INFLUENCE OF ORGANIC, INORGANIC AND BIO-FERTILIZERS ON MORPHOLOGICAL CHARACTERS AND YIELD OF MUSTARD

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CERTIFICATE

This is to certify that the thesis entitled " **INFLUENCE OF ORGANIC, INORGANIC AND BIO-FERTILIZERS ON MORPHOLOGICAL CHARACTERS AND YIELD OF MUSTARD**" submitted to the Department of Agricultural Botany, Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of MASTERS OF SCIENCE (M.S.) in **AGRICULTURAL BOTANY**, embodies the result of a piece of bonafide research work carried out by **JAHID HASAN**, Registration No. **19-10123** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

June, 2021

Dhaka, Bangladesh

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Dedicated to

My

Beloved Parents

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INFLUENCE OF ORGANIC, INORGANIC AND BIO-FERTILIZERS ON MORPHOLOGICAL CHARACTERS AND YIELD OF MUSTARD

ABSTRACT

Bio-fertilizer and organic products plays a significant role in crop cultivation with reduced chemical fertilizer use which are eco-friendly natural sources. Use of inorganic fertilizer in combination with bio-fertilizer and organic manure maximize mustard yield and also can be considered as an alternative to sustainable agriculture development. The present study aims to influence of organic, inorganic and bio-fertilizers on morphological characters and yield of mustard (BARI Sarisha-14), conducted at the farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka-1207 during the period of November 2019 to February 2020. Fourteen treatments *viz*. (i) Control (no fertilizer), (ii) Cowdung 100%, (iii) Inorganic fertilizer 100%, (iv) Decoprima 100%, (v) Cowdung 100% + Inorganic fertilizer 100%, (vi) Cowdung 100% + Inorganic fertilizer 75%, (vii) Cowdung 100% + Inorganic fertilizer 50%, (viii) Cowdung 100% + Decoprima100%, (ix) Inorganic fertilizer 100% + Decoprima 100%, (x) Inorganic fertilizer 75% + Decoprima 100%, (xi) Inorganic fertilizer 50% + Decoprima 100%, (xii) Cowdung 100% + Inorganic fertilizer 100% + Decoprima 100%, (xiii) Cowdung 100% + Inorganic fertilizer 75% + decoprima 100% and (xiv) Cowdung 100% + Inorganic fertilizer 50% + Decoprima 100% were considered for the present study. The experiment was laid out in randomized complete block design (RCBD) with three replications. The results of this study showed that the sole application of either organic or inorganic fertilizers and combined application of organic and inorganic fertilizers influence the growth and yield of mustard. Among the performance of all treatments, cowdung 100% + inorganic fertilizer 100% + decoprima 100% gave the highest plant height (97.81 cm), number of leaves plant^{-1} (45.80) number of branches plant^{-1} (9.33), length of inflorescence (40.22 cm), number of silliquae inflorescence^{-1} (40.73), number of filled silliquae plant^{-1} (98.73), number of seeds silliquae^{-1} (37.93), seed weight of 100 siliquae (13.50 g), seed weight plant^{-1} (9.60 g) and seed yield (1803.00 kg ha^{-1}) whereas control treatment (no fertilizer) showed least result on the respected parameters. But no significant difference was found between T_{11} (Cowdung 100% + Inorganic fertilizer 100% + Decoprima 100%) and T_{12} (Cowdung 100% + Inorganic fertilizer 75% + Decoprima 100%) treatments though both the sole and/or combined application of organic fertilizer (cowdung) and bio-fertilizer (decoprima) contribute to reduce the amount of inorganic fertilizer. Combined application of organic fertilizer (cowdung) and bio-fertilizer (decoprima) contributed to reduce the amount of inorganic fertilizers for mustard cultivation under the climatic and edaphic condition of Sher-e-Bangla Agricultural University.

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ABBREVIATIONS AND ACRONYMS

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

CHAPTER I

INTRODUCTION

Mustard *(Brassica* sp.) is one of the most important oil seed crops of the world after soybean and groundnut (FAO, 2012). It is the main cultivable edible *rabi* oilseed crop of Bangladesh. It is commonly known as 'Sarisha' in Bangla and is being cultivated throughout the country during the winter season (November to March). It has a remarkable demand for edible oil in Bangladesh. It accounts for 59.4% of total oil seed production in the country and it covers the major portion of the total edible oil requirement of the country (AIS, 2010). Bangladesh occupies the 5th place in respect of total oil seed production in the world and mustard occupies the first position in respect of area (61.2%) and production (52.6%) among the oil crops grown in Bangladesh (BBS, 2010).

Mustard oil plays an important role as a fat substitute in our daily diet. This oil is widely used in cooking and as medical ingredients. Mustard is not only a rich source of energy (about 9 kcal g^{-1}), but also rich in fat soluble vitamins like A, D, E and K (Alim *et al*., 2020). Seeds of mustard contain 40-45% oil and 20-25% protein. Mustard oilcake contains 40% protein that is used as nutritious animal feed and high quality manure for crop production (Alim *et al*., 2020). With increasing population, the demand of edible oil is increasing day by day. Therefore, it is highly accepted that the production of edible oil should be increased considerably to fulfill the demand.

The area under mustard is declining due to late harvesting of high yielding T. *aman* rice and increased cultivation of *boro* rice. The decrease in an area of 104,000 hectare and production 68,000 tons of mustard and rapeseed in last ten years has been reported (Anonymous, 2006). Among the oil seed crops grown in Bangladesh, mustard tops the list in respect of both production and acreage (BBS, 2015). The present area and production of mustard is 3.25 lac hectare and 3.59 lac metric ton respectively (BBS, 2018). The average yield of mustard in Bangladesh is very low (1.08 t/ha) (BBS, 2018) compared to other mustard growing countries of the world. The major reasons for low yield of rapeseed-mustard in our country are due to lack of high yielding variety and proper management practices e.g. balanced manure and fertilizer application, use of organic matter to maintain soil fertility level etc. There is a great scope of increasing yield of mustard by selecting high yielding varieties and improving management practices (Bhuiyan *et al.*, 2008).

Nutrient management is one of the most important factors that affect the mustard productivity. Soil fertility quality can be improved by adding organic matter. The addition of organic matter to the soil has a very important function in fertilizing the topsoil layer, increasing the population of microorganisms in the soil, increasing the water absorption capacity and overall improving the quality of soil fertility. The addition of organic matter to mustard planting has the potential to reduce the use of synthetic chemical fertilizers (Agustina *et al*., 2012). But application of all the needed fertilizer through chemical fertilizers had deleterious effect on soil fertility and unsustainable yields. It is necessary to use organic matter source like cowdung, farmyard manure, vermicompost, poultry manure etc. which are good source of nutrients required by plants for quality produce. Cowdung is a good source of organic matter and play a vital role in soil fertility improvement as well as supplying primary, secondary and micronutrients for crop production. Cowdung application has been known to improve physical, chemical and biological properties of soil (Zamil, 2004).

Use of chemical fertilizers in combination with organic manure is essentially required to improve the soil health (Prasad *et al.* 2010). Balanced nutrient management through conjunctive use of organic, inorganic and bio-fertilizers facilitate profitable and sustainable crop production and also maintain soil quality (Singh and Sinsinwar, 2006).

Biofertilizer can help in increasing plant nutrient in the soil. It is cheaper, pollution free, environment friendly and renewable. The future of agriculture, thus, depends on the use of biofertilizers as a potential source of the nutrients

(Chauhan *et al*., 1996). Under the present study, Decoprima was used as biofertilizer. It is a *trichoderma* based biofertilizer which is a microbial composition of *trichoderma*, *geobacillus* and *streptomyces*. Decoprima is also considered as bio-fungicide (microbial) which is very effective against fuserium wilt and bacterial wilt and also used in soil before plantation to protect against soil borne diseases (Indo-Bangla Agrotech Ltd., 2020). *Trichoderma* makes nutrients available to the plants through different biological processes. In contrast to synthetic fertilizers, they improves soil properties and microbial activities. They can maintain soil fertility for longer period as compared to chemical fertilizers (Bhandari *et al*., 2021). Use of decoprima in crop field, two way benefit can be made as increased plant nutrition as well as plant protection (Prabha *et al*., 2016).

Keeping all the above facts in view, the present investigation was undertaken to study the influence of cowdung, inorganic fertilizers and bio-fertilizer (decoprima) on morphology, yield contributing characters and yield of mustard with the following objectives:

1. To investigate the effects of sole application of cowdung, inorganic fertilizer and bio-fertilizer (decoprima) on morphology, yield contributing characters and yield of mustard
2. To investigate the effects of combined application of cowdung, inorganic fertilizer and bio-fertilizer (decoprima) on morphology, yield contributing characters and yield of mustard

CHAPTER II

REVIEW OF LITERATURE

The response of mustard to different levels organic, inorganic and biofertilizer for its successful cultivation has been investigated by numerous investigators in various parts of the world. In Bangladesh, there have not enough studies on the influence of either organic and/or inorganic or biofertilizer application or in combination on the growth and yield of mustard. However, the available research findings in this connection over the world have been reviewed in this chapter.

2.1 Effect of integrated fertilizer management on mustard

2.1.1 Morphological characters

Sugianti and Zulhaedar (2021) carried out a study to evaluate the effectiveness of several fertilization regimens using the organic fertilizer enriched with *Trichoderma* sp. in increasing the growth and production of green mustard (*Brassica juncea*). The application of organic fertilizer in combination with half of the standard dose of inorganic fertilizers was recommended for improving the production of green mustard based on the higher agronomic efficiency obtained relative to standard inorganic fertilization. Finally it was reported that fertilization is important to support plant growth in the agricultural cultivation systems. Organic fertilizers can be used to reduce the excessive use of inorganic fertilizers in improving crop production.

Mahato *et al*. (2018) conducted an experiment to find out the effects of *Trichoderma viride* on growth and yield of wheat. The experiment consisted of seven treatments; (T_1: Control; T_2: Soil + NPK; T_3: Soil inoculated *Trichoderma*; T_4: *Trichoderma* + FYM; T_5: *Trichoderma* + ½ NPK; T_6: *Trichoderma* + NPK and T_7 = *Trichoderma* + NPK + FYM) laid out in completely randomized design (CRD) with three replications. The results showed that *Trichoderma viride* increased the plant height (4.6%), root weight (1.5%) and leaf length (0.3%) over control; while root length (17.4%), number of leaves (8.4%), tiller number (10.8%) highlighted the negative impact of *T. viride* on wheat plant. *T. viride* displayed antagonism with inorganic fertilizer. When *T. viride* and NPK were accompanied with farmyard manure, most of the growth parameter showed the highest value.

Beenish *et al*. (2018) conducted a field experiment to study the organic manures and biofertilizers: Effect on the growth and yield of Indian mustard varieties. The treatments consisted of five mustard varieties and 10 fertilizer treatments. Regarding fertilizer treatments T_7 (75% N through vermicompost + Azotobacter) produced significantly tallest plants, the highest number of primary and secondary branches/plant.

Kumar *et al*. (2018) conducted a field experiment to study the effect of organic and inorganic sources of nutrients on yield, quality and nutrients uptake by mustard (*Brassica juncea* L.). The experimental results revealed that maximum growth parameters (plant height, branches plant^{-1}, dry matter accumulation and leaf area index) were recorded with application of 50% RDF+ FYM 6 t/ha + Vermicompost 2 t/ha+ bio-fertilizer than the rest of the treatments. Application of FYM and vermicompost improved the physiochemical properties of soil which may improved the sustainability of production system.

Thaneshwar *et al.* (2017) observed significant increase in the plant height of mustard from 126.33 to 143.10 cm when the three levels of vermicompost were applied along with RDF. They further noted that the treatment receiving application of vermicompost 5 t ha^{-1} produced the tallest plants (143.10 cm) of mustard. The application of RDF (N:P:K @ 120:60:40:30 kg ha^{-1}) + vermicompost 5 t ha^{-1} also produced maximum dry matter yield (24.37 g) per plant.

Khambalkar *et al.* (2017) reported that the treatment receiving application of 50 percent RDF (60:30:30:20 N:P:K:S kg ha^{-1}) + FYM 6 t ha^{-1} +

Vermicompost 2 t ha^{-1} + Azotobacter and PSB recorded the highest plant height values of 31.50, 134.33, 193.50 and 198.66 cm, at 30, 60, 90 and at harvest of mustard, respectively.

Saha *et al.* (2015) conducted a trial to study the effect of integrated nutrient management on growth and productivity of rapeseed-mustard cultivars at pulse and oilseed research station, Berhampore, West Bengal during *rabi* season on Entisols (pH 6.6) and observed that the treatment receiving application of 100:50:50:30 N:P:K:S kg ha^{-1} + Azotobacter + PSB recorded the highest plant height (132 cm)) of mustard.

Lepcha *et al.* (2015) conducted a field experiment entitled influence of different organic and inorganic sources of nitrogen on growth of Indian mustard and observed that application of 20 percent nitrogen through FYM + 20 percent nitrogen through vermicompost + 20 percent nitrogen through neem cake + 20 percent nitrogen through poultry manure + 20 percent nitrogen through inorganics produced the highest (7.64 kg) dry matter yield of mustard over rest of the treatment combinations which was significantly superior over control.

Parihar *et al.* (2014) observed that the application of three levels of sulphur (20, 40, 60 kg ha^{-1}) caused variation in the plant height of mustard from 161.11 to 183.05 cm. They also reported that the plant height varied significantly from 158.30 to 186.25 cm due to the application of fortified vermicompost @ 20, 40, and 60 t ha^{-1}.

Rundala *et al.* (2013) reported that dual inoculation with *Azotobacter+PSB* significantly increased plant height, dry matter accumulation per plant and number of branches per plant over control.

Tripathi *et al.* (2011) studied the effect of integrated nutrient management on mustard and the data indicated that the higher plant height (202.3 cm) and dry matter yield per plot (7.48 kg) of mustard was observed in the treatment receiving application of 100 percent RDF + 2 t FYM + 40 kg sulphur + 25 kg zinc sulphate + 1 kg boron + Azotobacter (seed inoculation). They also reported that the application of 100% recommended dose of fertilizer along with FYM, sulphur, zinc, boron and Azotobacter (seed treatment) resulted in maximum dry matter accumulation, total branches per plant.

Singh *et al*. (2006) carried out a field experiment to evaluate the response of Indian mustard 'RH-30'to FYM (2.5 and 5 t/ha) and inorganic N (0, 40, 80 kg/ha) applied alone or in combination with biofertilizers (*Azotobacter chroococcum* and *Azospirillum*). Branches per plant significantly increased with the application of FYM + biofertilizers (5 t increased + *Azotobactor chroococcum* + *Azospirillum*) over the control.

Gudadhe *et al.* (2005) studied the effect of biofertilizers on growth and yield of mustard and reported that application of graded levels of recommended dose of fertilizers alone or in combinations of Azotobacter and PSB alone or both recorded plant height of mustard varied from131.8 to 156.3 cm and the highest plant height (156.3 cm) was observed in the treatment receiving application of 100 percent RDF + Azotobacter and PSB.

Vyas (2005) carried out a field experiment on interactive effects of nitrogen and biofertilizers on Indian mustard and reported that the treatment receiving application of 40 kg P_2O_5 + Azotobacter and PSB recorded the higher plant height (119.4 cm).

Murudkar (2002) reported that the periodical plant height varied significantly from 6.54 to 8.12 cm at 30 DAS, 136.08 to 164.33 cm at 60DAS and 167.31 to 187.38 cm due to the various treatment combinations of integrated nutrient management. The maximum number of silique per plant were produced (184.17) due to the application of recommended dose of fertilizer along with glyricidia @ 5 t ha^{-1}.

