of seeds siliqua^{-1} (18.74) was recorded at B_0. B_0 scored higher shelling percentage (50.06%) and B_2 scored lower shelling percentage (46.52%). B_2 scored higher stover yield (5.52 t ha^{-1}) and B_0 scored lower stover yield (3.96 t ha^{-1}). Higher grain yield (2.17 t ha^{-1}) was obtained at B_2 and lower grain yield (1.38 t ha^{-1}) was obtained at B_0. Maximum harvest index (28.57%) was recorded at B_2 which was statistically similar with B_1 (27.90%) and minimum harvest index (25.97%) was recorded at B_0. Maximum weight of 1000-seed (3.260 g) was found at B_2 and minimum weight of 1000-seed (2.92 g) was found at B_0.

In terms of combination effect of variety with planting method and biochar, at 30 DAS tallest plant (43.26cm) was found at $V_1P_2B_2$ and shortest plant (27.42 cm) was observed at $V_2P_1B_0$. At 40 DAS tallest plant (97.19cm) was found at $V_1P_1B_2$ and shortest plant (39.36 cm) was observed at $V_2P_1B_0$. At 50, 60 DAS and at harvest $V_1P_2B_2$ showed the tallest plant 121.40, 130.40 and 137.60 cm and $V_2P_1B_0$ scored the shortest plant 44.35, 59.02 and 72.32 cm. At 40, 50 and 60 DAS, maximum number of primary branches plant^{-1} 11.93, 12.93 and 14.07 were recorded at $V_2P_2B_2$. At 40, 50 and 60 DAS, minimum number of primary branches 4.39, 5.23 and 5.87 were found at $V_1P_1B_0$. At 30, DAS highest leaf SPAD value (54.42) was observed for $V_2P_1B_2$ and $V_2P_2B_0$ showed the lowest leaf SPAD value (51.80). At 40 DAS highest leaf SPAD value (60.88) was observed for $V_2P_1B_2$ and $V_1P_1B_0$ showed the lowest leaf SPAD value (52.63). At 50 and 60 DAS highest leaf SPAD value (63.67 and 64.65) was observed for $V_2P_2B_2$ and $V_1P_1B_0$ showed the lowest leaf SPAD value (56.98 and 56.75).

$V_1P_2B_2$ scored the highest number (44.3) of silquae plant^{-1} and $V_2P_1B_0$ scored the lowest number (60.13) of siliquae plant^{-1}. Maximum siliqua length (5.74 cm) was scored at $V_2P_2B_2$ and minimum siliqua length (3.74 cm) was recorded at $V_1P_1B_0$. Maximum number of seeds siliqua^{-1} (33.57) was recorded at $V_2P_2B_2$ and minimum number of seeds siliqua^{-1} (10.27) was recorded at $V_1P_1B_0$. $V_1P_2B_0$ scored the highest shelling percentage (53.72%) and $V_2P_2B_2$ scored the lowest shelling percentage (45.57%). $V_1P_2B_1$ scored the highest stover yield (6.82 t ha^{-1}) and $V_2P_1B_0$ scored the lowest stover yield (2.69 t ha^{-1}). Highest grain yield (2.75 t ha^{-1}) was obtained at $V_1P_2B_2$ and lowest grain yield (0.97 t ha^{-1}) was obtained at $V_2P_1B_0$. Maximum harvest index (30.18%) was recorded at $V_2P_2B_2$ and minimum harvest index (24.33%) was recorded at $V_1P_1B_0$. Maximum weight of 1000-seed (3.49 g) was found at $V_1P_2B_2$ and minimum weight of 1000-seed (2.58 g) was found at $V_1P_1B_0$. The results in this study revealed that, BARI Sarisha-11 (V_1) cultivated with the SMI planting method at 30 x30 cm spacing (P_2) and application of biochar 10 t ha^{-1} (B_2) performed best compared to other treatment combinations.

RECOMMENDATION

The study was undertaken at the environment of Sher-e-Bangla Agricultural University farm which may not be similar to those of the rural farmer’s field environment. Moreover, the soil condition and nutritional status of the Sher-e-Bangla Agricultural University is different from the farmer’s ones. So, results obtained from this study may not be applicable in the farmer’s field. So for wider acceptability of the result this experiment may be conducted at different Agro Ecological Zone (AEZ) of the country taking more varieties, more spacing and more biochar doses.

