GROWTH AND YIELD OF MUSTARD AS INFLUENCED BY FERTILIZER MANAGEMENT AND MECHANICAL WEEDING

FATEMA NASRIN

DEPARTMENT OF AGRONOMY

SHER-E-BANGLA AGRICULTURAL UNIVERSITY

DHAKA-1207

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BY
FATEMA NASRIN
REGISTRATION NO. 13-05367

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Approved by:

Professor Dr. Md. Shahidul Islam	**Professor Dr. Md. Jafar Ullah**
Supervisor	**Co-supervisor**

Prof. Dr. Md. Shahidul Islam
Chairman
Examination Committee

DEPARTMENT OF AGRONOMY
Sher-e-Bangla Agricultural University
Sher-e-Bangla Nagar
Dhaka-1207

CERTIFICATE

*This is to certify that the thesis entitled, "**GROWTH AND YIELD OF MUSTARD AS INFLUENCE BY FERTILIZER MANAGEMENT AND MECHANICAL WEEDING**" submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of "**MASTER OF SCIENCE (MS) in AGRONOMY**," embodies the result of a piece of bona-fide research work carried out by **FATEMA NASRIN**, Registration no. **13-05367** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

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

Date:
Place: Dhaka, Bangladesh

Professor Dr. Md. Shahidul Islam
Department of Agronomy
Sher-e-Bangla Agricultural University
Dhaka-1207

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ABSTRACT

A Farm experiment was conducted at the Sher-e-Bangla Agricultural University (SAU), during November 2018 to February 2019 with view to study the growth yield of mustard as influenced by poutry manure and weeding. The treatment factors were factor A; poultry manure [4 levels; P_0 - Recommended dose of fertilizer without poultry manure, P_1 - Recommended dose of fertilizer with recommended dose of poultry manure (10 t ha^{-1}) P_2 - 25 % reduction of recommended dose of fertilizer with recommended dose of poultry manure and P_3 - 50 % reduction of recommended dose of fertilizer (BARI, 2006) with recommended dose of poultry manure] and factor B: mechanical weesing [3 levels, M_0 - No mechanical weed control, M_1 - Mechanical weed control once (at 20 DAS) and M_2 - Mechanical weed control twice (at 15 and 30 DAS)]. Mustard cv. BARI Sharisha-14 was used as plant material for the present study. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. Poultry manure, mechanical weed control and their interactions showed significant variation on plant height, leaves $plant^{-1}$, branches $plant^{-1}$, dry weight $plant^{-1}$, siliqua $plant^{-1}$, seeds $silliqua^{-1}$, length of siliqua, weight of 1000-seeds/m^{-2}, grain yield, stover yield, biological yield, harvest index and weed population in mustard field. The tallest plant (95.33 cm) and highest number of leaves $plant^{-1}$ (16.73) at harvest was recorded from the combination of Recommended dose of fertilizer with poultry manure and two mechanical weeding at 15 and 30 DAS (P_1M_2) treatment. The maximum number of branches $plant^{-1}$ (8.07), highest dry matter weight $plant^{-1}$ (729.87 g), maximum number of $silliqua\ plant^{-1}$ (257.10), highest number of seeds $siliqua^{-1}$ (14.22), maximum weight of 1000-seed (3.32 g), highest grain yield (1.57 t ha^{-1}) and maximum harvest index (30.58 %) at harvest was found in combined use of 25% less poultry manure with poultry manure and two times weeding (P_2M_2) treatment. The maximum number of weed population (40.70 m^{-2}) was found from P_1M_0 (Recommended dose of fertilizer with poultry manure and no mechanical weeding) and the minimum weed (31.67 m^{-2}) was from 50% less poultry manure with poultry manure and two mechanical weeding at 15 DAS and 30 DAS (P_3M_2). 25% less recommended poultry manure with poultry manure and two times mechanical weeding showed better performance on growth and yield of mustard.