Mondal and Wahhab (2001) conducted field experiments to study the impact of reduced dose of chemical fertilizer and its combination with biofertilizer and vermicompost on morpho-physiological and biochemical traits of mustard *(Brassica campestris* cv. B_9). Mustard was cultivated using a full recommended dose of chemical fertilizer (N:P:K-100:50:50) and along with six different reduced doses of chemical fertilizer combined with biofertilizers and vermicompost. The performance of the crop was adjudged in terms of various parameters *viz*. leaf number, leaf area index (LAI), leaf area duration (LAD), leaf area ratio (LAR), crop growth rate (CGR), net assimilation rate (NAR), photosynthetic rate (PR)) and biochemical attributes such as total chlorophyll, sugar and proline content of physiologically active leaves of mustard.

2.1.2 Yield attributing characters

Mahato *et al*. (2018) conducted an experiment to find out the effects of *Trichoderma viride* on growth and yield of wheat. The experiment consisted of seven treatments; (T_1: Control; T_2: Soil + NPK; T_3: Soil inoculated *Trichoderma*; T_4: *Trichoderma* + FYM; T_5: *Trichoderma* + ½ NPK; T_6: *Trichoderma* + NPK and T_7 = *Trichoderma* + NPK + FYM) laid out in completely randomized design (CRD) with three replications. The results showed that *Trichoderma viride* increased the panicle weight (9.1%) and number of grains (3.8%) over control; while panicle number (6.7%) and panicle length (8.4%) highlighted the negative impact of *T. viride* on wheat plant.

Beenish *et al*. (2018) conducted a field experiment to study the organic manures and biofertilizers: Effect on the growth and yield of Indian mustard varieties. The treatments consisted of five mustard varieties and 10 fertilizer treatments. Amongst fertilizer treatments T_7 (75% N through vermicompost + Azotobacter) produced significantly the highest yield attributing characters.

Kumar *et al*. (2018) conducted a field experiment to study the effect of organic and inorganic sources of nutrients on yield, quality and nutrients uptake by mustard (*Brassica juncea* L.) variety Pusa Mustard 30 (LES-43). The experimental results revealed that maximum yield attributes (siliqua length, siliqua plant^{-1}, seeds siliqua^{-1} and test weight) were recorded with application of 50% RDF+ FYM 6 t/ha + Vermicompost 2 t/ha+ bio-fertilizer than the rest of the treatments.

Chandan *et al.* (2018) reported that the treatment receiving application of 75 percent RDF + 40 kg Sulphur + 5 t vermicompost ha^{-1} with superimposition of Azotobacter and PSB recorded the highest silique per plant (274).

Singh *et al.* (2018) found that application of RDF 100 percent + FYM 5 t ha^{-1} + vermicompost 2.5 t ha^{-1} + Azotobacter produced highest number of silique per plant (240) as compared to number of silique (193) observed in the control treatment.

Thaneshwar *et al.* (2017) observed that the application of RDF (N:P:K @ 120:60:40:30 kg ha^{-1}) + vermicompost 5 t ha^{-1} also produced maximum number of silique on primary branches (164.61), maximum total number of silique (286.3) per plant, while application of RDF + vermicompost 2 t ha^{-1} produced maximum number of silique on secondary branch (102.38).

Brar *et al.* (2016) conducted a field experiment on response of brown sarson *(Brassica campestries* var. Brown sarson) to integrated nutrient management and concluded that the highest number of silique (132.3) were registered in the treatment receiving application of Azotobacter + PSB over Azotobacter alone (115.1) and without inoculation (109.1).

Pal and Pathak (2016) studied the effect of integrated nutrient management on yield and economics of mustard and concluded that the application of compost and PSB along with 80 kg phosphorus and 60 kg sulphur recorded the maximum number of silique per plant (476.50).

Saha *et al.* (2015) conducted a trial to study the effect of integrated nutrient management on growth and productivity of rapeseed-mustard cultivars at pulse and oilseed research station, Berhampore, West Bengal during *rabi* season on Entisols (pH 6.6) and observed that the treatment receiving application of 100:50:50:30 N:P:K:S kg ha^{-1} + Azotobacter + PSB recorded the maximum number of silique per plant of mustard.

Lepcha *et al.* (2015) conducted a field experiment entitled influence of different organic and inorganic sources of nitrogen on yield attributes of Indian mustard and observed that application of 20 percent nitrogen through FYM + 20 percent nitrogen through vermicompost + 20 percent nitrogen through neem cake + 20 percent nitrogen through poultry manure + 20 percent nitrogen through inorganics produced the highest number of silique per plant (522.83) of mustard over control.

Parihar *et al.* (2014) observed that the application of fortified vermicompost @ 20, 40, and 60 t ha^{-1} was found beneficial for producing the maximum number of silique per plant in mustard and it ranged from 151.79 to 182.01 per plant with an average value of 166.9.

Rundala *et al.* (2013) reported that the significantly maximum values of yield attributes of mustard were recorded under application of 75% RDF through FYM + 25% through fertilizers being at par with 50% RDF through FYM + 50% through fertilizers. Results further indicated that dual inoculation with *Azotobacter+PSB* significantly increased siliquae per plant, seeds per siliqua and test weight of mustard over control.

De and Sinha (2012) observed that the treatment receiving application of 50 percent RDF (60:30:30 N:P:K) kg ha^{-1} + FYM 2.5 t ha^{-1} + Vermicompost 1.25 t ha^{-1} + Neem cake 1.25 t ha^{-1} + Poultry manure 1.25 t ha^{-1} registered the highest number of silique per plant (189.74).

Tripathi *et al.* (2011) studied the effect of integrated nutrient management on mustard and the data indicated that the higher number of silique per plant (279.7) of mustard was observed in the treatment receiving application of 100 percent RDF + 2 t FYM + 40 kg sulphur + 25 kg zinc sulphate + 1 kg boron + Azotobacter (seed inoculation). They also reported that the application of 100% recommended dose of fertilizer along with FYM, sulphur, zinc, boron and Azotobacter (seed treatment) resulted in maximum seeds per siliqua and 1000 seed weight of mustard. While, the application of 75 percent RDF + 5 FYM t ha^{-1} + Lime significantly improved the number of silique per plant (226) over rest of the treatment combinations as reported by Pati and Mahapatra (2015).

Kapor *et al.* (2010) reported that the application of sulphur @ 15, 30, 45 and 60 kg ha^{-1} was found to cause a significant increase in the number of silique from 249.3 to 308.8 per plant with an average value of 279.50 of mustard.

Mahesh babu *et al.* (2008) conduced a field experiment in Dharwad, Karanataka, on soybean and reported that application of RDF (40 kg N, 80 kg P_2O_5 and 25 kg K_2O ha^{-1}) with recommended dose of FYM (5 t ha^{-1}) recorded highest values of yield components like number of pods per plant and number of seeds per pod compared to other treatments.

Singh (2007) observed that the application of FYM @ 10 t ha^{-1} with 120 kg N + 40 kg P_2O_5 + 40 kg K_2O ha^{-1} significantly increased yield traits such as siliquae per plant, seeds per siliqua and test weight of 1000 seeds of mustard over control.

Singh *et al*. (2006) carried out a field experiment to evaluate the response of Indian mustard 'RH-30'to FYM (2.5 and 5 t/ha) and inorganic N (0, 40, 80 kg/ha) applied alone or in combination with biofertilizers (*Azotobacter chroococcum* and *Azospirillum*). Siliquae per plant, seeds per siliquae, 1000-seed weight, seed oil content, oil yield, and yield of seed and stover significantly increased with the application of FYM + biofertilizers (5 t increased + *Azotobactor chroococcum* + *Azospirillum*) over the control.

Pir *et al.* (2005) conducted an experiment on loamy sand soil of Sardarkrushi Nagar, Gujarat and observed that application of FYM 10 t + 50 kg P_2O_5 ha^{-1} significantly improved number of siliquae per plant and test weight of mustard compared with control.

Gudadhe *et al.* (2005) studied the effect of biofertilizers on growth and yield of mustard and reported that application of graded levels of recommended dose of fertilizers alone or in combinations of Azotobacter and PSB alone or both. The highest number of silique (251) per plant and dry matter yield of mustard (4.44 kg) was observed in the treatment receiving application of 100 percent RDF + Azotobacter and PSB.

Vyas (2005) carried out a field experiment on interactive effects of nitrogen and biofertilizers on Indian mustard and stated that the maximum number of silique per plant (193.4) in mustard were observed in the treatment receiving application of NP @ 90:40 kg + Azotobacter. They further reported that the treatment receiving application of 40 kg P_2O_5 + Azotobacter and PSB recorded the higher number of silique (173.6) per plant.

Murudkar (2002) reported that the maximum number of silique per plant were produced (184.17) due to the application of recommended dose of fertilizer along with glyricidia @ 5 t ha^{-1}.

2.1.3 Yield parameters

Sugianti and Zulhaedar (2021) carried out a study with the treatments of P_1 (control without fertilization); P_2 (standard fertilization with 150 kg/ha urea + 50 kg/ha NPK); P_3 (2000 kg/ha organic fertiliser); P_4 (2500 kg/ha organic fertilizer); P_5 (3000 kg/ha organic fertilizer); P_6 (75 kg/ha urea + 25 kg/ha NPK + 2000 kg/ha organic fertilizer); P_7 (75 kg/ha urea + 25 kg/ha NPK + 2500 kg/ha organic fertilizer); and P_8 (75 kg/ha urea + 25 kg/ha NPK + 3000 kg/ha organic fertilizer). Treatments with combined application of organic and inorganic fertilizers (P_6, P_7 and P_8) resulted in significantly higher yield of mustard greens, compared to the standard fertilization regimen using inorganic fertilizers (P_2) and treatments only with organic fertilizer at different doses (P_3, P_4 and P_5).

Alim *et al*. (2020) conducted an experiment using two mustard varieties BARI Sarisha-14 (V_1) and BARI Sarisha-16 (V_2) in combination with six integrated nutrient managements (INM) *viz*., 75% RDF (Recommended dose of fertilizer) (T_1), 75% RDF + Vermicompost (VC) @ 2.5 t ha^{-1} (T_2), 100% RDF (90:27:32:15:1, N:P:K:S:Zn:B) - (T_3), 100% RDF + Vermicompost (VC) @ 2.5 t ha^{-1} (T_4), 125% RDF (T_5) and 125% RDF + Vermicompost (VC) @ 2.5 t ha^{-1} (T_6) to the sub-plot. The highest seed yield (1.82 t ha^{-1}) was obtained from BARI Sarisha-16 and the lower seed yield (1.51 t ha^{-1}) was observed in BARI Sarisha-14. Among the INM treatments, the highest seed yield (1.91 t ha^{-1}) was recorded from T_2 which was statistically similar to T_4. Therefore, BARI Sarisha-16 should be grown with 75% RDF + Vermicompost (VC) @ 2.5 t ha^{-1} for obtaining higher yield.

Mahato *et al*. (2018) conducted an experiment to find out the effects of *Trichoderma viride* on growth and yield of wheat. The experiment consisted of seven treatments; (T_1: Control; T_2: Soil + NPK; T_3: Soil inoculated *Trichoderma*; T_4: *Trichoderma* + FYM; T_5: *Trichoderma* + ½ NPK; T_6: *Trichoderma* + NPK and T_7 = *Trichoderma* + NPK + FYM). The results showed that *Trichoderma viride* increased the grain yield (36.5%), biological yield (13.7%), and biomass yield (2.7%) over control. *T. viride* displayed antagonism with inorganic fertilizer. When *T. viride* and NPK were accompanied with farmyard manure, most of the yield parameter showed the highest value. Using *T. viride* with a full dose of NPK during sowing stage may not be efficient and economical in terms of productivity. Introducing farmyard manure to *T. viride* gives better yield than *T. viride* alone.

Beenish *et al*. (2018) conducted a field experiment to study the organic manures and biofertilizers: Effect on the growth and yield of Indian mustard varieties. The treatments consisted of five mustard varieties and 10 fertilizer treatments. Amongst fertilizer treatments T_7 (75% N through vermicompost + Azotobacter) produced significantly highest seed and stover yield. The mustard variety Rani Supplied with 75% N through vermicompost + Azotobacter realised the highest gross, net returns and benefit cost ratio.

Kumar *et al*. (2018) conducted a field experiment to study the effect of organic and inorganic sources of nutrients on yield, quality and nutrients uptake by mustard (*Brassica juncea* L.) variety Pusa Mustard 30 (LES-43). The experimental results revealed that maximum yield parameters (grain and stover), nutrient uptake (N,P, K and S) by grain and stover and available soil nutrient (N, P, K and S) were recorded with application of 50% RDF+ FYM 6 t/ha + Vermicompost 2 t/ha+ bio-fertilizer than the rest of the treatments. The increment in seed yield with application of 50% RDF+ FYM 6 t/ha + Vermicompost 2 t ha^{-1} + Bio-fertilizers was 168.35% over control. Maximum gross return, net return were recorded with the application of 50% RDF+ FYM 6 t ha^{-1} + Vermicompost 2 t ha^{-1} + Bio-fertilizers, however B: C ratio was lower than the use of RDF only but in application of FYM and vermicompost improved the physiochemical properties of soil which may improved the sustainability of production system.

Chandan *et al.* (2018) reported that the treatment receiving application of 75 percent RDF + 40 kg Sulphur + 5 t vermicompost ha^{-1} with superimposition of Azotobacter and PSB recorded the highest seed yield of 17.80 q ha^{-1} and highest stover yield (61.50 q ha^{-1}). They further reported that the treatment receiving application of RDF + 40 kg sulphur + 2 t poultry manure + Azotobacter + PSB produced higher (16.70 q ha^{-1}) seed yield of mustard.

Singh *et al.* (2018) found that application of RDF 100 percent + FYM 5 t ha^{-1} + vermicompost 2.5 t ha^{-1} + Azotobacter also produced highest seed yield (2316 kg ha^{-1}) of mustard.

Sahoo *et al.* (2018) opined that the treatment receiving the application of 75 percent STR + FYM @ 5 t ha^{-1} + zinc @ 5 kg ha^{-1} + Azotobacter registered the higher seed yield and stover yield of mustard (24.15 and 4993.83 kg ha^{-1}, respectively).

Majumder *et al.* (2017) observed the significant variation in seed yield of mustard from 10.13 to 13.83 q ha^{-1} as a result of various treatments combinations and further reported that the highest seed yield (13.83 q ha^{-1}) was observed in the treatment receiving application of FYM 5 t ha^{-1} + Zinc (EDTA) 10 kg ha^{-1} + 40 kg sulphur through elemental sulphur.

Thaneshwar *et al.* (2017) observed that the application of RDF (N:P:K @ 120:60:40:30 kg ha^{-1}) + vermicompost 5 t ha^{-1} also produced maximum seed yield (22.75 q ha^{-1}) and maximum stover yield (79.26 q ha^{-1}). Whereas, Jaiswal *et al.* (2015) opined that the treatment receiving application of RDF + 40 kg Sulphur ha^{-1} + 2 kg boron ha^{-1} showed higher (32.00 q ha^{-1}) stover yield of mustard.

Brar *et al.* (2016) conducted a field experiment on response of brown sarson *(Brassica campestries* var. Brown sarson) to integrated nutrient management and concluded that highest seed yield was recorded due to the application of Azotobacter + PSB (995.1 kg ha^{-1}) over Azotobacter alone (827.3 kg ha^{-1}) and without inoculation (797.8 kg ha^{-1}) at harvest.

Pal and Pathak (2016) studied the effect of integrated nutrient management on yield and economics of mustard and concluded that the application of compost and PSB along with 80 kg phosphorus and 60 kg sulphur recorded the highest seed yield of mustard (2633.36 kg ha^{-1}).