REFERENCES

Afroz, M.M., Sarkar, M.A.R., Bhuiya, M.S.U. and Roy, A.K. (2011). Effect of sowing date and seed rate on yield performance of two mustard varieties. *J. Bangladesh Agril. Univ*. **9**(1): 5-8.

Ahmad, N., Saleem M. T., Rashid M. and Jalil A. (1994). Sulfur status and crop response in Pakistan soils. National fertilizer development center. Pub. No. 7/94. Planning. Develop. Division. Islamabad. Pp. 1-5.

Ahmed, Z. and Kashem M. A. (2017). Performance of mustard varieties in haor area of Bangladesh. *Bangladesh Agron. J.* **20** (1): 1-5

AIS (Agricultural Information Service) (2015). Krishi Diary (In Bangla). Agro for Sereal crop, Khamarbari, Farmgate, Dhaka, Bangladesh. 16 p.

Aiken, R., Baltensperger, D., Krall, J., Pavlista, A. and Johnson, J. (2015). Planting methods of affect emergence, flowering and yield of spring oil seed crops in the U. S. central High plains. *Industrial Crops Prod*. **69**: 273-277.

Akhter, S.M.M. (2005). Effect of harvesting time on shattering, yield and oil content of rapeseed and mustard. M.S. Thesis, SAU, Dhaka, Bangladesh.

Alam, M.M., Begum, F. and Roy, P. (2014). Yield and yield attributes of rapeseed – mustard (brassica) genotypes grown under late sown condition. *Bangladesh J. Agril. Res.* **39**(2): 311-336

Ali, M. H., Zoman, S. M., Altaf, H. and Hassan S. M. (1996). Variation in yield and oil and protein content in rape seed (*B. compestris*) inrelation to levels of Nitrogen, Sulphur and plant density. *Indian J. Agron*. **41**(2): 290-295.

Anders, E., Watzinger, A., Rempt, F., Kitzler, B., Wimmer, B., Zehetner, F. and Soja, G., (2013). Biochar affects the structure rather than the total biomass of microbial communities in temperate soils. *Agricul. Food Sci*. **22**(4): 404-423.

BBS (Bangladesh Bureau of Statistics) (2006). Monthly Statistical Bulletin of Bangladesh. January, Statistics Div., Ministry of Planning, Govt. People's Repub. Bangladesh. 54.

Aziz, K.M.T. (2014). Growth and yield performance of mustard and rapeseed varieties as influenced by different sowing techniques. M. S. thesis, SAU, Dhaka, Bangladesh.

BARI (1999). Annual report 1998-1999. Oilseed Research Centre. Bangladesh Agricultural Research Institute. Joydebpur, Gazipur.

BARI (2001). Annual Report of 2000-2001. Oilseed Research Centre. Bangladesh Agril. Res. Inst. Joydebpur, Gazipur, Bangladesh.

Basak, N. C., Panditb, J. C. and Khurram, M. M. H. (2007). On-farm evaluation of three mustard varieties under different fertilizer packages. *Bangladesh J. Sci. Ind. Res*. **42**(3): 335-340.

BBS (Bangladesh Bureau of Statistics). (2010). Statistical Yearbook of Bangladesh, Statistics Division. Ministry of Planning, Govt People's Repub Bangladesh. Pp. 101–125.

BBS (Bangladesh Bureau of Statistics). (2011). Statistical Year Book of Bangladesh. Min. Plan., Govt. Peoples Repub. Bangladesh. Pp. 1-330.

Beck, D.A., Johnson, G.R. and Spolek, G.A. (2011). Amending greenroof soil with biochar to affect runoff water quantity and quality. *Environ. Pollution*. **159**(8–9): 2111-2118.

Begum, F., Hossain, F., Mondal, M.R.I. (2012). Influence of Sulphur on morpho–physiological and yield parameters of rapeseed. *Bangladsh J. Agril Res*. **37**(4): 645–652.

Bhan, S., Uttam, S. K. and Awasthi, V. D. (1995). Effect of plant spacing and direction of sowing on growth and yield of rain fed mustard (*B. juncea*). *Indian J. Agron.* **40**(4): 636-638.

Bhowmik, B., Mitra, B. and Bhadra, K. (2014). Diversity of insect pollinators and their effect on the crop yield of Brassica juncia L., NPJ-93, from Southern West Bengal. Int. J. Recent Sci. Res. 5(6): 1207-1213.

Chan, K.Y., Van Zwieten, L., Meszaro, I., Downie, A. and Joseph, S. (2008). Using poultry litter biochars as soil amendments. *Australian J. Soil Res*. **46**: 437-444.