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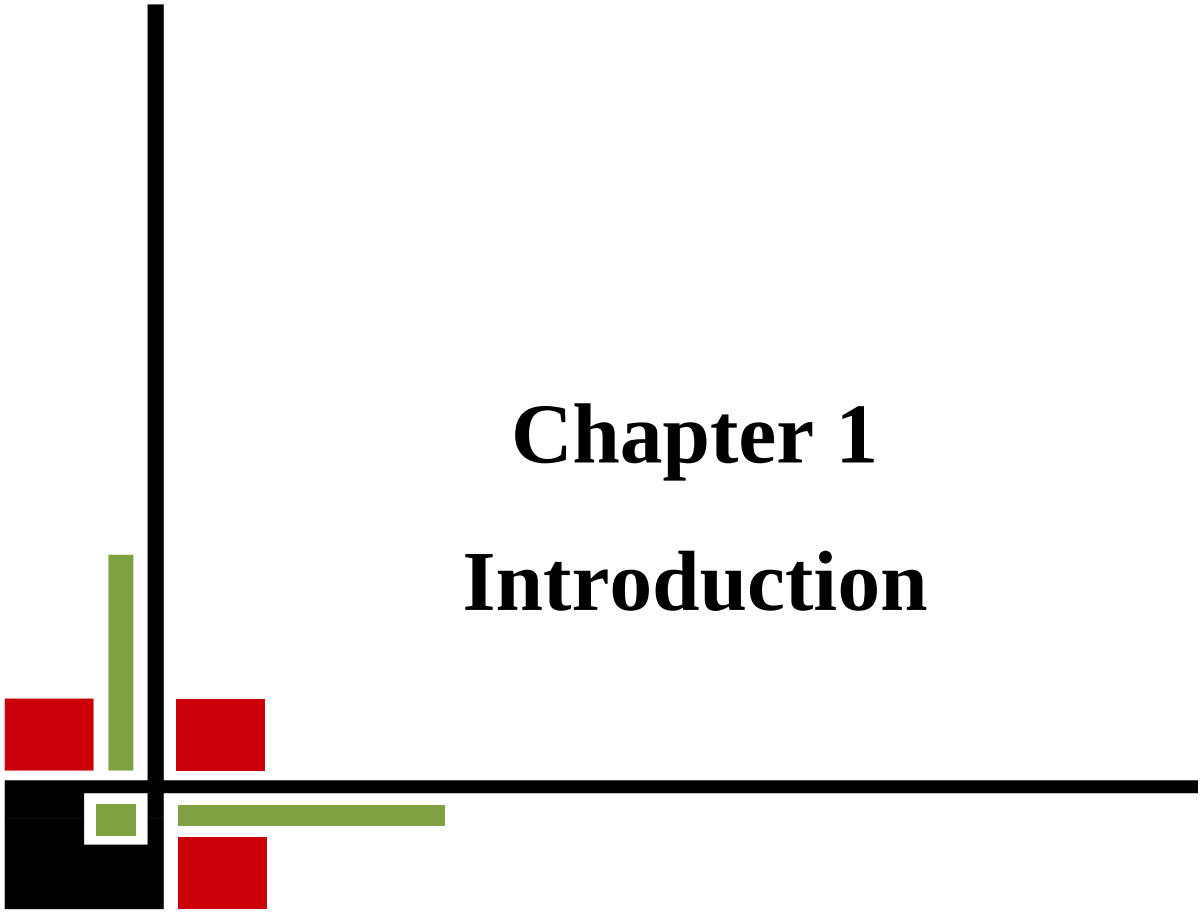
LIST OF ABBREVIATIONS

AEZ	Agro-Ecological Zone
Anon.	Anonymous
AIS	Agriculture Information Service
BARC	Bangladesh Agricultural Research Council
BAU	Bangladesh Agricultural University
BBS	Bangladesh Bureau of Statistics
BINA	Bangladesh Institute of Nuclear Agriculture
BNNC	Bangladesh National Nutrition Council
BRRI	Bangladesh Rice Research Institute
CRRI	Central Rice Research Institute
CV %	Percent Coefficient of Variance
cv.	Cultivar (s)
DAT	Days After Transplanting
DRR	Directorate of Rice Research
eds.	Editors
et al.	et alii (and others)
etc.	et cetera (and other similar things)
FAO	Food and Agricultural Organization
IARI	Indian Agricultural Research Institute
ICAR	Indian Council of Agricultural Research

IRRI	International Rice Research Institute
L.	Linnaeus
LSD	Least Significant Difference
i.e.	id est (that is)
MoP	Muriate of Potash
NPTs	New Plant Types
SAU	Sher-e-Bangla Agricultural University
SRDI	Soil Resources and Development Institute
TDM	Total Dry Matter
TSP	Triple Super Phosphate
UNDP	United Nations Development Programme
var.	Variety
viz.	Namely