Saha *et al.* (2015) conducted a trial to study the effect of integrated nutrient management on growth and productivity of rapeseed-mustard cultivars at pulse and oilseed research station, Berhampore, West Bengal during *rabi* season on Entisols (pH 6.6) and observed that the treatment receiving application of 100:50:50:30 N:P:K:S kg ha^{-1} + Azotobacter + PSB recorded the highest seed yield and stover yield (4572 kg ha^{-1}) of mustard.

Pati and Mahapatra (2015) studied the effect of integrated nutrient management on yield and nutrient uptake of mustard and found that the application of 75 percent RDF + 5 FYM t ha^{-1} + Lime produced the higher seed yield (1722 kg ha^{-1}) and stover yield (2759 kg ha^{-1}) of mustard.

Kansotia *et al.* (2015) observed that the sole application of vermicompost @ 2, 4 and 6 t ha^{-1} found to be beneficial for producing higher seed yield of mustard (1058.67, 1241.56 and 1456.00 kg ha^{-1}, respectively) over rest of the treatment combinations. They also observed that the sole application of vemicompost @ 2.0, 4.0, and 6.0 t ha^{-1} was found beneficial for producing higher stover yield of mustard from 1426.2 to 1933.6 kg ha^{-1} with average value of 1679.9 kg ha^{-1}.

Lepcha *et al.* (2015) conducted a field experiment entitled influence of different organic and inorganic sources of nitrogen on growth, yield and oil content of Indian mustard and observed that application of 20 percent nitrogen through FYM + 20 percent nitrogen through vermicompost + 20 percent nitrogen through neem cake + 20 percent nitrogen through poultry manure + 20 percent nitrogen through inorganics produced the highest seed yield (21.52 q ha^{-1}), stover yield (57.91 q ha^{-1}) of mustard over rest of the treatment combinations.

Pal and Pathak (2016) studied the effect of integrated nutrient management on yield and economics of mustard and concluded that the application of compost and PSB along with 80 kg phosphorus and 60 kg sulphur recorded the maximum number of silique per plant (476.50) and the highest seed yield of mustard (2633.36 kg ha^{-1}).

Singh *et al.* (2014) observed that the application of RDF + vermicompost @ 5 t ha^{-1} registered the highest seed yield (17.40 q ha^{-1}) and stover yield (79.26 q ha^{-1}) of mustard. They further reported that the treatment receiving application of RDF + vermicompost @ 5 t ha^{-1} produced the highest number of silique per plant (286.53) and highest dry matter yield of mustard. They also reported that the application of RDF (120:60:40:30 NPKS kg ha^{-1}) along with various levels of vermicompost and FYM was found to be useful for producing maximum seed yield and stover yield of mustard.

Parihar *et al.* (2014) observed that the application of sulphur @ 20, 40, 60 kg to mustard was found to be beneficial for enhancing the yield of mustard from 14.67 to 16.09 q ha^{-1}. They further reported that the application of fortified vermicompost @ 20, 40, and 60 t ha^{-1} resulted in producing seed yield of mustard from 13.78 to 18.65 q ha^{-1}.

Kansotia *et al*. (2013) carried out a field experiment on Indian mustard (*Brassica juncea* L.). Application of vermicompost up to 6 t/ha and 80 kg N/ha + 40 kg P_2O_5/ha significantly increased the growth parameters, yield attributes, yields, nutrient content, nutrient uptake in seed, straw and total nitrogen and phosphorus uptake and protein content and observed that available nitrogen, phosphorus and potassium of soil after harvest of mustard were significant higher than over control and lower levels. The combined effect of vermicompost × inorganic fertilizer was found significant pertaining to seed yield, N content and uptake in seed, P uptake in stover and protein content in seed.

Baber and Dongale (2013) reported that the highest stover yield of mustard was recorded in the treatment receiving 100% Inorganic and 25% Inorganic + organic fertilizer (2.79 t ha^{-1}) which was significantly superior to the other treatments.

Jat *et al.* (2013) conducted a field experiment at Agronomy Farm of S.K.N. College of Agriculture, Jobner, Jaipur (Rajasthan) and the results revealed that each successive increasing levels of FYM (10 t ha^{-1}) and mineral nutrients (40 kg S ha^{-1}+ 25 kg $ZnSO_4$ ha^{-1}+ 50 kg $FeSO_4$ ha^{-1}) individually and in combination significantly increased the seed and stover yield of mustard as compared to control.

Ola *et al.* (2013) conducted a field experiment on groundnut and recorded that application of FYM @ 8 t ha^{-1} + 50% RDF produced significantly higher seed yield over control.

Rundala *et al.* (2013) reported that the significantly maximum values of yield of mustard were recorded under application of 75% RDF through FYM + 25% through fertilizers being at par with 50% RDF through FYM + 50% through fertilizers except stover yield which was at par with 100% RDF through FYM over rest of the treatments. Results further indicated that dual inoculation with *Azotobacter+PSB* significantly increased seed and stover yield of mustard and net returns over control.

Babar and Dongale (2013) reported that application of different levels of RDF (125, 100, 75 and 50 percent) along with graded levels of FYM (50 and 25 percent on the basis of nitrogen content) caused variation in the seed yield 0.27 to 1.10 t ha^{-1} and stover yield from 0.62 to 2.79 t ha^{-1} of mustard. Among the various treatment combinations the application of 100 percent NPK through inorganics + 25 percent N through FYM produced the highest seed yield (1.10 t ha^{-1}) and stover yield (2.79 t ha^{-1}) of mustard.

De and Sinha (2012) observed that the treatment receiving application of 50 percent RDF (60:30:30 N:P:K) kg ha^{-1} + FYM 2.5 t ha^{-1} + Vermicompost 1.25 t ha^{-1} + Neem cake 1.25 t ha^{-1} + Poultry manure 1.25 t ha^{-1} registered the highest seed yield (13.47 q ha^{-1}) of mustard. Further they also reported that the seed yield of mustard varied significantly from 12.46 to 13.47 q ha^{-1} due to the integration of inorganics with organics.

Haque *et al*. (2012) evaluated three *Trichoderma*-enriched biofertilizers in mustard and tomato cultivation at field condition. Application of 50% N fertilizer along with 50% *Trichoderma*-enriched biofertilizers augmented 108 and 203% yields over control both in mustard and tomato, respectively which were 81.90 and 61.82% in mustard and tomato at standard doses of Nitrogen, Phosphorus and Potassium fertilizers. The present results suggest that

Trichoderma-enriched biofertilizer could save at least 50% N fertilizer uses for mustard and tomato and could reduce excessive uses of NPK for crop cultivation.

Chattopaddhyay and Ghosh (2012) reported that the application of nitrogen, phosphorous and potassium @ 80:80:40 in combination with sulphur @ 60 kg ha^{-1} through SSP produced maximum stover yield (39.50 q ha^{-1}) of mustard and further reported that the application of sulphur @ 15, 30, 45 and 60 kg integrated with FYM @ 0, 1.5 and 3.0 t ha^{-1} in rapeseed was found to be beneficial for improving the yield of rapeseed from 2251 to 3268 kg ha^{-1}.

Singh and pal (2011) reported that the application of either FYM (10 t ha^{-1}) or Zn (25kg $ZnSO_4$ ha^{-1}) or seed treatment along with RDF (120:17.6:16.6:40, N:P:K:S) enhanced the mustard seed yield by 12.0, 11.5 and 13.0%, respectively over RDF alone.

Tripathi *et al.* (2011) studied the effect of integrated nutrient management on mustard and the data indicated that the maximum seed yield (1809 kg ha^{-1}) of mustard was observed in the treatment receiving application of 100 percent RDF + 2 t FYM + 40 kg sulphur + 25 kg zinc sulphate + 1 kg boron + Azotobacter (seed inoculation).

Haque *et al*. (2010) evaluated the effects of *Trichoderma*-enriched biofertilizer (BioF) such as BioF/compost (household/kitchen wastes composted with *Trichoderma harzianum* T22) and BioF/liquid (*T. harzianum* T22 broth culture contains spores and mycelia) alone or in combination with NPK fertilizer for the growth, dry matter production, yield and yield attributes of mustard (*Brassica campestris*) grown under field condition. Recommended doses of NPK and 50% BioF/compost + 50% NPK showed similar effects on growth, dry matter accumulation and yield of mustard. Seed yield per plant was increased by 5.34% over the recommended dose of NPK, when the crop was fertilized with 50% BioF/compost along with 50% NPK. Since 20% reduced yield is accepted in organic faming worldwide, the treatments namely

BioF/compost, 50% BioF/compost + 50% NPK and 75% BioF/compost + 25% NPK might be recommended for mustard cultivation in Bangladesh, which may reduce cultivation cost and also reduce environmental pollution.

Tripathi *et al.* (2010) reported that the application of 2 t FYM + 40 kg S along with RDF or 75% RDF resulted in significant increase in mustard yield i.e. 18.2 and 20.3% over RDF (1.69 t ha^{-1}) and 75% RDF (1.57 t ha^{-1}) alone.

Kapor *et al.* (2010) reported that the application of sulphur @ 15, 30, 45 and 60 kg ha^{-1} was found to cause a significant increase in seed yield of mustard.

Akbari *et al.* (2010) recorded that the maximum yield of soybean and groundnut were recorded with enriched compost @ 6 t ha^{-1} and that for sesame under 100% RDF.

Yadav *et al*. (2010) from Allahabad reported that the maximum yield was obtained by the sulphur application @ 40 kg/ha and by the source of biofertilizer (B1) @ Azotobacter10 kg seed inoculates. The interaction between sulphur and biofertilizer was significant and the maximum increase in yield was obtained by applied sulphur @ 40 kg^{-1} kg ha^{-1}, withbiofertilizer Azototobacter10 kg^{-1} seed inoculate.

Kumpawat (2010) reported that application of FYM 5 t ha^{-1} along with Rhizobium+ PSB recorded the highest seed yield (1642kg ha^{-1}).

Singh *et al.* (2009) conducted an experiment on mustard at Nagaland, India and reported that the application of integrated nutrient management recorded significantly higher yield over the control in respect of seed and stover yield of mustard crop. Among the treatment, treatment T_s (50% NPK+VC at 2 t ha^{-1}) produced significantly higher seed and stover yield.

Mahesh babu *et al.* (2008) conduced a field experiment in Dharwad, Karanataka, on soybean and reported that application of RDF (40 kg N, 80 kg P_2O_5 and 25 kg K_2O ha^{-1}) with recommended dose of FYM (5 t ha^{-1}) recorded highest values of seed yield compared to other treatments.

Arya *et al.* (2007) observed that the application of 50% RDF + FYM @ 5 t ha^{-1} + bio-fertilizers *(Rhizobium* + PSB) significantly enhanced the seed and stover yield of mustard as compared to control.

Bhat *et al.* (2007) conducted an experiment at Rajouri, Jammu and Kashmir on Indian mustard reported that application of 25% FYM-N (20 kg N) + 75% fertilizer N (60 kg N) + 40 kg S ha^{-1} produced significantly higher seed yield than 100% N through fertilizers and control.

Chand and Ram (2007) carried out a field experiment at Rajasthan on Indian mustard and reported that application of FYM @ 10 t ha^{-1} + 75% RDF + inoculation with bio-fertilizers *(Bacillus megaterium* + *Azotobacter chroococum*) significantly increased seed yield and stover yield over the control.

Nagdive *et al*. (2007) observed that the application of 75% (45:22.5:22.5 kg NPK ha^{-1}) RDF + FYM @ 5 t ha^{-1} + bio-fertilizers (*Azotobacter* + PSB) significantly enhanced seed yield of mustard as compared to control.

Singh (2007) observed that the application of FYM @ 10 t ha^{-1} with 120 kg N + 40 kg P_2O_5 + 40 kg K_2O ha^{-1} significantly increased seed and stover yield of mustard over control.

Singh *et al*. (2006) carried out a field experiment to evaluate the response of Indian mustard 'RH-30'to FYM (2.5 and 5 t/ha) and inorganic N (0, 40, 80 kg/ha) applied alone or in combination with biofertilizers (*Azotobacter chroococcum* and *Azospirillum*). Yield of seed and stover significantly increased with the application of FYM + biofertilizers (5 t increased + *Azotobactor chroococcum* + *Azospirillum*) over the control.

Pir *et al.* (2005) conducted an experiment on loamy sand soil of Sardarkrushi Nagar, Gujarat and observed that application of FYM 10 t + 50 kg P_2O_5 ha^{-1}

significantly improved seed and stover yield and oil yield of mustard compared with control.

Gudadhe *et al.* (2005) studied the effect of biofertilizers on yield of mustard and reported that application of graded levels of recommended dose of fertilizers alone or in combinations of Azotobacter and PSB alone or both recorded seed yield of mustard from 1041 to 1266 kg ha^{-1} and maximum seed yield was observed in the treatment receiving application of 100 percent RDF + Azotobacter + PSB.

Zamil *et al*. (2004) carried out a pot experiment to find out the effects of different animal manure on yield, quality and nutrient uptake by mustard cv. Agrani. The experiment comprised of two levels of cage system poultry manure, deep litter system poultry manure, cowdung and bio-gas slurry *viz*. 10 and 20 ton ha^{-1}, one control and one chemical fertilizer @ recommended dose. Cage system poultry manure @ 20 ton ha^{-1} significantly increased the seed and straw yield of mustard and cowdung showed lower performance. In straw and seed the highest uptake of N, P, K, Ca, Mg and S was obtained from cage system poultry manure @ 20 ton ha^{-1}. Seed yield was found to be significantly and positively correlated with branch and effective pod per plant. The overall results suggest that cage system poultry manure @ 20 ton ha^{-1} gave best performance among the parameters studied.

Premi *et al.* (2004) conducted an experiment to study the effect of farmyard manure (5.0, 10.0 and 15.0 t ha) and vermicompost (2.5, 5.0 and 7.5 t ha^{-1}) on the yield, yield components of Indian mustard cv. RH-30 and reported maximum seed yield (1460 kg ha^{-1}) of Indian mustard with recommended dose of NPK fertilizer @ (80 : 40 : 40 kg ha^{-1}) and it was at par with 7.5 t ha^{-1} vermicompost (1310 kg ha^{-1}) and FYM @ 15.0 t ha^{-1} (1340 kg ha^{-1}).

Abdul *et al*. (2004) conducted an experiment to evaluate the effects of biofertilizers (Azotobacter, Klebsiella, Proteus and phosphate solubilizers) on the performance of Indian mustard cv. ‘T-9’. The effect of these microbial inoculants was examined on the vegetative growth (shoot length, fresh and dry weights and number of leaves per plant) at 80 and 100 days after sowing. The yield characteristics (pods per plant, seeds per pod, 1000-seed weight and seed yield) at harvest were also studied. It was observed that *Azotobacter*, applied alone, resulted in the highest values for the parameters measured although all the combinations gave better results compared to the un-inoculated control.

Abdul and Ahmad (2003) studied the effects of biofertilizers (Azotobacterand PSB) on the performance of Indian mustard cv.'T-9'. The effects of these microbial inoculantswere examined on the yield characteristics (pods per plant, seeds per pod, 1000-seed weight and seed yield) at harvest were studied. Azotobacter, applied alone, resulted in the highest values for the parameters measured although all the combinations gave better results compared to the un-inoculated control.

Abraham and Lal (2002) reported that that 33 percent recommended dose of NPK along with PSB + Azospirrilum + poultry manure significantly increased the oil content and protein content in seed. However the highest seed yield and biological yield were greatest in 100% NPK treatment.

Murudkar (2002) reported that the significant variation in seed yield between 6.38 and 12.75 was observed as a consequence of various treatment combinations of integrated nutrient management.