Chaniyara, N. J. Solanki, R. M. and Bhalu, V. B. (2002). Effect of interand intra row spacings on yield of mustard. *Agric. Sci. Digest*. **22**(1): 48 – 50.

Chauhan, A. K., Singh, Mahak and Badwal, K. S. (1992). Effect of nitrogen level and row spacing on the performance of rape. (*B. napus* L) *Indian J. Agron*. **37**(4): 851-853.

Chen, Y., Shinogi, Y., Taira, M. (2010). Influence of biochar use on sugarcane growth, soil parameters, and groundwater quality. *Soil Res*. **48**(7): 526-530.

Chhay, T., Vor, S., Borin, K. and Preston, T. R. (2013**).** Effect of different levels of biochar on the yield and nutritive value of Celery cabbage (*Brassica chinensis var*), Chinese cabbage (*Brassica pekinensis*), Mustard green (*Brassica juncea*) and Water spinach (*Ipomoea aquatica*). *Livestock Res. Rural Dev*. **25**(8): 1-8

Ching, L. L. (2017). Record yield achieved with System of Crop Intensification, Third World Network, 131 Jalan Macalister, 10400 Penang, Malasia, website: www.twn.my, www.biosafety-info.net.

Diepenbrock, W. (2000). Yield analysis of winter oilseed rape (*Brassica napus* L.) a review. *Field Crops Res*. **67**: 35-49.

Ferdous, L. J. (2014). Performance of rapeseed and mustard varieties with different planting techniques.M.S. Thesis, SAU Dhaka, Bangladesh.

Ghosh, J. (1994). Effect of sowing dates and plant densities on productivity and economics of yellow sarson (*B. Compestries*) sub spp *olecifera*. *J. Appl. Natur. Sci.* **39**(1): 54-57.

Glaser, B., Lehmann, J. and Zech, W. (2002). Ameliorating physical and chemical properties of highly weathered soils in the tropics with charcoal-a review. *Biol. Fert. Soils*. **35**(4): 219-230.

Gomez, K. A. and Gomez, A. A. (1984). Statistical Procedure for Agricultural Research. 2nded. John Wiley and Sons. New York. p. 64.

Gonzaga, M. I. S., Souza, D. C. F., Almeida, A. Q., Mackowiak, C., Lima, I. S.,Santos, J. C. and Andrade, R. S. (2019). Nitrogen and phosphorus uptake efficiency in Indian mustard cultivated during three growth cycles in a copper contaminated soil treated with biochar. *Ciência Rural*. **49**(1): 315-319.

Helal, M.U., Islam, M. N., Kadir, M. M. and Miah, N. H. (2016). Performance of rapeseed and mustard (*Brassica* sp.) varieties/lines in north-east region (sylhet) of Bangladesh. *Adv. Plants Agric. Res.* **5**(1): 457–462.

Hossain, M.F., Zakaria, A. K. M. and Jahan, M. H. (1996). Technical Report on variety Screening Adaptive Research Oilseeds. Rural Development Academy, Bogra, Bangladesh. Pp.6-34.

Hossain, M.B., Alam, M.S., and Ripon, M.A. (2013). Effect of irrigation and sowing method on yield and yield attributes of mustard. Rajshahi University. *J. Life Earth Agric*. Sci. **41**: 65-70.

Hossain, M. D., Ahmed, D. K. U., Chowdhury, M. F. N., Kanij Mohoua Roksana, K. M., Islam, S. and Barman, A. (2015). Experimental study on Grain weight, Moisture, Ash, Carbohydrates, Protein, Oil, Total energy and minerals content of different varieties of Rapeseed and Mustard (*Brassica* spp.). *Int. J. Sci. Res. Pub.* **12**(5): 395-400.

Iraddi, V.S., (2008). Response of mustard [*Brassica juncea* (L.)] varieties to date of sowing and row spacing in northern transition zone of karnataka. MS in Agronomy, Department of Agronomy, College of Agriculture, Dharwad University of Agricultural Sciences, Dharwad—580005. pp. 1-81.

Islam, N., Choudhury, M. and Karim, M. R. (1994). Effects on sowing date on growth and development of mustard and rapes. *Prog. Agric*. **59**: 23-29.

Islam, M. N., Rahman, M. S., Ahmed F., Alom, M. S. and Akhteruzzaman M. (2013). Performance of different HYV mustard varieties with sugarcane (*Saccharum officinarum*) as intercrop in farmers' fields. *Bangladesh J. Agril. Res.* **38**(2): 211-217.