Chapter 1

Introduction

CHAPTER I

INTRODUCTION

Mustard *(Brassica campestris*) belongs to the family Brassicaceae, is an important oil seed crop in Bangladesh. Although about seven oil seed crops are grown in the country but mustard (*Campestris and Juncea*) alone occupies about 70% of the oilseed land followed by sesame (*Sesamum indicum*), groundnut (*Arachis hypogaea*), linseed (*Linum usitatissimum*), soybean (*Glycine max*), sunflower (*Helianthus annuus*) and niger (*Guizotia abyssinica*) (BBS, 2008). It is originated from Asia Minor, but now is cultivating as a main commercial oil crop in Canada, China, Australia and India including Bangladesh. It was reported that mustard is a popular crop in crop rotation, which increases cropping intensity since it enhances yields of wheat, barley and breaks disease cycles in cereal grains (Mondal and Wahhab, 2001). It is mainly self-pollinating crop, although on an average 7.0 to 30.0% out-crossing does occur under natural field conditions.

Mustard is the main cultivable edible oil seed crop of Bangladesh. Mustard is the most important popular oil crop, which is grown in Rabi season in Bangladesh. Domestic production of edible oil almost entirely comes from rapeseed and mustard occupying only about 2% area of total cropped area in Bangladesh. Mustard covers the land area of 2,16,800 hectares in Bangladesh and produces about 1,83,500 metric tons of oil seeds indicating quite lower yield (846.4 t ha^{-1}) compared to world average yield of 1.97 t ha^{-1} (DRMR, 2015). Bangladesh stands the 5^{th} place in respect of total oil seed production in the world and the first position in respect of area and production among the oil crops grown in Bangladesh. Mustard covers about 61.2% of the total acreage under oil seed and 52.6% of the total oil seed production in Bangladesh. Oil seed crops including mustard are very important for human food as oils for cooking and frying purposes, as whole seed for condiments in prickles, flavouring curries and vegetables and have gained third position among the

crops next to cereals and legumes (Downey, 1990). The mustard oil is also used in preparing vegetable ghee, hair oil, medicines, soaps, lubricating oil and in tanning industries. The oil content in mustard seeds varies from 37–49 % (Bhowmik *et al.,* 2014). The oil cake is left after extraction is utilized as cattle feed and manure. Mustard oil is not only rich source of energy (about 9 k cal/g) but also rich in soluble vitamins A, D, E and K. The National Nutrition Council (NNC) of Bangladesh reported that recommended dietary allowance (RDA) per capita per day should be 6 g of oil for a diet with 27000 k cal. On RDA basis, the edible oil need for 150 million peoples is 0.39 million tons of oil equivalent to 0.82 million tons of oilseed (NNC, 1984). Mustard seeds contain 40–45 % oil and 20–25 % protein (Mondal and Wahhab, 2001).

The area and production of oilseeds are gradually declining due to lack of HYV, high infestation of diseases and pests, compared to other crops, instability of yield due to micro-climatic fluctuation, expansion of irrigation facilities and more profitable crops are available in place of in the cropping patterns. Most oilseeds crops respond positively with high management, yet they cannot compete with other high value crops. The yield of oil seed can be augmented with the use of high yielding varieties and appropriate agronomic management. Fertilizer is the most important input to boost up the production of oilseed crops. Fertilizer is the depending source of nutrient that can be used to boost up growth and yield of mustard (Islam *et at.*, 1992 and Zaho *et al.*, 1997). Chemical fertilizers have contributed significantly towards the pollution of water, air and soil. Therefore, the current trend is to explore the possibility of supplementing chemical fertilizers with organic ones, which are eco-friendly and cost effective.

Organic manures, valuable by products of farming and allied industries, contribute to plant growth through their favourable effects on physical, chemical and biological properties of the soil. Availability of soil P is also enhanced by addition of organic manures, presumably due to chelation of captions by organic acids and other decay products. Inorganic fertilizers when