Mondal and Wahhab (2001) conducted field experiments to study the impact of reduced dose of chemical fertilizer and its combination with biofertilizer and vermicompost on morpho-physiological and biochemical traits of mustard *(Brassica campestris* cv. B_9). Mustard was cultivated using a full recommended dose of chemical fertilizer (N:P:K-100:50:50) and along with six different reduced doses of chemical fertilizer combined with biofertilizers and vermicompost. The performance of the crop was adjudged in terms of harvest index (HI). The data revealed that vermicompost application significantly stimulated most of the yield parameters. It was concluded that 25% reduced dose of chemical fertilizer and its combination with vermicompost (T_4) was optimum for most of the parameters studied as compared to the control.

CHAPTER III

MATERIALS AND METHODS

The experiment was carried out at the farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from November 2019 to February 2020 to study the influence of cowdung, inorganic fertilizers and bio-fertilizer (decoprima) on morphology, yield contributing characters and yield of mustard. The materials and methods that were used for conducting the experiment are presented under the following headings:

3.1 Experimental location

The present piece of research work was conducted in the experimental field of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka. The location of the site is 90°33´E longitude and 23°77´N latitude with an elevation of 8.2 m from sea level. Location of the experimental site presented in Appendix I.

3.2 Soil

The soil of the experimental area belongs to the Modhupur Tract (UNDP, 1988) under AEZ No. 28 and was dark grey terrace soil. The selected plot was medium high land and the soil series was Tejgaon (FAO, 1988). The characteristics of the soil under the experimental plot were analyzed in the Soil Testing Laboratory, SRDI, Khamarbari, Dhaka. The details of morphological and chemical properties of initial soil of the experiment plot were presented in Appendix II.

3.3 Climate

The climate of experimental site was subtropical, characterized by three distinct seasons, the winter from November to February and the pre-monsoon period or hot season from March to April and the monsoon period from May to October (Edris *et al.*, 1979). Details on the meteorological data of air temperature, relative humidity, rainfall and sunshine hour during the period of the experiment was collected from the Weather Station of Bangladesh, Sher-e-Bangla Nagar, presented in Appendix III.

3.4 Experimental details

3.4.1 Treatments: Single factor experiment consisted of 14 treatments

In this study, I used cowdung as a source of organic fertilizer, decoprima as biofertilizer which enriched with *Trichoderma*, *Geobacillus* and *streptomyces* and different inorganic fertilizers, urea as a source of nitrogen, TSP as a source of phosphorus, Muriate of Potash as a source of potassium, Gypsum as a source of sulphur, $ZnSO_4$ as a source of zinc and Boric acid as a source of boron. The fourteen treatments under as follows:

T_0 = Control

T_1 = Cowdung 100%

T_2 = Inorganic fertilizer 100%

T_3 = Decoprima 100%

T_4 = Cowdung 100% + Inorganic fertilizer 100%

T_5 = Cowdung 100% + Inorganic fertilizer 75%

T_6 = Cowdung 100% + Inorganic fertilizer 50%

T_7 = Cowdung100% + Decoprima100%

T_8 = Inorganic fertilizer 100% + Decoprima 100%

T_9 = Inorganic fertilizer 75% + Decoprima 100%

T_{10} = Inorganic fertilizer 50% + Decoprima 100%

T_{11} = Cowdung 100% + Inorganic fertilizer 100% + Decoprima 100%

T_{12} = Cowdung 100% + Inorganic fertilizer 75% + Decoprima 100%

T_{13} = Cowdung 100% + Inorganic fertilizer 50% + Decoprima 100%

3.4.2 Experimental design and layout

The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. The area of the experimental plot was divided into three equal portions. Each portion was divided into 14 equal unit plots. The size of each unit plot 2 m × 1 m. Distances between plot to plot and replication to replication were 0.5 m and 1 m, respectively. The layout of the experiment field is presented in Appendix IV.

3.5 Test crop: BARI Sarisha-14

BARI Sarisha-14 was considered as plant material for the present study. It is a high yielding variety developed by the Bangladesh Agricultural Research Institute (BARI). BARI Sarisha-14, a short duration variety introducing plant height 75-85 cm, leaf light green, smooth, siliqua/plant 80-102, two chambers are present in pod but as like as four chambers. Seed/siliqua 22-26, seed color pink, 1000 seed weight 3.5-3.8 g, crop duration 75-80 days (BARI, 2016).

3.6 Land preparation

The plot selected for the experiment was opened in the last week of October, 2019 with a power tiller, and was exposed to the sun for a few days, after, which the land was harrowed, ploughed and cross-ploughed several times followed by laddering to obtain a good tilth. Weeds and stubble were removed and finally obtained a desirable tilth of soil for seed sowing. The land preparation was completed on 3rd November 2019. The individual plots were made by making ridges (20 cm high) around each plot to restrict lateral runoff of irrigation water.

3.7 Collection and preparation of initial soil sample

The initial soil samples were collected before land preparation from a 0-15 cm soil depth. The samples were collected by means of an auger from different location covering the whole experimental plot and mixed thoroughly to make a composite sample. After collection of soil samples, the plant roots, leaves etc. were picked up and removed. Then the samples were air-dried and sieved through a 10-mesh sieve and stored in a clean plastic container for physical and chemical analysis and subsequently analyzed from Soil Resources Development Institute (SRDI), Farmgate, Dhaka- 1215.

3.8 Organic fertilizer, inorganic fertilizers and bio-fertilizer application

Application of organic fertilizer, inorganic fertilizer, bio-fertilizer (decoprima) and fertilizer application was completed on 4th November, 2019 according to treatments.

Organic fertilizer: Cowdung was applied as a source of organic fertilizer at the rate of 10 t ha^{-1} as 100% cowdung.

Inorganic fertilizers: 100% doses of inorganic fertilizer per hectare basis were as follows considering the recommended doses of Fertilizer Recommendation Guide (FRG) (2018):

Nutrients	Doses ha^{-1}
Urea	**130 kg**
TSP	**38 kg**
MP	**75 kg**
Gypsum	**80 kg**
$ZnSO_4$	**3 kg**
Borax	**13 kg**

Half of urea along with full amount of other fertilizers were applied during final land preparation as basal dose and thoroughly mixed with soil. The remaining Urea was top dressed in two equal installments at 25 and 40 days after sowing (DAS), respectively.

Decoprima: It is a *Trichoderma* based bio-fertilizer as well as bio-pesticide consisted of *trichoderma* (4.35×10^5 cfu/g), geobacillus (1.94×10^6 cfu/g) and *Streptomyses* (1.16×10^6 cfu/g). It was applied at the rate of 1.5 kg ha^{-1}. At first 1.5 kg Decoprima was mixed with 15 liter of water for 24 hours. After that 750 liter of water was added with it for 1 hectare application (Indo-Bangla Agrotech Ltd., 2020).

3.9 Seed sowing

Seeds were sown continuously @ 7 kg ha^{-1} on 7 November 2019 by hand as uniform as possible in the 30 cm apart lines. A strip of the same crop was established around the experimental field as border crop. After sowing the seeds were covered with soil and slightly pressed by hand. Thinning operation was done to maintain uniform population density.

3.10 Intercultural Operation

After establishment of seedlings, various intercultural operations were accomplished for better growth and development of mustard.

3.10.1 Weeding and thinning

Different types of weeds were controlled manually for the first time and removed from the field on 22 November 2019. At the same time thinning was done. The final weeding and thinning were done after 25 days of sowing, on 2 December 2020. Care was taken to maintain uniform plant population per plot.

3.10.2 Irrigation

Irrigation was done at three times. The first irrigation was given in the field on 27 November 2020 at 20 days after sowing (DAS) through irrigation channel. The second irrigation was given at the stage of maximum flowering (35 DAS). The final irrigation was given at the stage of seed formation (50 DAS).

3.10.3 Pest management

The crop was infested with aphids (*Lipaphis erysimi*) at the time of siliquae filling. The insects were controlled successfully by spraying Malathion 50 EC @ 2 ml L^{-1} water. The insecticide was sprayed thrice, the first on 22 November 2019; the second on 23 December 2019 and the last on 12 January, 2020. The crop was kept under constant observations from sowing to harvesting.

3.11 General observations of experimental field

The plots under experiment were frequently observed to notice any change in plant growth and other characters were noted down immediately to make necessary measures.

3.12 Harvesting and post harvest operation

The crop was harvested plot wise when 90% siliquae were matured. After collecting sample plants, harvesting was done on 13 February 2020. The harvested plants were tied into bundles and carried to the threshing floor. The plants were sun dried by spreading the bundles on the threshing floor. The seeds were separated from the stover by beating the bundles with bamboo sticks. Seed and straw yield per plot were recorded after drying the plants in the sun followed by threshing and cleaning. At harvest, seed yield was recorded plot wise.

3.13 Data Collection and Recording

Experimental data were recorded from 40 DAS and continued until harvest. The followings data were recorded during the experiment:

3.13.1 Morphological parameters

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

3.13.2 Yield contributing parameters

1. Length of inflorescence (cm)
2. Number of silliquae inflorescence^{-1}
3. Number of filled silliquae plant^{-1}
4. Number of non-filled silliquae plant^{-1}
5. Length of silliquae (cm)
6. Number of seeds silliquae^{-1}

3.13.3 Yield parameters

1. Seed weight of 100 siliquae (g)
2. 1000 seed weight (g)
3. Seed weight plant^{-1} (g)
4. Seed yield plot^{-1} (g)
5. Seed yield ha^{-1} (kg)

3.14 Procedure of recording data

3.14.1 Morphological parameters

3.14.1.1 Plant height (cm)

Plant height was measured using a meter scale from the ground level to the apex of the plants in randomly selected 10 plants from specific rows of each plot at 40, 50, 60 and 70 DAS and the mean plant height (cm) was recorded.

3.14.1.2 Number of leaves plant^{-1}

Ten plants were selected randomly from the inner rows of each plot. Leaves plant^{-1} was counted from each plant sample at 40, 50, 60 and 70 DAS and then averaged.

3.14.1.3 Number of branches plant^{-1}

The branches plant^{-1} was counted from ten randomly sampled plants. It was done by counting total number of branches of all sampled plants at 40, 50, 60 and 70 DAS then the average data were recorded.

3.14.2 Yield contributing parameters

3.14.2.1 Length of inflorescence (cm)

Inflorescence length was measured by a meter scale. The measurement was taken from base to tip of the inflorescence from randomly selected 10 plants at 50, 60 and 70 DAS. Average length was taken was expressed in centimeter (cm).

3.14.2.2 Number of silliquae inflorescence^{-1}

Number of total siliquae and inflorescence of pre-selected ten plants at 50, 60 and 70 DAS from each unit plot was noted and the mean number was recorded. The number of siliquae inflorescence^{-1} was recorded by the following formula.

$$\text{No. of silliquae inflorescence}^{-1} = \frac{\text{Total number of siliquae}}{\text{Total number of inflorescence}}$$

3.14.2.3 Number of filled silliquae plant^{-1}

Number of total siliquae of pre-selected ten plants from each unit plot was noted. Among number of total siliquae from pre-selected ten plants, filled siliquae was separated. The number of filled siliquae plant^{-1} was calculated by the following formula.

$$\text{Number of filled silliquae plant}^{-1} = \frac{\text{Number of filled siliquae}}{\text{Number of plants}}$$

3.14.2.4 Number of non-filled silliquae plant^{-1}

Among number of total siliquae from pre-selected ten plants, non-filled siliquae was separated. The number of non-filled siliquae plant^{-1} was calculated by the following formula.

$$\text{Number of non-filled silliquae plant}^{-1} = \frac{\text{Number of non-filled siliquae}}{\text{Number of plants}}$$

3.14.2.5 Length of silliquae (cm)

The length of the siliquae was measured from the base to the tip of the 10 selected siliquae and then average then to have siliquae length. It was done using meter scale and expressed in centimeter (cm).

3.14.2.6 Number of seeds silliquae^{-1}

The number of seeds was counted from randomly taking 10 siliquae per treatment. The average value is calculated as the number of seeds siliquae^{-1}.

3.14.3 Yield parameters

3.14.3.1 Seed weight of 100 siliquae (g)

From preselected 10 plants from each plot, 100 siliquae were selected randomly. Seeds were separated and were weighed in gram (g).

3.14.3.2 Weight of 1000 seeds (g)

From the seed stock of each plot, 1000-seeeds were randomly collected and weighed by an electric balance. The 1000-seed weight was recorded in gram (g).

3.14.3.3 Seed weight plant^{-1} (g)

From preselected 10 plants from each plot, total seed were collected. Seeds were weighed and mean value was recorded in gram (g).

3.14.3.4 Seed yield plot^{-1} (g)

The crop was harvested plot wise the harvested plants were carried to the threshing floor. The plants were sun dried and seeds were separated. Per plot yields of seed were recorded after drying the plants in the sun followed by threshing and cleaning at 10% moisture level.

3.14.3.5 Seed yield ha^{-1} (kg)

Seed yield was calculated from well dried grains (at 10% moisture level) collected from the central area of inner rows of each plot (leaving boarder rows) and seed yield from 1 m^2 area was converted to kg ha^{-1}.

3.15 Statistical Analysis

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

CHAPTER IV

RESULTS AND DISCUSSION

The study was conducted to find out the influence of cowdung, inorganic fertilizers and bio-fertilizer on morphology, yield contributing characters and yield of mustard. Analyses of variance (ANOVA) of the data on different growth, yield parameters and yield of mustard are presented in Appendix V-XI. The results have been presented and discussed with the help of table and graphs and possible interpretations under the following headings:

4.1 Growth parameters

4.1.1 Plant height (cm)

Effect of different level of cowdung, inorganic fertilizers and bio-fertilizer (decoprima) treatments showed a statistically significant variation for plant height of mustard at different days after sowing (Figure 1 and Appendix V). Increased plant height was observed with increased cowdung, inorganic fertilizers and bio-fertilizer levels at all growth stages (Figure 1).

Results showed that at 40 DAS, the highest plant height (78.12 cm) was recorded from the treatment T_{11} (cowdung 100% + inorganic fertilizer 100% + decoprima 100%) which was statistically similar with T_{12} (cowdung 100% + inorganic fertilizer 75% + decoprima 100%) and T_{13} (cowdung 100% + inorganic fertilizer 50% + decoprima 100%) whereas the lowest plant height (50.87 cm) was observed from control treatment T_0 (control) which was significantly different from other treatments. Similar trend was observed in course of cropping duration increased.

At 50 DAS, the highest plant height (92.55 cm) was recorded from the treatment T_{11} (cowdung 100% + inorganic fertilizer 100% + decoprima 100%) followed by T_{12} (cowdung 100% + inorganic fertilizer 75% + decoprima

100%) and T_{13} (cowdung 100% + inorganic fertilizer 50% + decoprima 100%) while control treatment T_0 showed lowest plant height (70.24 cm).

Similarly, at 60 DAS, the highest plant height (94.91 cm) was achieved from the treatment T_{11} (cowdung 100% + inorganic fertilizer 100% + decoprima 100%) which was statistically identical with T_{12} (cowdung 100% + inorganic fertilizer 75% + decoprima 100%) whereas the lowest plant height (72.29 cm) was observed from control treatment T_0 (control) which was significantly different from other treatments.

Finally at 70 DAS, T_{11} (cowdung 100% + inorganic fertilizer 100% + decoprima 100%) recorded the highest plant height (97.91 cm) which was statistically identical with T_{12} (cowdung 100% + inorganic fertilizer 75% + decoprima 100%) followed by T_4 (cowdung 100% + Inorganic fertilizer 100%), T_8 (inorganic fertilizer 100% + decoprima 100%) and T_{13} (cowdung 100% + inorganic fertilizer 50% + decoprima 100%) while control treatment T_0 showed lowest plant height (73.43 cm) which was statistically similar with T_1 (cowdung 100%).