Jangir, R., Arvadia, L. K. and Kumar, S. (2017). Growth and yield of mustard (*Brassica juncea* L.), dry weight of weeds and weed control efficiency influence by different planting methods and weed management. *Int. J. Curr. Microbiol. App. Sci*. **6**(7): 2586-2593.

Khan G. M. and Agarwal S. K. (1985). Influence of sowing methods, moisture Stress and nitrogen levels on growth, yield components and seed yield of mustard. *Indian J. Agric. Sci.* **55**(5): 324–327.

Khan, A. A. (2015). Biochar application and shoot cutting duration (days) influenced growth, yield and yield contributing parameters of *Brassica napus* L. *J. Biol., Agric. and Healthcare*. **5**(5): 1-6.

Kumar, P., Dhingra, P. K., Singh, V. P. and Pannu, R. K. (1995). Yield oil content and nitrogen uptake in different *Brassica* genotypes as affected by irrigation and nitrogen application. *Crop Res.* **10**(2): 145-147.

Kumar, A., Singh, B. and Yadava, J. S. (2004). Effect of sowing time and crop geometry on teralocular Indian mustard (*B. juncea*) under South-West Haryana. *Indian J. Agril. Sci*.**74** (11): 594-596.

Laird, D., Fleming, P., Wang, B., Horton, R. and Karlen, D. (2010). Biochar impact on nutrient leaching from a Midwestern agricultural soil. *Geoderma*, **158**(3): 436-442.

Lathana, J. (2012). How millions of farmers are advancing agriculture for themselves.(http://independentsciencenews.org/un-sustainablefarming/how-millionsof-farmers-are-advancing-agriculture-for-themselves/)

Lehmann, J., Silva J. D., J.P., Steiner, C., Nehls, T., Zech, W. and Glaser, B. (2003). Nutrient availability and leaching in an archaeological Anthrosol and a Ferralsol of the Central Amazon basin: fertilizer, manure and charcoal amendments. *Plant Soil*. **249**: 343-357.

Lehmann, J., Gaunt, J. and Rondon, M. (2006). Bio-char sequestration in terrestrial ecosystems–a review. Mitigation and adaptation strategies for global change. **11**(2): 395-419.

Lehmann, J., Joseph, S. (2009). Biochar for Environmental Management - An Introduction in: Biochar for Environmental Management: Science and Technology, Earthscan. London, UK, pp. 1-12.

Liang, B., Lehmann, J., Solomon, D., Kinyangi, J., Grossman, J., O'Neill, B., Skjemstad, J.O., Thies, J., Luiza, F. J., Petersen, J. and Neves, E. G. (2006). Black carbon increases cation exchange capacity in soils. *Soil Sci. Soc. America J*. **70**: 1719-1730.

Liu, G. C. (2014). Analysis of materials properties with biochar improve Indian Mustard (*Brassica juncea*) growth inacidic soil in northern China. *Appl. Mech. Mat.* **540**: 239-242.

Mahan, R. S. and Singh U. P. (2003). Effect of different plant densities fertilizer combination on growth and yield of mustard var. Varuna under the condition of Bundelkhand region of U. P. M. S. Thesis. B. U. Jhansi.

Mamun, F. (2013). Influence of population density and variety on growth and yield of rapeseed-mustard.M.S. Thesis. SAU, Dhaka, Bangladesh.

Mamun, F., Ali, M.H., Chowdhury, I. F., Hasanuzzaman, M. and Matin, M.A. (2014). Performance of rapeseed and mustard varieties grown under different planting density. *Sci. Agri.* **8**(2): 70-75.

Momoh, E. J., Song, W. J. and Zhou, W. J. (2004). Seed yield and quality response of winter oil seed rape (*Brassica napus* L.) to plant density and nitrogen fertilization. *Indian J. Agril. Sci*. **74**(8): 420-424.

Pandey, N. M., Dubey S. K., and Singh, G. (2017). Effect of different planting geometry on growth and dry matter production of mustard varieties. *Indian J. Agric. Sci*. **34**(9): 363-373.

Pandit, N. R., Jan, M., Sarah, E. H., Andrew, R. Z., Bishnu, H. P. and Gerard, C. (2018). Multiyear double cropping biochar field trials in Nepal: Finding the optimal biochar dose through agronomic trials and cost benefit analysis. *Sci. Total Environ.* **38**(1): 1333-1341

Paul, S. (2018). Performance of different weed management techniques affecting growth and yield of mustard varieties. M. S. thesis, SAU, Dhaka, Bangladesh.