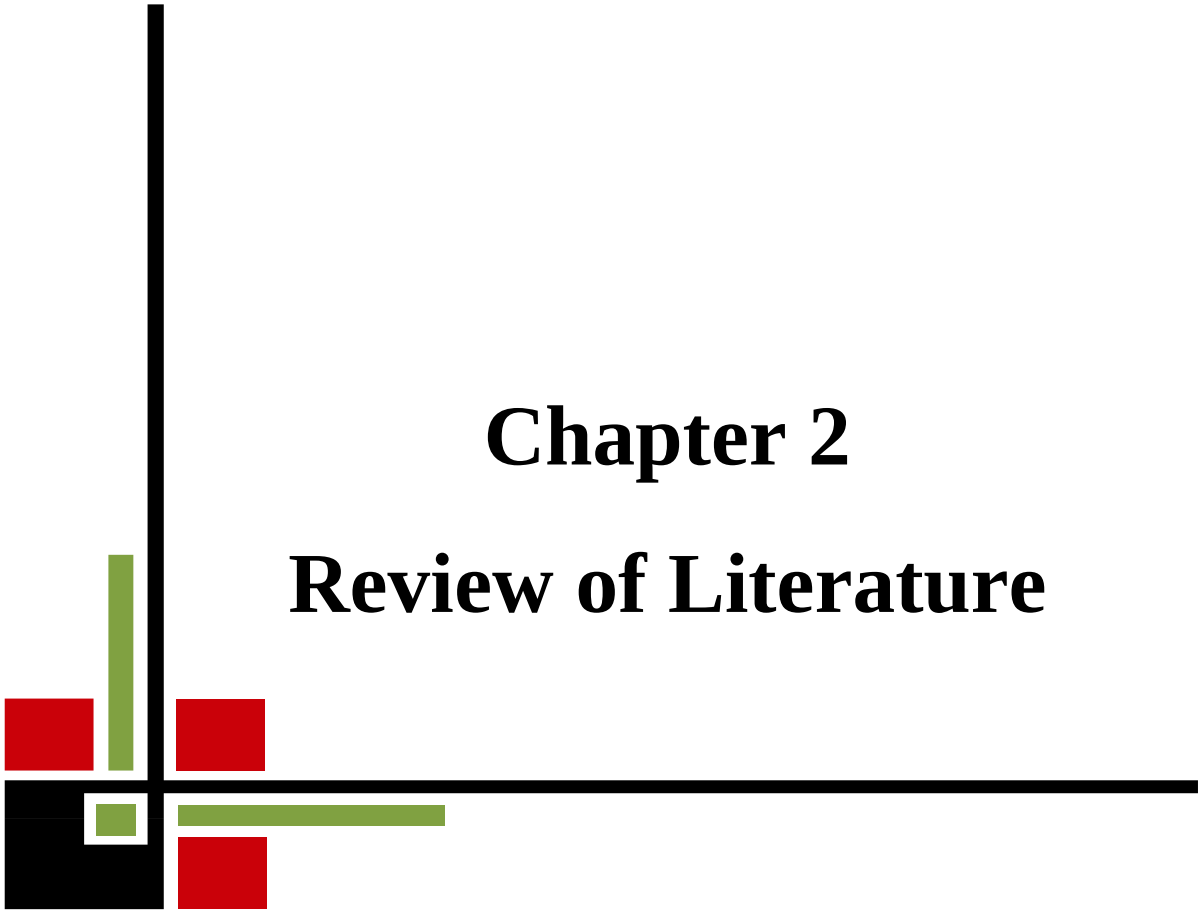
applied along with FYM can result in a remarkable increase in the yield (Ghosh *et al*., 2006). However, a major portion of the applied chemical nitrogen fertilizers is lost through the leaching, run off, emissions and volatilizations, which cause economic losses and serious environmental problems (Abdin *et al*., 2006; Galloway *et al*., 2008; Singh *et al*., 2010). Organic fertilizer viz. farm yard manure (FYM), bio-fertilizers or other organic manure are used for eco-friendly organic farming, however they are unable to replace chemical fertilizers in terms of crop productivity that because of their used as combined for better production of any crop.

The low productivity of mustard in the country might be the resultant of a number of factors *viz*. agronomic, edaphic, genetic and others. Among the agronomic factors, proper weed management may be a very serious issue (Singh, 1992). Weed competition in mustard is more serious during early stage; because crop growth during winter (Rabi) season remains slow during the first 4–6 weeks after sowing (Chauhan *et al.*, 2005). However, during later stage, it grows vigorously and has suppressing effect on weeds but in late sowing mustard affected during flowering and silliqua formation stage due to high temperature as it is a thermo sensitive crop. As this crop is grown in poor soil with poor management practices, weed infestation is one of the major causes of low productivity. The critical period of crop weed competition in rapeseed-mustard is 15-40 days and weeds cause alarming decline in crop production ranging from 15-60 % to a total failure yield (Shekhawat *et al*., 2012; Singh *et al.*, 2010; Banga and Yadav, 2001; Singh *et al*., 2001; Bhan, 1992) depending on weed flora, its intensity, stage, nature and duration of the crop weed competition. If left uncontrolled, the weeds in many fields are capable of reducing yields by more than 80 % (Singh *et al.*, 2012). Weeds compete with crops for light, moisture, space and plant nutrients and other environmental requirements and consequently interfere with the normal growth of crops (Upadhyay *et al*., 2012; Bijanzadeh and Ghadiri, 2006; Abdollahi and Ghadiri, 2004).