As a result in brief, the highest plants height at 40, 50, 60 and 70 DAS (78.12, 92.55, 94.91 and 97.81 cm, respectively) were found from the treatment T_{11} (cowdung 100% + inorganic fertilizer 100% + decoprima 100%) whereas the lowest plants height at 40, 50, 60 and 70 DAS (80.87, 70.24, 72.29 and 73.43 cm, respectively) were found from the control treatment T_0.

It is evident that decoprima is a *Trichoderma* based bio-fertilizer and *Trichoderma* has a great influence on plant growth. Treatment T_{11} (cowdung 100% + inorganic fertilizer 100% + decoprima 100%) that fertilizer combination may play a role in the control of cell division and elongation which is essential for the plant height. Mahato *et al*. (2018) obtained 4.6% increased plant height in wheat using *Trichoderma viride* in association with inorganic (NPK) organic (FYM) fertilizers over control. The result obtained from the present study was similar with findings of Kumar *et al*. (2018) and they reported that the highest plant height was recorded with application of 50% RDF+ FYM 6 t/ha + Vermicompost 2 t/ha + bio-fertilizer than the rest of the treatments. Similar result was also observed by Khambalkar *et al.* (2017) who recorded higher plant height from combined application of organic and inorganic fertilizers with bio-fertilizer compared to non bio-fertilizer treatments. Supported results were also observed by Saha *et al.* (2015) and Rundala *et al.* (2013).

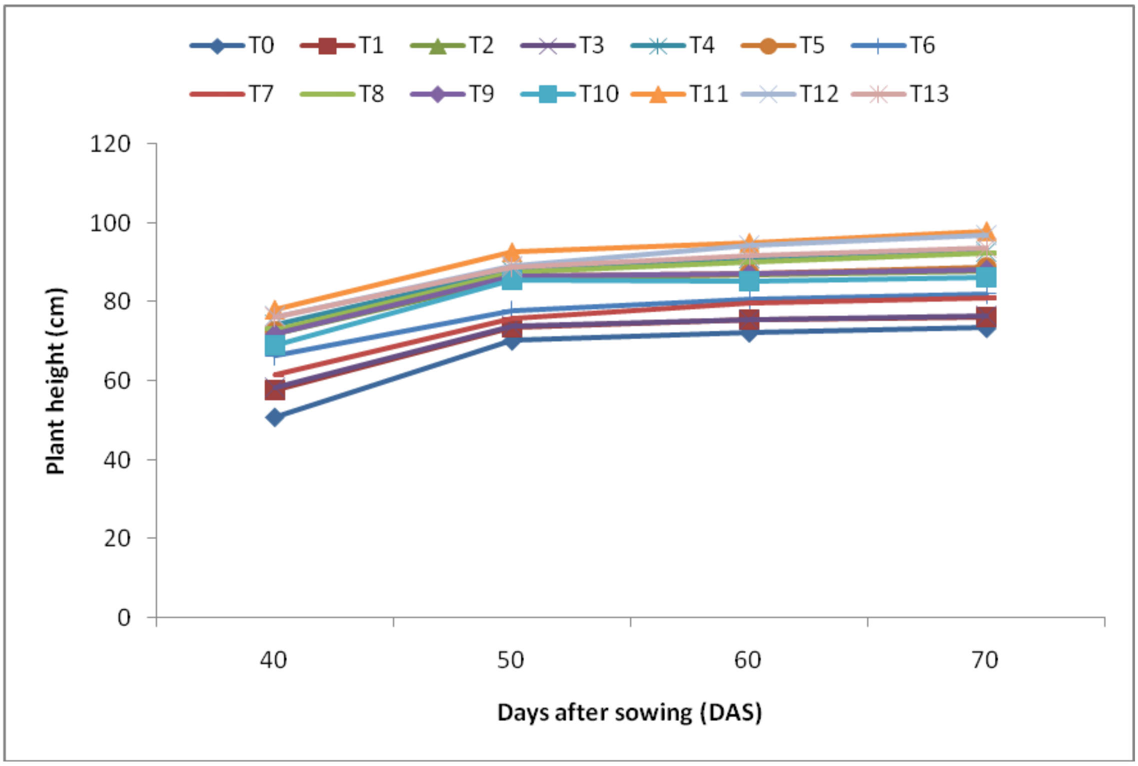

Figure 1. Plant height of mustard as influenced by cowdung, inorganic fertilizers and bio-fertilizer (LSD0.05 = 2.683, 2.629, 2.659 and 2.829 at 40, 50, 60 and 70 DAS, respectively)

T_0 = Control, T_1 = Cowdung 100%, T_2 = Inorganic fertilizer 100%, T_3 = Decoprima 100%, T_4 = Cowdung 100% + Inorganic fertilizer 100%, T_5 = Cowdung 100% + Inorganic fertilizer 75%, T_6 = Cowdung 100% + Inorganic fertilizer 50%, T_7 = Cowdung100% + Decoprima100%, T_8 = Inorganic fertilizer 100% + Decoprima 100%, T_9 = Inorganic fertilizer 75% + Decoprima 100%, T_{10} = Inorganic fertilizer 50% + Decoprima 100%, T_{11} = Cowdung 100% + Inorganic fertilizer 100% + Decoprima 100%, T_{12} = Cowdung 100% + Inorganic fertilizer 75% + Decoprima 100%, T_{13} = Cowdung 100% + Inorganic fertilizer 50% + Decoprima 100%

4.1.2 Number of leaves plant^{-1}

Data recorded on number of leaves plant^{-1} of mustard presented in Figure 2 influenced by different level of cowdung, inorganic fertilizers and bio-fertilizer treatments varied significantly at different days after sowing (Appendix VI). Results revealed that the higher number of leaves plant^{-1} was found with higher amount of cowdung, inorganic fertilizers and bio-fertilizer doses at all growth stages (Figure 2).

At 40 DAS, the treatment T_{11} (cowdung 100% + inorganic fertilizer 100% + decoprima 100%) gave the highest number of leaves plant^{-1} (21.47) which was statistically identical with T_{12} (cowdung 100% + inorganic fertilizer 75% + decoprima 100%) and T_{13} (cowdung 100% + inorganic fertilizer 50% + decoprima 100%) whereas the lowest number of leaves plant^{-1} (13.33) was observed from control treatment T_0 (control) and that was statistically similar with T_1 (cowdung 100%), T_3 (decoprima 100%) and T_7 (cowdung100% + Decoprima100%). Likewise, at 50, 60 and 70 DAS, similar inclination was found with the advancement of cropping period.

At 50 DAS, the highest number of leaves plant^{-1} (37.13) was recorded from the treatment T_{11} (cowdung 100% + inorganic fertilizer 100% + decoprima 100%) which was statistically identical with T_{12} (cowdung 100% + inorganic fertilizer 75% + decoprima 100%) and control treatment T_0 showed lowest number of leaves plant^{-1} (25.20) that was significantly different from other treatments.

Similarly, at 60 DAS, the highest number of leaves plant^{-1} (44.13) was achieved from the treatment T_{11} (cowdung 100% + inorganic fertilizer 100% + decoprima 100%) followed by T_{12} (cowdung 100% + inorganic fertilizer 75% + decoprima 100%) and T_{13} (cowdung 100% + inorganic fertilizer 50% + decoprima 100%) whereas the lowest number of leaves plant^{-1} (30.13) was observed from control treatment T_0 (control) which was significantly different from other treatments.

Finally at 70 DAS, T_{11} (cowdung 100% + inorganic fertilizer 100% + decoprima 100%) registered the highest number of leaves plant^{-1} (45.80) which was significantly different from other treatments followed by T_{12} (cowdung 100% + inorganic fertilizer 75% + decoprima 100%) and T_{13} (cowdung 100% + inorganic fertilizer 50% + decoprima 100%) while control treatment T_0 showed lowest number of leaves plant^{-1} (30.87) which was significantly different from other treatments.

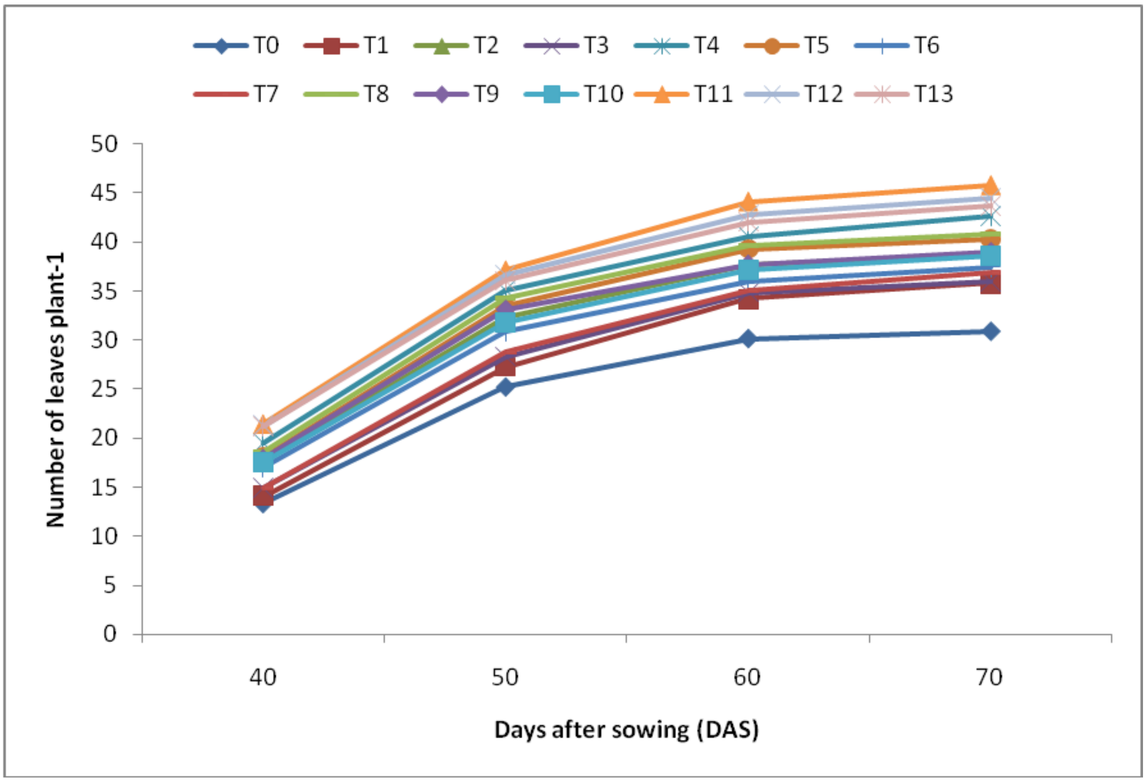

Figure 2. Number of leaves plant^{-1} of mustard as influenced by cowdung, inorganic fertilizers and bio-fertilizer (LSD0.05 = 2.26, 0.554, 0.894 and 0.769 at 40, 50, 60 and 70 DAS, respectively)

T_0 = Control, T_1 = Cowdung 100%, T_2 = Inorganic fertilizer 100%, T_3 = Decoprima 100%, T_4 = Cowdung 100% + Inorganic fertilizer 100%, T_5 = Cowdung 100% + Inorganic fertilizer 75%, T_6 = Cowdung 100% + Inorganic fertilizer 50%, T_7 = Cowdung100% + Decoprima100%, T_8 = Inorganic fertilizer 100% + Decoprima 100%, T_9 = Inorganic fertilizer 75% + Decoprima 100%, T_{10} = Inorganic fertilizer 50% + Decoprima 100%, T_{11} = Cowdung 100% + Inorganic fertilizer 100% + Decoprima 100%, T_{12} = Cowdung 100% + Inorganic fertilizer 75% + Decoprima 100%, T_{13} = Cowdung 100% + Inorganic fertilizer 50% + Decoprima 100%

As a result in brief, the highest number of leaves plant^{-1} at 40, 50, 60 and 70 DAS (21.47, 37.13, 44.13 and 45.80, respectively) was found from the treatment T_{11} (cowdung 100% + inorganic fertilizer 100% + decoprima 100%) whereas the lowest number of leaves plant^{-1} at 40, 50, 60 and 70 DAS (13.33, 25.20, 30.13 and 30.87, respectively) was found from the control treatment T_0.

Decoprima which is *Trichoderma* enriched biofertilizer that have significant role in increased photosynthetic rate, chlorophyll content and stomatal conductance which might be resulted highest number of leaves plant^{-1} from the treatment T_{11}. Mondal and Wahhab (2001) obtained similar result with the present study and reported that biofertilizer contributed to higher leaf number in mustard compared to non application biofertilizer effect which was also supported by Abdul *et al*. (2004). Therefore, alltogether it suggest that combined application of organic, inorganic and bio-fertilizer promoted the number of leaves of mustard.

4.1.3 Number of branches plant^{-1}

Number of branches plant^{-1} of mustard at different growth stages varied significantly due the effect of different level of cowdung, inorganic fertilizers and bio-fertilizer treatments (Appendix VII and Figure 3). It was observed that the higher levels of dung, inorganic fertilizers and bio-fertilizer showed higher number of branches plant^{-1} at all growth stages (Figure 3).

Results exhibited that at 40 DAS, the highest number of branches plant^{-1} (7.73) was recorded from the treatment T_{11} (cowdung 100% + inorganic fertilizer 100% + decoprima 100%) which was significantly same with T_4 (cowdung 100% + Inorganic fertilizer 100%), T_{12} (cowdung 100% + inorganic fertilizer 75% + decoprima 100%) and T_{13} (cowdung 100% + inorganic fertilizer 50% + decoprima 100%) whereas the lowest number of branches plant^{-1} (3.40) was observed from control treatment T_0 (control) which was significantly same with T_1 (cowdung 100%) and T_3 (decoprima 100%). Similar sequence was also observed for number of branches plant^{-1} at 50, 60 and 70 DAS.

At 50 DAS, the highest number of branches plant^{-1} (9.07) was recorded from the treatment T_{11} which was statistically identical with T_{12} followed by T_4

while control treatment T_0 showed lowest number of branches plant^{-1} (5.33). Similarly, at 60 DAS, the treatment T_{11} showed the highest number of branches plant^{-1} (9.20) followed by T_4 and T_{12} whereas the lowest number of branches plant^{-1} (5.60) was observed from T_0 (control) treatment which was statistically similar with T_1 (cowdung 100%).

Finally at 70 DAS, T_{11} listed the highest number of branches plant^{-1} (9.33) which was significantly different from other treatments followed by T_4 and T_{12} while control treatment T_0 showed lowest number of branches plant^{-1} (5.77) which was statistically similar with T_1.