Pietikainen, J., Kiikkila, O. and Fritze, H. (2000).Charcoal as a habitat for microbes and its effects on the microbial community of the underlying humus. *Oikos*. **89**: 231–242.

Rahman, M.M. (2002). Status of Oilseeds and Future Prospects in Bangladesh. Paper presented in Review Workshop on the Impact of Technology Transfer on Oil Crops, Held at BARI on 29 April, 2002

Reibe, K., Gotz, K. P., Rob, C. L., Doring, T. F., Ellmer, F. and Ruess, L. (2015). Impact of quality and quantity of biochar and hydrochar on soil Collembola and growth of spring wheat. *Soil Biol.Biochem*. **83**: 84-87.

Roy, L.R. (2008). Influence of weeding on growth and yield of rapeseed varieties. M.S. Thesis, SAU, Dhaka, Bangladesh.

Roy, S. (2015). Growth and yield of rapeseed and mustard varieties as affected planting method. M.S. thesis, SAU, Dhaka, Bangladesh.

Satpathy, P.C. (2007). The System of Mustard Intensification. Posted at (http://sri.ciifad.cornell.edu/aboutsri/othercrops/otherSCI/InOr_SMI_Satpathy07.pdf)

Sarkees, N.A. (2013). Response of growth, yield and oil of rapeseed to sowing method and seeding rate. *IOSR J. Agric. Sci.* **3**(1): 01-06.

Schomberg, H. H., Gaskin, J. W., Harris, K., Das, K. C., Novak, J. M., Busscher, W. J. and Rehrah, D. (2012). Influence of biochar on nitrogen fractions in a coastal plain soil. *J. Environ. Quality*, **41**(4): 1087-1095.

Sharma, M. L. (1993). Response of mustard varieties to spacing. *Narayana J. Agron*. **1**(l): 47-49.

Sharma, S. K., Ram, D. S., Mohan, R. and Gupta, S. K. (1998). Effect of crop geometry and nitrogen quality and oil yield of *Brassica spp*. *Indian J. Agron*. **12**(3): 498-501.

Sierts H. P. and Geister G. (1987). Yield components stability in winter rape (*Brassica napus* L.) as a function of competition within the crop. In Proc. of the 7th Int. Rapeseed Con. p. 182, Poznan, Poland.

Singh, B. (1994). Response of nitrogen levels in relation to plant densities on growth and yield of mustard var. Varuna. M. S. Thesis, B.U. Jhansi.

Singh, B. (1995). Response of fertilizer combination and row spacing on growth and yield of mustard variety Varuna under the condition of bundelkland region of U. P. M. S. Thesis, B.U. Jhansi.

Singh, U. P. and Chauhan D. V. S. (2000). Studies on the effect of plant densities, Nitrogen levels and growth hormones on growth yield and quality of mustard

(*Brassica juncea*) under the condition of Bundelkhand region of U. P. Ph D. Thesis. B. U. Jhansi.

Singh, D. and Ram, V. (2005). Performance of mustard (*Brassica juncea* cross) varieties to phosphorus doses on growth and yield under the condition of Bundelkhand and region of U. P. M. sc. (Ag.) Agronomy Thesis B. U. Jhansi.

Silva, M. I. (2017) Potential impacts of using sewage sludge biochar on the growth of plant forest seedlings. *Ciência Rural*. **47**(1): 1-5.

Sokchea, H., Borin, K. and Preston, T. R. (2015). Carry-over effects of biochar on yield of Mustard Green vegetable (*Brassica juncea*) and on soil fertility. Center for Livestock and Agriculture Development. Pras Teat village, Sangkat Rolous, Khan Dong Kor, Phnom Penh. PO Box 2423 Phnom Penh 3, Cambodia.

Spokas, K.A., Cantrell, K.B., Novak, J.M., Archer, D.A., Ippolito, J.A., Collins, H.P., Boateng, A.A., Lima, I. M., Lamb, M. C., McAloon, A. J., Lentz, R. D. and Nichols, K. A. (2012). Biochar: A Synthesis of its agronomic impact beyond carbon sequestration. *J. Environ. Qual*. **41**: 973-989.

SRDI (Soil Resource Development Institute). (1991). Land and Soil Resource Utilization Guide: Mymensingh Sadar Thana, Mymensingh. (In Bangali). SRDI, Ministry of Agricultural, Dhaka, Bangladesh. p. 3.