Weeds being injurious, harmful or poisonous are a constant source of trouble for the successful growth and development of crops. Weeds pose severe problem for crop husbandry, reducing the soil fertility and moisture, act as alternate host for insect and pest and develop a potential threat to the succeeding crops. Besides lowering production, weeds also decrease oil quality and quantity (Bagherani and Shimi, 2001). Several methods have been used for weed control in rapeseed, like hand weeding, cultivation in row cropping and use of chemicals. Hand weeding is still the conventional weed control practice in rapeseed. While the studies of Chauhan *et al.* (2005) and Yadav (2004) revealed that hand weeding twice increased seed and oil yields, siliquae plant^{-1} and 1000 seeds weight. Bowerman (1990) also reported that significant yield increase could be achieved mainly where the level of weed control is high. The taller plant, greater number of branches plant^{-1}, number of seeds siliqua^{-1}, number of siliquae plant^{-1}, 1000 seeds weight and crop yield were recorded for the weed-free control condition, followed by hand weeding at 30 and 45 days after sowing (DAS) (Sharma and Jain, 2002). Most workers informed about a single weeding from 20 to 40 DAS through which yield loss of mustard can be minimized (Yadav *et al.*, 1999).

Most farmers of Bangladesh do not adopt fertilizer management and weed control in mustard field due to its short life span, although weeding is essential for achieving a higher yield of mustard. Therefore, the present investigation was conducted with the following objectives:

i. To find out the effect of organic and chemical fertilizer on of growth and yield performance of mustard
ii. To evaluate the weed management techniques on growth and yield performance of mustard and
iii. To find out the best combination among the fertilizer management and weed management techniques for potential production of mustard.



Chapter 2

Review of Literature

CHAPTER II

REVIEW OF LITERATURE

Judicious use of both organic and inorganic sources of nutrients can alone lead to sustainable maintenance of soil fertility and productivity and increase seed and oil production of mustard. In maintaining soil fertility and sustainable crop production, use of organic manures has great significance. However, available information regarding use of organic manures in mustard is meagre. On the other hand, recommended intercultural operation like weeding can reduce crop-weed competition and increase overall crop production. An attempt was made in this section to collect and study the research work carried out by eminent scientists in Bangladesh and abroad regarding the influence of poultry manure and mechanical weed control method on growth and yield of mustard to gather knowledge helpful in conducting the present research work and subsequently writing up the result and discussion. The research works and their findings have been briefly reviewed in this chapter under the following main heads.

2.1 Effect of Fertilizer management

2.1.1 Plant height (cm)

Meitei and Bajpay (2019) carried out an experiment to evaluate the effect of organic manures with or without combination of inorganic fertilizers on transplanted Gobhi Sarson (*Brassica napus* L.) on various growth and yield attributing traits of transplanted Gobhi sarson. The effect of eight treatments *viz.,* (T_1) 20 t ha^{-1} Farm yard manure, (T_2) 10 t ha^{-1} Farm yard manure + ½ Nitrogen, (T_3) 10 t ha^{-1} Poultry manure, (T_4) 5 t ha^{-1} Poultry manure + ½ Nitrogen, (T_5) 5 t ha^{-1} Farm yard manure + 5 t ha^{-1} Poultry manure, (T_6) 5 t ha $^{-1}$ Vermicompost, (T_7) 40:12 (Recommended Dose of Fertilizer) and (T_8) Control were studied. The findings revealed that among various treatments combination, Treatment T_4: application of 5 t ha^{-1} Poultry manure + ½ Nitrogen, produced significantly taller rapeseed plants (147.0 cm).

Murali *et al*. (2018) conducted a field experiment to find out the effect of different levels of organic manure on the growth and yield of mustard (*Brassica juncea* L.) under Jatropha (*Jatropha circus* L.) based agroforestry system. The soil of experimental plot was sandy loam in texture, nearly neutral in soil reaction (pH 6.7), low in organic carbon (0.35%), N (230 kg ha^{-1}), P (20 kg ha^{-1}) and K (98 kg ha^{-1}), The treatment comprised of 3 levels of Farm Yard Manure (FYM), Vermicompost (VC) and Poultry Manure (PM) *viz*. T_1 (control), T_2 (100% FYM), T_3 (100% PM), T_4 (100% VC), T_5 (50% FYM + 50% VC), T_6 (50% FYM + 50% PM), T_7 (50% FYM + 25% VC + 25% PM), T_8 (25% FYM + 25% VC + 50% PM) and T_9 (25% FYM + 25% PM + 50% VC). The result showed that the tallest plant (169.27 cm) was recorded at 80 DAS from treatment T_5 (50% FYM + 50% VC).