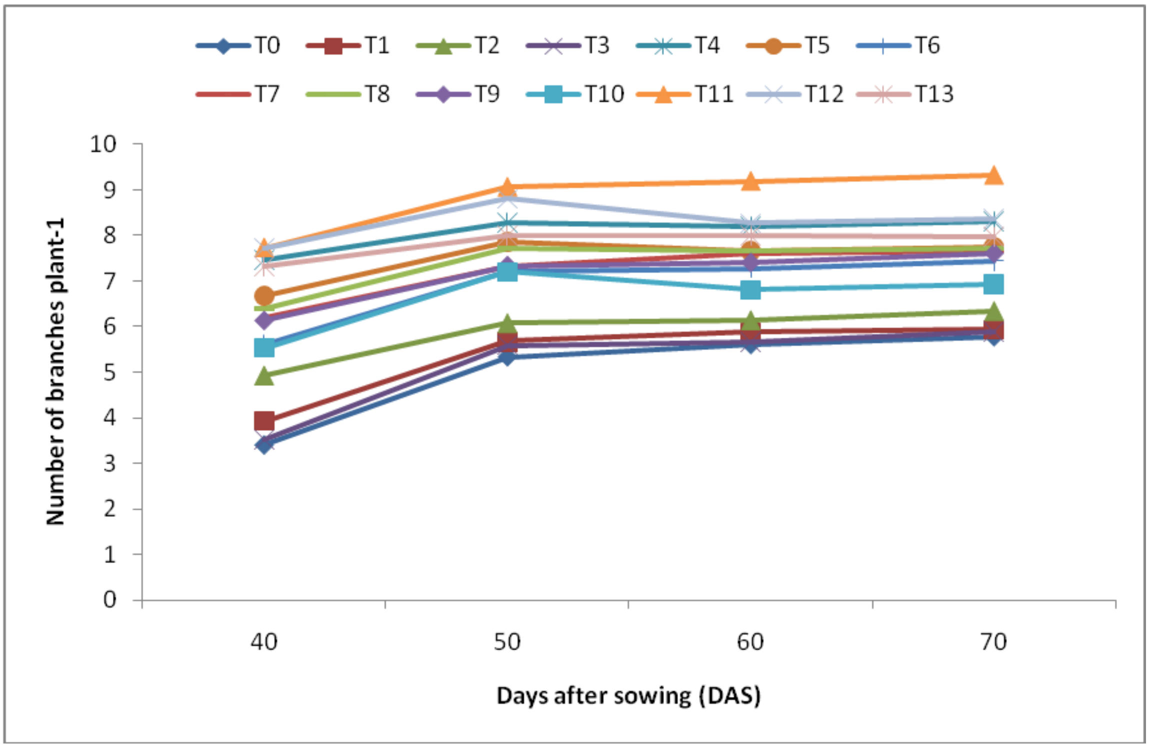

Figure 3. Number of branches plant^{-1} of mustard as influenced by cowdung, inorganic fertilizers and bio-fertilizer (LSD0.05 = 0.541, 0.281, 0.364 and 0.408 at 40, 50, 60 and 70 DAS, respectively)

T_0 = Control, T_1 = Cowdung 100%, T_2 = Inorganic fertilizer 100%, T_3 = Decoprima 100%, T_4 = Cowdung 100% + Inorganic fertilizer 100%, T_5 = Cowdung 100% + Inorganic fertilizer 75%, T_6 = Cowdung 100% + Inorganic fertilizer 50%, T_7 = Cowdung100% + Decoprima100%, T_8 = Inorganic fertilizer 100% + Decoprima 100%, T_9 = Inorganic fertilizer 75% + Decoprima 100%, T_{10} = Inorganic fertilizer 50% + Decoprima 100%, T_{11} = Cowdung 100% + Inorganic fertilizer 100% + Decoprima 100%, T_{12} = Cowdung 100% + Inorganic fertilizer 75% + Decoprima 100%, T_{13} = Cowdung 100% + Inorganic fertilizer 50% + Decoprima 100%

As a result in brief, the highest number of branches plant^{-1} at 40, 50, 60 and 70 DAS (7.73, 9.07, 9.20 and 9.33, respectively) was found from the treatment T_{11} (cowdung 100% + inorganic fertilizer 100% + decoprima 100%) whereas the lowest number of branches plant^{-1} at 40, 50, 60 and 70 DAS (3.40, 5.33, 5.60 and 5.77, respectively) was found from the control treatment T_0. Doni *et al.* (2017) reported increased photosynthetic rate, chlorophyll content, stomatal conductance etc. with the application of *Trichoderma* enriched biofertilizer; that is why the treatment T_{11} might have given highest number of branches plant^{-1}. Beenish *et al.* (2018) and Rundala *et al.* (2013) also obtained higher number of branches plant^{-1} with biofertilizer in association with organic and inorganic fertilizer compared to control which supported the present findings. Therefore, alltogether it suggests that combined application of organic, inorganic and bio-fertilizer promoted the number of branches of mustard.

4.2 Yield contributing parameters

4.2.1 Length of inflorescence (cm)

Significant influence was recorded on length of inflorescence of mustard pressured by different level of cowdung, inorganic fertilizers and bio-fertilizer treatments at different cropping duration (Table 1 and Appendix VIII).

Results revealed that at 50 DAS, the highest length of inflorescence (37.17 cm) was recorded from the treatment T_{11} (cowdung 100% + inorganic fertilizer 100% + decoprima 100%) which was statistically similar with T_{12} (cowdung 100% + inorganic fertilizer 75% + decoprima 100%) whereas the lowest length of inflorescence (32.02 cm) was observed from control treatment T_0 (control) which was statistically identical with T_1 (cowdung 100%), T_2 (inorganic fertilizer 100%) and T_3 (decoprima 100%).

Similarly, at 60 DAS, the highest length of inflorescence (42.58 cm) was achieved from the treatment T_{11} (cowdung 100% + inorganic fertilizer 100% + decoprima 100%) followed by T_4 (cowdung 100% + Inorganic fertilizer 100%)

and T_{12} (cowdung 100% + inorganic fertilizer 75% + decoprima 100%) whereas the lowest length of inflorescence (33.03 cm) was observed from control treatment T_0 (control) which was statistically similar with T_1 (cowdung 100%), T_2 (inorganic fertilizer 100%) and T_3 (decoprima 100%).

Table 1. Inflorescence length of mustard as influenced by cowdung, inorganic fertilizers and bio-fertilizer (decoprima)

Treatments	Length of inflorescence (cm)		
	50 DAS	60 DAS	70 DAS
T_0	32.02 e	33.03 g	34.02 g
T_1	32.71 e	33.59 fg	34.58 fg
T_2	32.80 e	33.96 efg	34.62 fg
T_3	32.70 e	33.05 g	34.04 g
T_4	35.39 bc	38.77 b	39.56 a
T_5	35.20 bc	37.58 c	38.59 bc
T_6	33.09 de	34.63 de	35.23 ef
T_7	34.45 cd	35.41 d	36.41 d
T_8	34.87 c	37.35 c	38.29 c
T_9	33.15 de	34.93 de	35.89 de
T_{10}	32.87 de	34.23 ef	35.15 ef
T_{11}	37.17 a	42.58 a	40.22 a
T_{12}	36.79 ab	39.24 b	39.76 a
T_{13}	35.32 bc	38.33 bc	39.31 ab
LSD0.05	1.484	0.9405	0.9100
CV(%)	6.52	8.26	7.44

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

T_0 = Control, T_1 = Cowdung 100%, T_2 = Inorganic fertilizer 100%, T_3 = Decoprima 100%, T_4 = Cowdung 100% + Inorganic fertilizer 100%, T_5 = Cowdung 100% + Inorganic fertilizer 75%, T_6 = Cowdung 100% + Inorganic fertilizer 50%, T_7 = Cowdung100% + Decoprima100%, T_8 = Inorganic fertilizer 100% + Decoprima 100%, T_9 = Inorganic fertilizer 75% + Decoprima 100%, T_{10} = Inorganic fertilizer 50% + Decoprima 100%, T_{11} = Cowdung 100% + Inorganic fertilizer 100% + Decoprima 100%, T_{12} = Cowdung 100% + Inorganic fertilizer 75% + Decoprima 100%, T_{13} = Cowdung 100% + Inorganic fertilizer 50% + Decoprima 100%

Finally at 70 DAS, T_{11} (cowdung 100% + inorganic fertilizer 100% + decoprima 100%) gave the highest length of inflorescence (40.22 cm) which was statistically identical with T_4 (cowdung 100% + Inorganic fertilizer 100%)

and T_{12} (cowdung 100% + inorganic fertilizer 75% + decoprima 100%) followed by T_{13} (cowdung 100% + inorganic fertilizer 50% + decoprima 100%) while control treatment T_0 showed lowest length of inflorescence (34.02 cm) which was statistically similar with T_3 (decoprima 100%), T_1 (cowdung 100%) and T_2 (inorganic fertilizer 100%).

As a result in brief, the highest length of inflorescence at 50, 60 and 70 DAS (37.17, 42.58 and 40.22 cm, respectively) was found from the treatment T_{11} (cowdung 100% + inorganic fertilizer 100% + decoprima 100%) whereas the lowest length of inflorescence at 50, 60 and 70 DAS (32.02, 33.03 and 34.02 cm, respectively) was found from the control treatment T_0. These results are consistent with other morphological parameters such as plant height (Figure 1), number of leaves plant^{-1} (Figure 2) and number of branches plant^{-1} (Figure 3) of this experiment. Under the present study, T_{11} gave the highest length of inflorescence which might be due to the cause of the presence of *Trichoderma* enriched biofertilizer in this treatment which have significant contribution on increased plant height, photosynthetic rate, chlorophyll content, stomatal conductance etc. (Doni *et al*., 2017).

4.2.2 Number of silliquae inflorescence^{-1}

Data presented in Table 2 on number of silliquae inflorescence^{-1} at different cropping duration was significantly influenced due to the effect of different level of cowdung, inorganic fertilizers and bio-fertilizer treatments (Appendix IX).

Results indicated that at 50 DAS, the highest number of silliquae inflorescence^{-1} (29.53) was recorded from the treatment T_{11} (cowdung 100% + inorganic fertilizer 100% + decoprima 100%) which was statistically similar with T_{12} (cowdung 100% + inorganic fertilizer 75% + decoprima 100%) while control treatment T_0 showed lowest number of silliquae inflorescence^{-1} (15.33) which was significantly different from other treatments.

Similarly, at 60 DAS, the treatment T_{11} (cowdung 100% + inorganic fertilizer 100% + decoprima 100%) showed the highest number of silliquae inflorescence^{-1} (39.40) which was statistically identical with T_{12} (cowdung 100% + inorganic fertilizer 75% + decoprima 100%) followed by T_4 (cowdung100% + inorganic fertilizer 100%) whereas the lowest number of silliquae inflorescence^{-1} (21.27) was observed from control treatment T_0 (control).

Table 2. Number of silliquae inflorescence^{-1} length of mustard as influenced by cowdung, inorganic fertilizers and bio-fertilizer (decoprima)

Treatments	Number of silliquae inflorescence^{-1}		
	50 DAS	60 DAS	70 DAS
T_0	15.33 h	21.27 h	23.50 g
T_1	23.87 f	26.93 fg	27.87 ef
T_2	23.87 f	28.60 ef	29.40 de
T_3	18.80 g	26.07 g	26.73 f
T_4	28.67 bc	34.73 b	35.47 b
T_5	28.07 cd	33.90 bc	34.87 b
T_6	24.47 f	30.07 de	30.57 cd
T_7	27.07 e	31.00 de	31.90 cd
T_8	27.33 de	32.27 cd	33.00 bc
T_9	24.60 f	30.67 de	31.73 cd
T_{10}	24.47 f	29.20 ef	30.00 de
T_{11}	29.53 a	39.40 a	40.73 a
T_{12}	29.00 ab	38.80 a	39.83 a
T_{13}	28.13 cd	34.00 bc	34.90 b
LSD0.05	0.8066	2.225	2.395
CV(%)	6.72	6.96	8.24

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

T_0 = Control, T_1 = Cowdung 100%, T_2 = Inorganic fertilizer 100%, T_3 = Decoprima 100%, T_4 = Cowdung 100% + Inorganic fertilizer 100%, T_5 = Cowdung 100% + Inorganic fertilizer 75%, T_6 = Cowdung 100% + Inorganic fertilizer 50%, T_7 = Cowdung100% + Decoprima100%, T_8 = Inorganic fertilizer 100% + Decoprima 100%, T_9 = Inorganic fertilizer 75% + Decoprima 100%, T_{10} = Inorganic fertilizer 50% + Decoprima 100%, T_{11} = Cowdung 100% + Inorganic fertilizer 100% + Decoprima 100%, T_{12} = Cowdung 100% + Inorganic fertilizer 75% + Decoprima 100%, T_{13} = Cowdung 100% + Inorganic fertilizer 50% + Decoprima 100%

Finally at 70 DAS, T_{11} (cowdung 100% + inorganic fertilizer 100% + decoprima 100%) also recorded the highest number of silliquae inflorescence^{-1} (40.73) which was statistically identical with T_{12} (cowdung 100% + inorganic fertilizer 75% + decoprima 100%) followed by T_4 (cowdung 100% + inorganic fertilizer 100%), T_5 (cowdung 100% + inorganic fertilizer 75%) and T_{13} (cowdung 100% + inorganic fertilizer 50% + decoprima 100%) while control treatment T_0 showed lowest number of silliquae inflorescence^{-1} (23.50) that was significantly different from other treatments.

As a result in brief, T_{11} (cowdung 100% + inorganic fertilizer 100% + decoprima 100%) gave the highest number of silliquae inflorescence^{-1} at 50, 60 and 70 DAS (29.53, 39.40 and 40.73, respectively) whereas control treatment T_0 gave the lowest number of silliquae inflorescence^{-1} at 50, 60 and 70 DAS (13.33, 21.27 and 23.50, respectively). These results are also consistent with the results of length inflorescence (Table 1) of this study.

Application of *Trichoderma* enriched biofertilizer, organic manure have significant positive effective on soil fertility and productivity on yield contributing parameters and yield (Kumar *et al*., 2018) which might be the cause of higher number of silliquae inflorescence^{-1} in treatment T_{11}.

4.2.3 Number of filled silliquae plant^{-1}

Effect of different level of cowdung, inorganic fertilizers and bio-fertilizer treatments showed a statistically significant variation for number of filled silliquae plant^{-1} of mustard (Table 3 and Appendix X). Results revealed that the highest number of filled silliquae plant^{-1} (98.73) was recorded from the treatment T_{11} (cowdung 100% + inorganic fertilizer 100% + decoprima 100%) that was statistically identical with T_{12} (cowdung 100% + inorganic fertilizer 75% + decoprima 100%) followed by T_4 (cowdung 100% + Inorganic fertilizer 100%), T_5 (cowdung 100% + inorganic fertilizer 75%) and T_{13} (cowdung 100% + inorganic fertilizer 50% + decoprima 100%). On the other hand, the lowest number of filled silliquae plant^{-1} (43.80) was observed from T_0 (control) treatment which was significantly different from other treatments. It is evident that biofertilizer and organic fertilizer help to increase dry matter production in mustard (Gudadhe *et al.,* 2005 and Singh *et al.,* 2014) which might be resulted higher number of filled silliquae plant^{-1} in T_{11}, under the present study. Supported result was also observed by Beenish *et al*. (2018), Kumar *et al*. (2018), Rundala *et al.* (2013) and Singh *et al*. (2006). Kumar *et al*. (2018) recorded that the highest number of siliqua plant^{-1} from the application of NPK-RDF+ FYM + Vermicompost + bio-fertilizer over control which was supported by Beenish *et al*. (2018), Rundala *et al.* (2013) and Singh *et al*. (2006).

4.2.4 Number of non-filled silliquae plant^{-1}

Data recorded on number of non-filled of mustard presented in Table 3 influenced by different level of cowdung, inorganic fertilizers and bio-fertilizer treatments varied significantly (Appendix X). Results showed that the lowest number of non-filled silliquae plant^{-1} (4.40) was recorded from the treatment T_4 (cowdung 100% + Inorganic fertilizer 100%) that was significantly similar to T_5 (Cowdung 100% + Inorganic fertilizer 75%). On the other hand, the highest number of non-filled silliquae plant^{-1} (8.33) was observed from control treatment T_0 which was significantly different from other treatments followed by T_1 (cowdung 100%), T_2 (inorganic fertilizer 100%) and T_3 (decoprima 100%), T_{12} (cowdung 100% + inorganic fertilizer 75% + decoprima 100%) and T_{13} (cowdung 100% + inorganic fertilizer 50% + decoprima 100%). Under the present study, control treatment included no nutrient application, as a result of lower dry matter content in control treatment or in lower biofertilizer and organic manure treatment (Gudadhe *et al.,* 2005) which might be the cause of higher non-filled silliquae plant^{-1} in control treatment.