Steiner, C. (2004). Microbial response to charcoal amendments of highly weathered soil and Amazonian dark earths in central Amazonia: Preliminary results, In: Amazonian Dark Earths: Explorations in Time and Space, Glaser, B. and Woods, W.I., Eds., Springer, Heidelberg. pp. 95–212.

Steiner, C., Teixeira, W.G., Lehmann, J., Nehls, T., Mace Do, J.L.V., Blum, W.E.H. and Zech, W. (2007). Long term effects of manure, charcoal and mineral fertilization on crop production and fertility on a highly weathered Central Amazonian upland soil. *Plant Soil*. **291**: 275-290.

Thies, J. and Suzuki, K. (2003). Amazonian dark earths: Biological measurements, In: Amazonian Dark Earths: Origin, Properties, Management, Lehmann, J. et al., Eds., Kluwer, Dordrecht. 287–332.

Uddin M. M. H., Islam M. N., Kadir M. and Miah N. H. (2016). Performance of rapeseed and mustard (*Brassica* sp.) varieties/lines in north-east region (sylhet) of Bangladesh. *Adv. Plants Agric. Res.* **5**(1): 457- 462.

Uvarov, A.U. (2000) Effects of smoke emissions from a charcoal kiln on the functioning of forest soil systems: A microcosm study, *Environ. Monit. Assess*. **60**: 337- 357.

Uzoma, K. C., Inoue, M., Andry, H., Fujimaki, H., Zahoor, A. and Nishihara, E. (2011). Effect of cow manure biochar on maize productivity under sandy soil condition. *British Soci. Soil Sci*. **27**(2): 205-212.

Van Zweiten, L., Kimber, S., Morris, S., Downie, A., Berger, E., Rust, J., and Scheer, C. (2010): Influence of Biochars on Flux of N_2O and CO_2 from Ferrosol. *Soil Res*. **48**: 555-568.

Wacal, C., Sasagawa, D., Basalirwa, D., Acidri, R. and Nishihara, E. (2016). Effect of Biochar on Continuously Cropped Sesame (*Sesamum indicum* L.). Conference: The 21st Meeting of CSSJ (Crop Science Society of Japan), At Ibaraki University-Japan.

Winsley, P. (2007). Biochar and bioenergy production for climate change mitigation. *New Zealand Sci. Rev.* **64**(1): 5-10.

Yadav, A., Singh, A. K., A., Chaudhari, R and Mishra, S. (2014). Effect of planting geometry on growth and yield of mustard [*Brassica juncea* (L.)] varieties. *J. Pharma. Phytochem*. **7**(3): 2624-2627.