Reddy and Singh (2018) set up a field experiment during the Rabi season of 2017 on mustard crop (var. DHARA) to study the effect of integrated nitrogen management on growth and yield of mustard. The experiment consisted of 80 kg of nitrogen to mustard of which 50 kg of nitrogen was supplied by urea and 30 kg of nitrogen was supplied either by poultry manure or by farmyard manure or by vermicompost with and without *Azotobacter* seed inoculation; which was compared with 80 kg of nitrogen supplied through urea alone. The result showed that application of 50 kg nitrogen through urea + 30 kg nitrogen through poultry manure + *Azotobacter* (seed inoculation) gave significantly higher plants height (153.53 cm).

Prasad *et al.* (1991) from the study on Indo-gangetic alluvial soil of Allahabad reported that incorporation of poultry manure as a source of organic matter @ 5 and 10 t ha^{-1} brought about significant increase plant height of mustard over control. They recorded that application of 100 kg P_2O_5 in combination with 10 t ha^{-1} poultry manure significantly increased the plant height of mustard.

2.1.2 Number of branches plant^{-1}

Meitei and Bajpay (2019) carried out an experiment to evaluate the effect of organic manures with or without combination of inorganic fertilizers on transplanted Gobhi Sarson (*Brassica napus* L.) on various growth and yield attributing traits of transplanted Gobhi sarson. The effect of eight treatments *viz.*, (T_1) 20 t ha^{-1} Farm yard manure, (T_2) 10 t ha^{-1} Farm yard manure + ½ Nitrogen, (T_3) 10 t ha^{-1} Poultry manure, (T_4) 5 t ha^{-1} Poultry manure + ½ Nitrogen, (T_5) 5 t ha^{-1} Farm yard manure + 5 t ha^{-1} Poultry manure, (T_6) 5 t ha^{-1} Vermicompost, (T_7) 40:12 (Recommended Dose of Fertilizer) and (T_8) Control were studied on various growth and yield attributing parameters of *Brassica napus*. The findings revealed that upon various treatments combination, Treatment T_4: application of 5 t ha^{-1} Poultry manure + ½ Nitrogen, produced significantly higher number of branches plant^{-1} (8.3).

Murali *et al*. (2018) conducted a field experiment to find out the effect of different levels of organic manure on the growth and yield of mustard (*Brassica juncea* L.) under Jatropha (*Jatropha circus* L.) based agroforestry system. The soil of experimental plot was sandy loam in texture, nearly neutral in soil reaction (pH 6.7), low in organic carbon (0.35%), N (230 kg ha^{-1}), P (20 kg ha^{-1}) and K (98 kg ha^{-1}), The treatment comprised of 3 levels of Farm Yard Manure (FYM), Vermicompost (VC) and Poultry Manure (PM) viz. T_1 (control), T_2 (100% FYM), T_3 (100% PM), T_4 (100% VC), T_5 (50% FYM + 50% VC), T_6 (50% FYM + 50% PM), T_7 (50% FYM + 25% VC + 25% PM), T_8 (25% FYM + 25% VC + 50% PM), T_9 (25% FYM + 25% PM + 50% VC). The result showed that maximum number of branches per plant (5.26) at 80 DAS was recorded from treatment T_5 (50% FYM + 50% VC).

Prasad *et al.* (1991) from the study on Indo-gangetic alluvial soil of Allahabad reported that application of 100 kg P_2O_5 in combination with 10 t ha^{-1} poultry manure significantly increased the number of branches per plant of mustard.

2.1.3 Dry weight plant^{-1} (g)

Murali *et al*. (2018) conducted a field experiment to find out the effect of different levels of organic manure on the growth and yield of mustard (*Brassica juncea* L.) under Jatropha (*Jatropha circus* L.) based agroforestry system. The soil of experimental plot was sandy loam in texture, nearly neutral in soil reaction (pH 6.7), low in organic carbon (0.35%), N (230 kg ha^{-1}), P (20 kg ha^{-1}) and K (98 kg ha^{-1}), The treatment comprised of 3 levels of Farm Yard Manure (FYM), Vermicompost (VC) and Poultry Manure (PM) viz. T_1 (control), T_2 (100% FYM), T_3 (100% PM), T_4 (100% VC), T_5 (50% FYM + 50% VC), T_6 (50% FYM + 50% PM), T_7 (50% FYM + 25% VC + 25% PM), T_8 (25% FYM + 25% VC + 50% PM), T_9 (25% FYM + 25% PM + 50% VC). The result showed that maximum dry weight (76.03 g) at 80 DAS was recorded from treatment T_5 (50% FYM + 50% VC).