4.2.5 Length of silliquae (cm)

Statistically insignificant result on length of silliquae of mustard was found due the effect of different level of cowdung, inorganic fertilizers and bio-fertilizer treatments (Table 3 and Appendix X). However, the highest length of silliquae (4.91 cm) was recorded from the treatment T_{11} (cowdung 100% + inorganic fertilizer 100% + decoprima 100%) followed by T_{12} (cowdung 100% + inorganic fertilizer 75% + decoprima 100%) whereas the lowest length of silliquae (3.27 cm) was observed from control treatment T_0. Similar result was also reported by Kumar *et al*. (2018) and found that the highest siliqua^{-1} length was recorded from the application of NPK-RDF + FYM + Vermicompost + bio-fertilizer over control.

4.2.6 Number of seeds silliquae^{-1}

Significant influence was recorded on number of seeds silliquae^{-1} of mustard pressured by different level of cowdung, inorganic fertilizers and bio-fertilizer treatments (Table 3 and Appendix X). Results exhibited that the treatment T_{11} (cowdung 100% + inorganic fertilizer 100% + decoprima 100%) showed the highest number of seeds silliquae^{-1} (37.93) that was statistically identical with T_{12} (cowdung 100% + inorganic fertilizer 75% + decoprima 100%) followed by T_4 (cowdung 100% + Inorganic fertilizer 100%) and T_{13} (cowdung 100% + inorganic fertilizer 50% + decoprima 100%). The lowest number of seeds silliquae^{-1} (26.87) was observed from control treatment T_0 which was significantly different from other treatments.

Generally organic manure helps to increase dry matter production in plants (Thaneshwar *et al.,* 2017; Lepcha *et al.,* 2015) while, biofertilizer also has a significant contribution to increase dry matter production in plants (Rundala *et al.,* 2013; Tripathi *et al.*, 2011) which might be contributed to produce higher number of seeds silliquae^{-1}. Combined application of biofertilizer and organic manure in T_{11} might be the possible reason for higher production of seeds silliquae^{-1}. Beenish *et al.* (2018) also found higher number of seeds silliquae^{-1} from biofertilizer treatment in association with organic and inorganic fertilizers which was also supported by Kumar *et al*. (2018), Rundala *et al.* (2013) and Tripathi *et al.* (2011). Kumar *et al*. (2018) recorded that the highest number of seeds siliqua^{-1} from the application of NPK-RDF+ FYM + Vermicompost + bio-fertilizer over control.

Table 3. Yield contributing parameters of mustard regarding number of filled silliquae plant^{-1}, number of non-filled silliquae plant^{-1}, length of silliquae and number of seeds silliquae^{-1} as influenced by cowdung, inorganic fertilizers and bio-fertilizer (decoprima)

Treatments	Yield contributing parameters			
	Number of filled silliquae plant^{-1}	Number of non-filled silliquae plant^{-1}	Length of silliquae (cm)	Number of seeds silliquae^{-1}
T_0	43.80 h	8.33 a	3.27	26.87 h
T_1	56.20 f	6.60 b	4.45	30.67 f
T_2	60.67 e	6.53 b	4.47	31.27 ef
T_3	51.80 g	6.87 b	4.31	29.00 g
T_4	83.70 b	4.40 g	4.78	35.40 b
T_5	82.27 b	4.60 fg	4.59	34.80 bc
T_6	63.07 e	5.80 cd	4.53	32.87 de
T_7	68.07 d	5.13 e	4.55	33.13 d
T_8	75.07 c	5.00 ef	4.58	33.47 cd
T_9	65.07 de	5.40 de	4.53	33.07 d
T_{10}	62.00 e	6.00 c	4.50	32.73 de
T_{11}	98.73 a	6.10 c	4.91	37.93 a
T_{12}	98.40 a	6.47 b	4.83	37.23 a
T_{13}	83.20 b	6.50 b	4.69	35.13 b
LSD0.05	4.203	0.431	1.716^{NS}	1.574
CV(%)	5.98	7.90	4.70	6.06

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

T_0 = Control, T_1 = Cowdung 100%, T_2 = Inorganic fertilizer 100%, T_3 = Decoprima 100%, T_4 = Cowdung 100% + Inorganic fertilizer 100%, T_5 = Cowdung 100% + Inorganic fertilizer 75%, T_6 = Cowdung 100% + Inorganic fertilizer 50%, T_7 = Cowdung100% + Decoprima100%, T_8 = Inorganic fertilizer 100% + Decoprima 100%, T_9 = Inorganic fertilizer 75% + Decoprima 100%, T_{10} = Inorganic fertilizer 50% + Decoprima 100%, T_{11} = Cowdung 100% + Inorganic fertilizer 100% + Decoprima 100%, T_{12} = Cowdung 100% + Inorganic fertilizer 75% + Decoprima 100%, T_{13} = Cowdung 100% + Inorganic fertilizer 50% + Decoprima 100%

4.3 Yield parameters

4.3.1 Seed weight of 100 siliquae (g)

Effect of different level of cowdung, inorganic fertilizers and bio-fertilizer treatments showed a statistically significant variation for seed weight of 100 siliquae of mustard (Table 4 and Appendix XI). Results indicated that the highest seed weight of 100 siliquae (13.50 g) was recorded from the treatment T_{11} (cowdung 100% + inorganic fertilizer 100% + decoprima 100%) that was statistically identical with T_{12} (cowdung 100% + inorganic fertilizer 75% + decoprima 100%) followed by T_4 (cowdung 100% + Inorganic fertilizer 100%) and T_{13} (cowdung 100% + inorganic fertilizer 50% + decoprima 100%). On the other hand, the lowest seed weight of 100 siliquae (9.33 g) was observed from T_0 (control) treatment which was significantly different from other treatments. The highest result from the treatment T_{11} might be due to the cause of *Trichoderma* enriched biofertilizer and organic manure which helps to increase chlorophyll content, photosynthetic rate and dry matter production. Similar result was observed by Haque *et al*. (2010), Haque *et al*. (2012), Beenish *et al*. (2018) and Rundala *et al.* (2013).

4.3.2 Thousand (1000) seed weight (g)

Weight of 1000 seeds of mustard was not varied significantly due the effect of different level of cowdung, inorganic fertilizers and bio-fertilizer treatments (Table 4 and Appendix XI). However, the highest 1000 seed weight (4.34 g) was recorded from the treatment T_{11} (cowdung 100% + inorganic fertilizer 100% + decoprima 100%) whereas the lowest 1000 seed weight (3.41 g) was observed from control treatment T_0. This result is in consistent with the result of seed weight of 100 siliquae. In treatment T_{11} that was combined with organic manure, inorganic fertilizer and *Trichoderma* enriched biofertilizer which help to increase seed weight of 100 siliquae that might be resulted higher 1000 seed weight with this treatment. Tripathi *et al.* (2011) and Singh *et al*. (2006) also found higher 1000 seed weight with the application of FYM + biofertilizers over the control.

4.3.3 Seed weight plant^{-1} (g)

Data recorded on seed weight plant^{-1} of mustard presented in Table 4 influenced by different level of cowdung, inorganic fertilizers and bio-fertilizer treatments varied significantly (Appendix XI). Results revealed that the highest seed weight plant^{-1} (9.60 g) was recorded from the treatment T_{11} (cowdung 100% + inorganic fertilizer 100% + decoprima 100%) followed by T_4 (cowdung 100% + Inorganic fertilizer 100%) and T_{12} (cowdung 100% + inorganic fertilizer 75% + decoprima 100%). On the other hand, the lowest seed weight plant^{-1} (4.57 g) was observed from control treatment T_0 which was significantly different from other treatments.

Under the present study, the treatment T_{11} showed the best performance in producing number of silliquae inflorescence^{-1}, length of inflorescence, number of seeds silliquae^{-1}, number of filled silliquae plant^{-1}, seed weight of 100 siliquae and 1000 seed weight which resulted highest seed yield plant^{-1} with this treatment. Similar result was observed by Haque *et al.* (2010) who achieved higher seed weight plant^{-1} with *Trichoderma*-enriched biofertilizer in combination with organic and inorganic fertilizer. Similar result was also observed by Haque *et al*. (2012), Beenish *et al*. (2018) and Rundala *et al.* (2013) which supported the present study.

4.3.4 Seed yield plot^{-1} (g)

Significant influence was recorded on seed yield plot^{-1} of mustard pressured by different level of cowdung, inorganic fertilizers and bio-fertilizer treatments (Table 4 and Appendix XI). Results revealed that the treatment T_{11} (cowdung 100% + inorganic fertilizer 100% + decoprima 100%) gave the highest seed yield plot^{-1} (360.70 g) which was statistically identical with T_{12} (cowdung 100% + inorganic fertilizer 75% + decoprima 100%) followed by T_4 (cowdung 100% + Inorganic fertilizer 100%) and T_{13} (cowdung 100% + inorganic fertilizer 50% + decoprima 100%) whereas the lowest seed yield plot^{-1} (138.00 g) was recorded from T_0 (control) treatment which was significantly different from other treatments. This are consistent with the previous results of different parameters includes plant height (Figure 1), number of leaves plant^{-1} (Figure 2), number of branches plant^{-1} (Figure 3), length of inflorescence (Table 1), number of silliquae inflorescence^{-1} (Table 2), number of filled silliquae plant^{-1} (Table 3), length of silliquae (Table 3), number of seeds silliquae^{-1} (Table 3), seed weight of 100 siliquae (Table 4), 1000 seed weight (Table 4) and seed weight plant^{-1} (Table 4). Similar result was also observed by Haque *et al.* (2012), Haque *et al.* (2010), Kumar *et al.* (2018), Beenish *et al.* (2018) and Rundala *et al.* (2013) which supported the present study. Therefore, it suggests that combined application of organic, inorganic and bio-fertilizer contribute to increase the seed yield of mustard than single application of cowdung or inorganic fertilizer or bio-fertilizer.

Table 4. Yield parameters of mustard as influenced by cowdung, inorganic fertilizers and bio-fertilizer (decoprima)

Treatments	Yield parameters				
	Seed weight of 100 siliquae (g)	1000 seed weight (g)	Seed weight plant^{-1} (g)	Seed yield plot^{-1} (g)	Seed yield ha^{-1} (kg)
T_0	9.33 h	3.41	4.57 f	138.00 h	690.00 h
T_1	10.17 g	3.98	5.60 e	174.70 f	873.30 f
T_2	10.67 f	3.98	5.73 e	195.30 e	976.70 e
T_3	10.00 g	3.95	5.43 e	166.70 g	833.30 g
T_4	12.67 b	4.15	8.37 b	308.00 b	1540.00 b
T_5	12.33 b	4.10	7.30 c	305.00 b	1525.00 b
T_6	11.00 ef	4.00	5.97 de	248.00 d	1240.00 d
T_7	11.50 cd	4.06	6.67 cd	283.00 c	1415.00 c
T_8	11.83 c	4.07	6.97 c	287.30 c	1437.00 c
T_9	11.33 de	4.01	6.07 de	285.80 c	1429.00 c
T_{10}	10.83 f	3.98	5.97 de	198.00 e	990.00 e
T_{11}	13.50 a	4.34	9.60 a	360.70 a	1803.00 a
T_{12}	13.33 a	4.23	8.40 b	358.00 a	1790.00 a
T_{13}	12.33 b	4.12	7.33 c	306.00 b	1530.00 b
LSD0.05	0.434	0.871^{NS}	0.791	7.206	23.63
CV(%)	6.89	6.52	5.33	8.87	8.86

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

T_0 = Control, T_1 = Cowdung 100%, T_2 = Inorganic fertilizer 100%, T_3 = Decoprima 100%, T_4 = Cowdung 100% + Inorganic fertilizer 100%, T_5 = Cowdung 100% + Inorganic fertilizer 75%, T_6 = Cowdung 100% + Inorganic fertilizer 50%, T_7 = Cowdung100% + Decoprima100%, T_8 = Inorganic fertilizer 100% + Decoprima 100%, T_9 = Inorganic fertilizer 75% + Decoprima 100%, T_{10} = Inorganic fertilizer 50% + Decoprima 100%, T_{11} = Cowdung 100% + Inorganic fertilizer 100% + Decoprima 100%, T_{12} = Cowdung 100% + Inorganic fertilizer 75% + Decoprima 100%, T_{13} = Cowdung 100% + Inorganic fertilizer 50% + Decoprima 100%

4.3.5 Seed yield ha^{-1} (kg)

Effect of different level of cowdung, inorganic fertilizers and bio-fertilizer treatments showed a statistically significant variation for seed yield ha^{-1} of mustard (Table 4 and Appendix XI). Results revealed that the highest seed yield ha^{-1} (1803.00 kg) was recorded from the treatment T_{11} (cowdung 100% + inorganic fertilizer 100% + decoprima 100%) that was statistically identical with T_{12} (cowdung 100% + inorganic fertilizer 75% + decoprima 100%) followed by T_4 (cowdung 100% + Inorganic fertilizer 100%) and T_{13} (cowdung 100% + inorganic fertilizer 50% + decoprima 100%). On the other hand, the lowest seed yield ha^{-1} (690.00 kg) was observed from control treatment T_0 (control) which was significantly different from other treatments. Under the present study, decoprima was used as an experimental material which was considered as *Trichoderma*-enriched biofertilizer that contributed positively on yield and yield attributes. Results also revealed that yield of mustard was increased from that treatments which were comprised with decoprima. Haque *et al*. (2012) found that application of 50% N fertilizer along with 50% *Trichoderma*-enriched biofertilizers augmented 108% yields over control in mustard. Similarly, Haque *et al*. (2010) found higher yield of mustard with *Trichoderma*-enriched biofertilizers along with NPK and compost compared to control. Similar result was also observed by Sugianti and Zulhaedar (2021). Kumar *et al*. (2018) also found the highest grain yield with application of 50% RDF+ FYM 6 t/ha + Vermicompost 2 t/ha+ bio-fertilizer than the rest of the treatments. Haque *et al*. (2010) reported that the application of 50% Nitrogen fertilizer and 50% *Trichoderma* enriched biofertilizer can increased the yield of mustard upto 108.36% over control condition. Beenish *et al*. (2018), Rundala *et al.* (2013) and Singh *et al.* (2018) also found similar result with the present study.

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was carried out during the period of November 2019 to February 2020 at the farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka-1207 to find out the influence of cowdung, inorganic fertilizers and bio-fertilizer on morphology, yield contributing characters and yield of mustard. BARI Sarisha-14 was considered as test crop. Fourteen treatments were comprised for the present study. The experiment was laid out in randomized complete block design (RCBD) with three replications. Data on different growth, yield contributing parameters and yield parameters were recorded and analyzed statistically.

Regarding growth parameters, all are affected significantly due to the effect of cowdung, inorganic fertilizers and bio-fertilizer treatments. Results exhibited that at 40, 50, 60 and 70 DAS, the maximum plant height (78.12, 92.55, 94.91 and 97.81 cm, respectively), the highest number of leaves plant^{-1} (21.47, 37.13, 44.13 and 45.80, respectively) and highest number of branches plant^{-1} (7.73, 9.07, 9.20 and 9.33, respectively) were recorded from the treatment T_{11} (cowdung 100% + inorganic fertilizer 100% + decoprima 100%) whereas the minimum plant height (80.87, 70.24, 72.29 and 73.43 cm, respectively), lowest number of leaves plant^{-1} (13.33, 25.20, 30.13 and 30.87, respectively) and lowest number of branches plant^{-1} (3.40, 5.33, 5.60 and 5.77, respectively) were observed from the control treatment T_0.