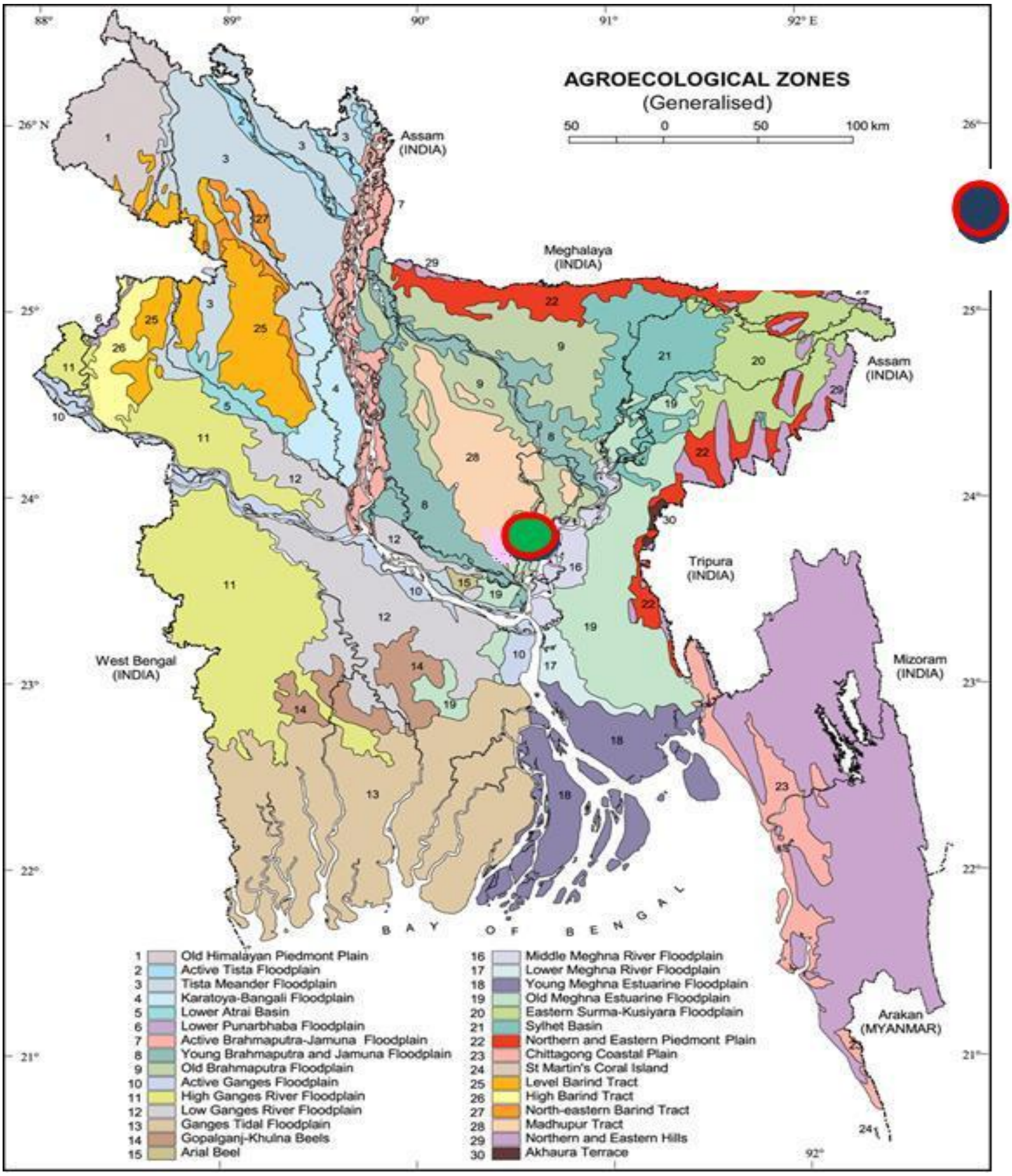
Yeasmin, M. (2013). Effect of inflorescence-top cutting on the yield and yield attributes of mustard varieties under different sowing times. M.S. Thesis, SAU, Dhaka, Bangladesh.

Yin, B. (2000). Bacterial functional redundancy along a soil reclamation gradient, *Appl. Environ. Microbiol*. **66**: 4361–4365.

Zackrisson, O., Nilsson, M.C., and Wardle, D.A. (1996). Key ecological function of charcoal from wildfire in the boreal forest, *Oecologia*, **77**: 10–19.

Zemanová,V., Břendová, K., Pavlíková, D., Kubátová, P. and Tlustoš. P. (2017). Effect of biochar application on the content of nutrients (Ca, Fe, K, Mg, Na, P) and amino acids in subsequently growing spinach and mustard. *Plant Soil Environ.* **63**(7): 322–327.

Appendix I. Map showing the experimental site under study



Appendix II. Monthly meteorological information during the period from November, 2017 to April, 2018

Year	Month	Air temperature (^oC)		Relative Humidity (%)	Total rainfall (mm)
		Maximum	Minimum		
2017-2018	November	28.89	11.88	56.58	51
	December	25.13	8.98	69.85	1.21
	January	23.97	9.28	71.09	Trace
	February	25.12	13.89	76.99	Trace
	March	29.21	14.09	75.89	1.01
	April	30.85	16.96	65.98	63

Source: Metrological Centre (Climate Division), Agargoan, Dhaka

Appendix III. Physico-chemical properties of soil in the study area

Characteristics	Value/concentration
Particle size analysis.	
% Sand	26
% Silt	45
% Clay	29
Textural class	silty-clay
P^H	6.3
Organic matter (%)	1.8
Total N (%)	.09
Phosphorus microgram/g soil	13.1
Potassium (ml equivalent/100 g soil	0.19

Appendix IV. Plant height of mustard as influenced by variety, planting method and biochar and also their combination at different days after sowing

Sources of variation	Degrees of Freedom	Mean square of plant height				
		30 DAS	40 DAS	50 DAS	60 DAS	At harvest
Replication	2	25.33	57.282	64.127	82.338	77.333
Factor A	1	550.3*	1957.6*	3727.4*	3002.69*	2408.4*
Factor B	1	79.92*	21.530*	251.11*	366.914*	362.33*
AB	1	19.44*	69.056*	8.604*	13.068*	6.275*
Factor C	2	113.7*	203.14*	232.02*	354.659*	192.66*
AC	2	0.816**	8.848*	2.590*	30.382*	3.635*
BC	2	1.626**	1.473**	4.037*	28.427*	1.349**
ABC	2	1.194*	2.201*	7.071*	27.658*	0.429**
Error	22	1.751	1.813	1.459	2.697	2.932