Reddy and Singh (2018) set up a field experiment during the Rabi season of 2017 on mustard crop (var. DHARA) to study the effect of integrated nitrogen management on growth and yield of mustard. The experiment consisted of 80 kg of nitrogen to mustard of which 50 kg of nitrogen was supplied by urea and 30 kg of nitrogen was supplied either by poultry manure or by farmyard manure or by vermicompost with and without *Azotobacter* seed inoculation; which was compared with 80 kg of nitrogen supplied through urea alone. The result showed that application of 50 kg nitrogen through urea + 30 kg nitrogen through poultry manure + *Azotobacter* (seed inoculation) gave significantly higher plant dry weight (59.95 g).

Prasad *et al.* (1991) from the study on Indo-gangetic alluvial soil of Allahabad reported that incorporation of poultry manure as a source of organic matter @ 5 and 10 t ha^{-1} brought about significant increase in dry matter accumulation of mustard over control. They recorded that application of 100 kg P_2O_5 in combination with 10 t ha^{-1} poultry manure significantly increased the plant dry matter weight of mustard.

2.1.4 Number of siliquae plant^{-1}

Meitei and Bajpay (2019) carried out an experiment to evaluate the effect of organic manures with or without combination of inorganic fertilizers on transplanted Gobhi Sarson (*Brassica napus* L.) on various growth and yield attributing traits of transplanted Gobhi sarson. The effect of eight treatments *viz.*, (T_1) 20 t ha^{-1} Farm yard manure, (T_2) 10 t ha^{-1} Farm yard manure + ½ Nitrogen, (T_3) 10 t ha^{-1} Poultry manure, (T_4) 5 t ha^{-1} Poultry manure + ½ Nitrogen, (T_5) 5 t ha^{-1} Farm yard manure + 5 t ha^{-1} Poultry manure, (T_6) 5 t ha^{-1} Vermicompost, (T_7) 40:12 (Recommended Dose of Fertilizer) and (T_8) Control were studied on various growth and yield attributing parameters of *Brassica napus*. The findings revealed that among various treatments combination, Treatment T_4: application of 5 t ha^{-1} Poultry manure + ½ Nitrogen, produced significantly higher number of siliquae plant^{-1} (303.0).

Murali *et al*. (2018) conducted a field experiment to find out the effect of different levels of organic manure on the growth and yield of mustard (*Brassica juncea* L.) under Jatropha (*Jatropha circus* L.) based agroforestry system. The soil of experimental plot was sandy loam in texture, nearly neutral in soil reaction (pH 6.7), low in organic carbon (0.35%), N (230 kg ha^{-1}), P (20 kg ha^{-1}) and K (98 kg ha^{-1}), The treatment comprised of 3 levels of Farm Yard Manure (FYM), Vermicompost (VC) and Poultry Manure (PM) viz. T_1 (control), T_2 (100% FYM), T_3 (100% PM), T_4 (100% VC), T_5 (50% FYM + 50% VC), T_6 (50% FYM + 50% PM), T_7 (50% FYM + 25% VC + 25% PM), T_8 (25% FYM + 25% VC + 50% PM), T_9 (25% FYM + 25% PM + 50% VC). The result showed that maximum number of siliquae plant^{-1} (5.85) at harvesting time was recorded from treatment T_5 (50% FYM + 50% VC).

Reddy and Singh (2018) set up a field experiment during the Rabi season of 2017 on mustard crop (var. DHARA) to study the effect of integrated nitrogen management on growth and yield of mustard. The experiment consisted of 80 kg of nitrogen to mustard of which 50 kg of nitrogen was supplied by urea and

30 kg of nitrogen was supplied either by poultry manure or by farmyard manure or by vermicompost with and without *Azotobacter* seed inoculation; which was compared with 80 kg of nitrogen supplied through urea alone. The result showed that application of 50 kg nitrogen through urea + 30 kg nitrogen through poultry manure + *Azotobacter* (seed inoculation) gave significantly higher number of siliquae plant^{-1} (365.75).

Prasad *et al.* (1991) from the study on Indo-gangetic alluvial soil of Allahabad recorded that application of 100 kg P_2O_5 in combination with 10 t ha^{-1} poultry manure significantly increased the number of siliquae per plant of mustard.