In terms of yield contributing parameters, all are influenced significantly except length of silliquae. Results showed that the treatment T_{11} (cowdung 100% + inorganic fertilizer 100% + decoprima 100%) represented the highest length of inflorescence (37.17, 42.58 and 40.22 cm at 50, 60 and 70 DAS, respectively) and highest number of silliquae inflorescence^{-1} (29.53, 39.40 and 40.73 at 50, 60 and 70 DAS, respectively) whereas control treatment T_0 gave the lowest length of inflorescence (32.02, 33.03 and 34.02 cm at 50, 60 and 70 DAS, respectively) and lowest number of silliquae inflorescence^{-1} (13.33, 21.27 and 23.50 at 50, 60 and 70 DAS, respectively). Likewise, the highest length of silliquae (4.91 cm) and the highest number of filled silliquae plant^{-1} (98.73) were recorded from the treatment T_{11} but the lowest length of silliquae (3.27 cm) and lowest number of filled silliquae plant^{-1} (43.80) were recorded from T_0 (control) treatment. Similarly, the lowest number of non-filled silliquae plant^{-1} (4.40) was recorded from the treatment T_4 (cowdung 100% + Inorganic fertilizer 100%) whereas the highest (8.33) was observed from control treatment T_0.

Regarding yield parameters, all the parameters affected significantly due to cowdung, inorganic fertilizers and bio-fertilizer effects except 1000 seed weight. However, the treatment T_{11} (cowdung 100% + inorganic fertilizer 100% + decoprima 100%) gave the highest number of seeds silliquae^{-1} (37.93), highest seed weight of 100 siliquae (13.50 g), highest 1000 seed weight (4.34 g), highest seed weight plant^{-1} (9.60 g), highest seed yield plot^{-1} (360.70 g) and highest seed yield ha^{-1} (1803.00 kg). On the other hand, the lowest number of seeds silliquae^{-1} (26.87), lowest seed weight of 100 siliquae (9.33 g), lowest 1000 seed weight (3.41 g), lowest seed weight plant^{-1} (4.57 g), lowest seed yield plot^{-1} (138.00 g) and lowest seed yield ha^{-1} (690.00 kg) were observed from control treatment T_0 (control).

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

1. Decoprima as bio-fertilizer in association with cowdung and inorganic fertilizer had a significant effect on growth, yield contributing parameters and yield parameters of mustard.
2. Use of decoprima in association with cowdung and inorganic fertilizer showed higher yield of mustard compared to other treatments where decoprima was not used.

3. Among 14 treatments, T_{11} (cowdung 100% + inorganic fertilizer 100% + decoprima 100%) gave the highest seed yield (1803.00 kg ha^{-1}) followed by T_{12} (cowdung 100% + inorganic fertilizer 75% + decoprima 100%).
4. Application of cowdung 100% + inorganic fertilizer 100% + decoprima 100% was most effective treatment regarding highest yield of mustard (1803.00 kg ha^{-1}) compared to other doses including control.

Recommendation

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

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APPENDICES

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

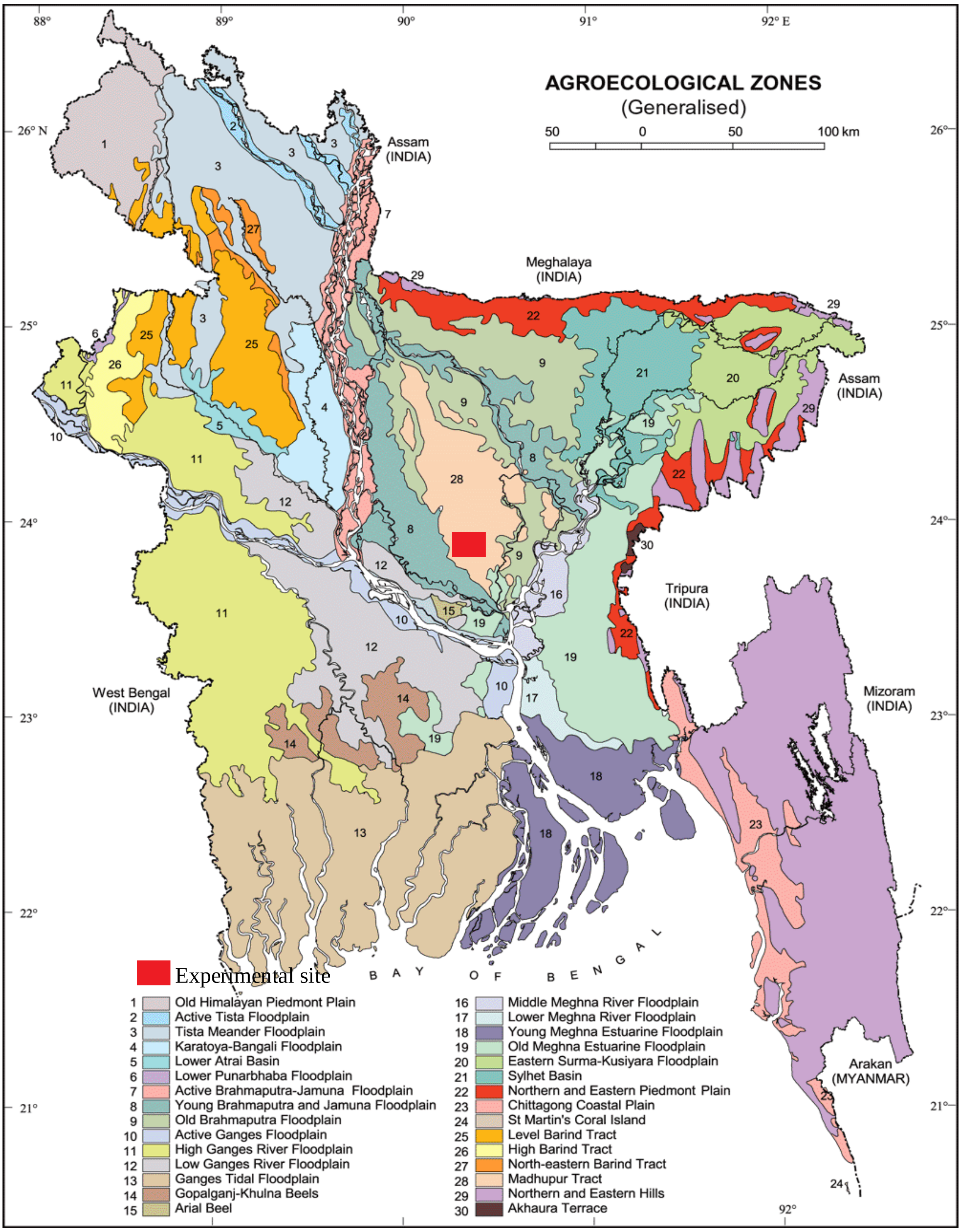


Figure 4. Experimental site

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

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

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

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

A. Morphological characteristics of the experimental field

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

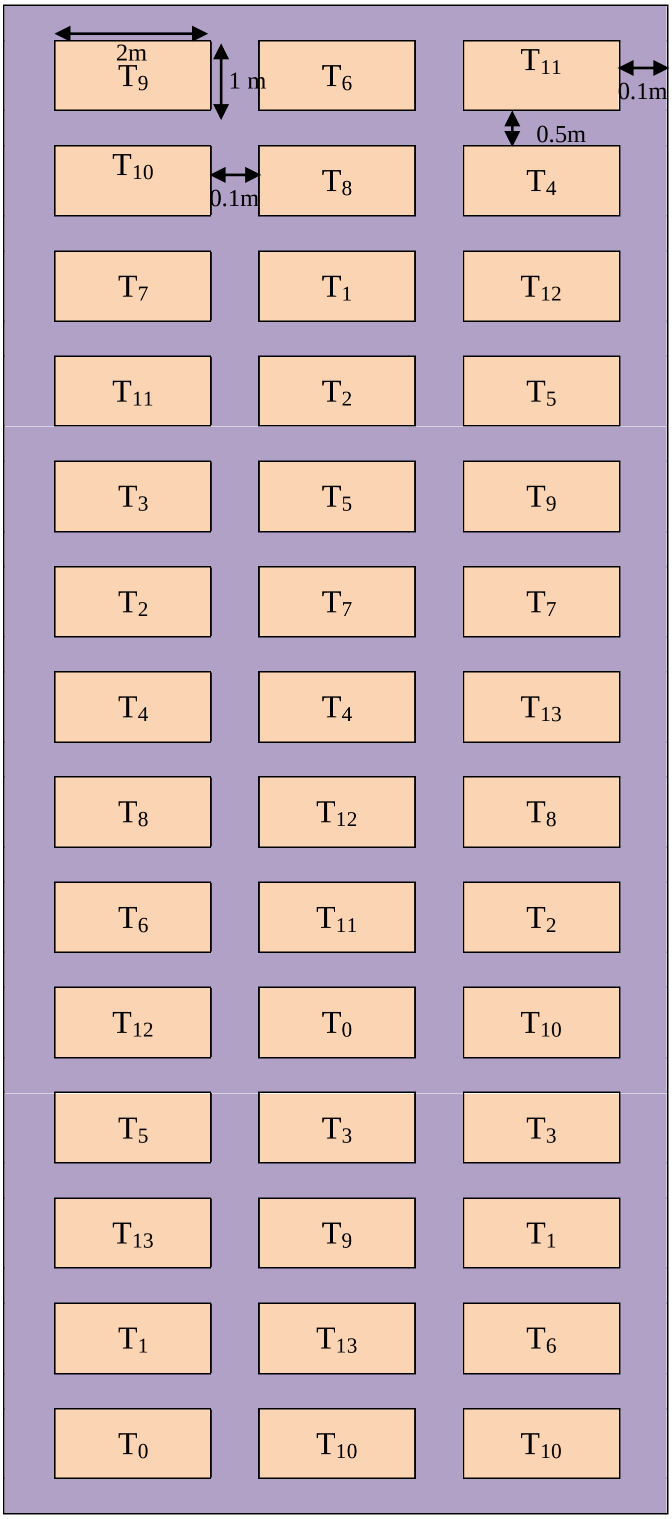
Source: Soil Resource Development Institute (SRDI)

B. Physical and chemical properties of the initial soil

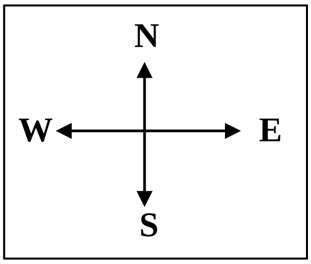
Characteristics	**Value**
Partical size analysis % Sand	27
%Silt	43
% Clay	30
Textural class	Silty Clay Loam (ISSS)
pH	5.6
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total N (%)	0.03
Available P (ppm)	20
Exchangeable K (me/100 g soil)	0.1
Available S (ppm)	45

Source: Soil Resource Development Institute (SRDI)

Appendix IV. Layout of the experiment field



Legend



T_0 = Control

T_1 = Cowdung 100%

T_2 = Inorganic fertilizer 100%

T_3 = Decoprima 100%

T_4 = Cowdung 100% + Inorganic fertilizer 75%

T_5 = Cowdung 100% + Inorganic fertilizer 50%

T_6 = Cowdung100% + Decoprima100%

T_7 = Cowdung 100% + Inorganic fertilizer 100%

T_8 = Inorganic fertilizer 100% + Decoprima 100%

T_9 = Inorganic fertilizer 75% + Decoprima 100%

T_{10} = Inorganic fertilizer 50% + Decoprima 100%

T_{11} = Cowdung 100% + Inorganic fertilizer 100% + Decoprima 100%

T_{12} = Cowdung 100% + Inorganic fertilizer 75% + Decoprima 100%

T_{13} = Cowdung 100% + Inorganic fertilizer 50% + Decoprima

Figure 5. Layout of the experimental plot

Appendix V. Mean square of plant height of mustard as influenced by cowdung, inorganic fertilizers and bio-fertilizer

Sources of variation	Degrees of freedom	Mean square of plant height (cm)			
		40 DAS	50 DAS	60 DAS	70 DAS
Replication	2	5.085	7.315	3.872	3.692
Treatment	13	205.37**	154.23*	161.259*	185.32*
Error	26	2.555	3.454	3.810	3.842

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

Appendix VI. Mean square of number of leaves plant^{-1} of mustard as influenced by cowdung, inorganic fertilizers and bio-fertilizer

Sources of variation	Degrees of freedom	Mean square of number of leaves plant^{-1}			
		40 DAS	50 DAS	60 DAS	70 DAS
Replication	2	2.503	1.170	1.680	1.169
Treatment	13	21.14**	40.66*	43.21**	47.85*
Error	26	5.813	2.989	3.984	3.110

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

Appendix VII. Mean square of number of branches plant^{-1} of mustard as influenced by cowdung, inorganic fertilizers and bio-fertilizer

Sources of variation	Degrees of freedom	Mean square of number of branches plant^{-1}			
		40 DAS	50 DAS	60 DAS	70 DAS
Replication	2	0.106	0.515	1.944	1.307
Treatment	13	6.713*	4.208*	3.550**	3.361**
Error	26	1.294	1.628	1.147	0.950

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

Appendix VIII. Mean square of inflorescence length of mustard as influenced by cowdung, inorganic fertilizers and bio-fertilizer

Sources of variation	Degrees of freedom	Mean square of length of inflorescence (cm)		
		50 DAS	60 DAS	70 DAS
Replication	2	2.196	4.820	8.783
Treatment	13	8.080**	24.13*	16.39*
Error	26	1.782	1.814	1.294

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

Appendix IX. Mean square of number of silliquae inflorescence^{-1} length of mustard as influenced by cowdung, inorganic fertilizers and bio-fertilizer

Sources of variation	Degrees of freedom	Mean square of number of silliquae inflorescence^{-1}		
		50 DAS	60 DAS	70 DAS
Replication	2	6.683	7.234	4.696
Treatment	13	37.47*	46.96*	48.49*
Error	26	1.131	2.586	2.879

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

Appendix X. Mean square of yield contributing parameters of mustard regarding number of filled silliquae plant^{-1}, number of non-filled silliquae plant^{-1}, length of silliquae and number of seeds silliquae^{-1} as influenced by cowdung, inorganic fertilizers and bio-fertilizer

Sources of variation	Degrees of freedom	Mean square of yield contributing parameters			
		Number of filled silliquae plant^{-1}	Number of non-filled silliquae plant^{-1}	Length of silliquae (cm)	Number of seeds silliquae^{-1}
Replication	2	13.807	1.860	0.012	1.155
Treatment	13	911.26*	4.998**	0.451^{NS}	26.73*
Error	26	6.090	1.066	0.045	1.993

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

Appendix XI. Mean square of yield parameters of mustard as influenced by cowdung, inorganic fertilizers and bio-fertilizer

Sources of variation	Degrees of freedom	Mean square of yield parameters				
		Seed weight of 100 siliquae (g)	1000 seed weight (g)	Seed weight plant^{-1} (g)	Seed yield plot^{-1} (g)	Seed yield ha^{-1} (kg)
Replication	2	1.310	0.013	0.182	138.41	354.376
Treatment	13	4.698**	0.130^{NS}	5.697**	746.24*	1693.31*
Error	26	0.267	0.069	0.222	21.37	66.049

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

Plate 1. Layout preparation

Plate 2. Seed sowing

Plate 3. Thinning operation in the field

Plate 4. Over all field view at flowering stage

Plate 5. Field visit by Supervisor

Plate 6. Over all field view at pod maturity stage

Plate 7. Data collection in the field

Plate 8. Over all field view at harvesting stage

Plate 9. Data collection during harvest

Plate 10. Data collection after harvest