Appendix V. Number of primary branches plant^{-1} of mustard as influenced by variety, planting method and biochar and also their combination at different days after sowing

Sources of variation	Degrees of Freedom	Mean square of number of primary branches plant^{-1}		
		40 DAS	50 DAS	60 DAS
Replication	2	3.916	4.111	6.025
Factor A	1	57.73*	48.79*	61.70*
Factor B	1	104.0*	94.77*	111.8*
AB	1	16.49*	12.35*	11.59*
Factor C	2	10.05*	12.99*	17.50*
AC	2	0.455**	0.180**	1.961*
BC	2	0.296**	1.807*	2.519*
ABC	2	0.083**	0.831*	0.757**
Error	22	0.024	0.053	0.032

Appendix VI. Leaf SPAD value of mustard as influenced by variety, planting method and biochar and also their combination at different days after sowing

Sources of variation	Degrees of Freedom	Mean square of leaf SPAD value			
		30 DAS	**40 DAS**	**50 DAS**	**60 DAS**
Replication	2	29.03	87.82	99.42	86.14
Factor A	1	4.040 ^{NS}	169.9*	15.98*	51.72*
Factor B	1	0.672 ^{NS}	2.031 ^{NS}	4.921 ^{NS}	13.92 ^{NS}
AB	1	3.648 ^{NS}	0.664**	2.502*	0.502**
Factor C	2	4.670 ^{NS}	26.58*	39.621*	57.14*
AC	2	1.744 ^{NS}	0.750**	0.781**	0.248**
BC	2	0.580 ^{NS}	3.330*	1.805*	0.139**
ABC	2	0.035	1.377*	6.227*	0.080**
Error	22	0.552	0.448	1.926	0.618

Appendix VII. Yield contributing parameters of mustard as influenced by variety, planting method and biochar and also their combination

Sources of variation	Degrees of Freedom	Mean square of yield contributing parameters				
		Length of siliqua	**Siliqua/ plant (No.)**	**Seeds/ siliqua (No.)**	**1000 seed weight**	**Shelling percentage**
Replication	2	1.219	35.362	39.326	4.577	293.4
Factor A	1	9.333*	1724.0*	2094.4*	0.912*	148.4*
Factor B	1	0.226 ^{NS}	3336.8*	175.16*	1.113*	2.806*
AB	1	0.570**	757.77*	58.906*	0.009**	7.156*
Factor C	2	1.337*	138.86*	48.556*	0.389*	37.96*
AC	2	0.102**	19.943*	0.879*	0.064**	22.24*
BC	2	0.063*	36.922*	0.798*	0.128**	3.802**
ABC	2	0.123**	20.289*	0.747**	0.154**	4.213*
Error	22	0.004	12.516	0.790	0.023	0.415

Appendix VIII. Yield parameters of mustard as influenced by variety, planting method and biochar and also their combination

Sources of variation	**Degrees of Freedom**	**Mean square of yield parameters**		
		Seed yield	**Stover yield**	**Harvest index**
Replication	2	0.889	2.676	92.12
Factor A	1	2.706*	38.31*	49.14*
Factor B	1	2.772*	12.39*	15.76*
AB	1	0.016**	0.084**	1.166*
Factor C	2	2.036*	8.012*	21.84*
AC	2	0.002**	0.050**	0.559**
BC	2	0.027**	0.096**	0.824*
ABC	2	0.040**	0.318*	0.427*
Error	22	0.028	0.034	1.398

PLATES

BARI Sarisha-11 BARI Sarisha-14

Plate 1. Photograph showing variation in seed coat colour, seed size and shape of two selected released varieties of rapeseed and mustard *(Brassica spp.*)

Plate 2. Collection of soil sample for the P^H and Organic Carbon percentage measurement

Plate 3. Processing and application of biochar

Plate 4. Seedlings in the poly bag

Plate 5. Transplanting of seedling in SMI plots

Plate 6. A view of the experimental plot

Plate 7. Performance of BARI Sarisha-11 in SMI method and 10 t ha^{-1} of Biochar

Plate 8. Growth of the mustard plant under SMI method