2.1.5 Number of seeds siliquae^{-1}

Meitei and Bajpay (2019) carried out an experiment to evaluate the effect of organic manures with or without combination of inorganic fertilizers on transplanted Gobhi Sarson (*Brassica napus* L.) on various growth and yield attributing traits of transplanted Gobhi sarson. The effect of eight treatments *viz.*, (T_1) 20 t ha^{-1} Farm yard manure, (T_2) 10 t ha^{-1} Farm yard manure + ½ Nitrogen, (T_3) 10 t ha^{-1} Poultry manure, (T_4) 5 t ha^{-1} Poultry manure + ½ Nitrogen, (T_5) 5 t ha^{-1} Farm yard manure + 5 t ha^{-1} Poultry manure, (T_6) 5 t ha^{-1} Vermicompost, (T_7) 40:12 (Recommended Dose of Fertilizer) and (T_8) Control were studied on various growth and yield attributing parameters of *Brassica napus*. The findings revealed that upon various treatments combination, Treatment T_4: application of 5 t ha^{-1} Poultry manure + ½ Nitrogen produced significantly higher number of seeds siliqua^{-1} (27.3).

Murali *et al*. (2018) conducted a field experiment to find out the effect of different levels of organic manure on the growth and yield of mustard (*Brassica juncea* L.) under Jatropha (*Jatropha circus* L.) based agroforestry system. The soil of experimental plot was sandy loam in texture, nearly neutral in soil reaction (pH 6.7), low in organic carbon (0.35%), N (230 kg ha^{-1}), P (20 kg ha^{-1}) and K (98 kg ha^{-1}), The treatment comprised of 3 levels of Farm Yard Manure (FYM), Vermicompost (VC) and Poultry Manure (PM) viz. T_1

(control), T_2 (100% FYM), T_3 (100% PM), T_4 (100% VC), T_5 (50% FYM + 50% VC), T_6 (50% FYM + 50% PM), T_7 (50% FYM + 25% VC + 25% PM), T_8 (25% FYM + 25% VC + 50% PM), T_9 (25% FYM + 25% PM + 50% VC). The result showed that maximum number of seeds siliqua^{-1} (13.46) at harvesting time was recorded from treatment T_5 (50% FYM + 50% VC).

Reddy and Singh (2018) set up a field experiment during the Rabi season of 2017 on mustard crop (var. DHARA) to study the effect of integrated nitrogen management on growth and yield of mustard. The experiment consisted of 80 kg of nitrogen to mustard of which 50 kg of nitrogen was supplied by urea and 30 kg of nitrogen was supplied either by poultry manure or by farmyard manure or by vermicompost with and without *Azotobacter* seed inoculation; which was compared with 80 kg of nitrogen supplied through urea alone. The result showed that application of 50 kg nitrogen through urea + 30 kg nitrogen through poultry manure + *Azotobacter* (seed inoculation) gave significantly higher number of seeds siliqua^{-1} (14.53).

2.1.6 Length of silliqua (cm)

Meitei and Bajpay (2019) carried out an experiment to evaluate the effect of organic manures with or without combination of inorganic fertilizers on transplanted Gobhi Sarson (*Brassica napus* L.) on various growth and yield attributing traits of transplanted Gobhi sarson. The effect of eight treatments *viz.*, (T_1) 20 t ha^{-1} Farm yard manure, (T_2) 10 t ha^{-1} Farm yard manure + ½ Nitrogen, (T_3) 10 t ha^{-1} Poultry manure, (T_4) 5 t ha^{-1} Poultry manure + ½ Nitrogen, (T_5) 5 t ha^{-1} Farm yard manure + 5 t ha^{-1} Poultry manure, (T_6) 5 t ha^{-1} Vermicompost, (T_7) 40:12 (Recommended Dose of Fertilizer) and (T_8) Control were studied on various growth and yield attributing parameters of *Brassica napus*. The findings revealed that upon various treatments combination, Treatment T_4: application of 5 t ha^{-1} Poultry manure + ½ Nitrogen produced significantly taller length of silliqua (8.56 cm).

Jamwal (2000) carried out a field experiment to study the effect of integrated nutrient management on growth, yield, quality, nutrient uptake and economics of mustard. The experimental soil was clay loam in texture, low in available N and organic malter, medium in available P and K contents with neutral soil reaction (pH). The experiment was laid out with nine (9) treatment combinations of organic and inorganic fertilizers. Mustard variety Pusa bold was sown in lines 30 cm apart using 5 kg seed ha^{-1}. The results revealed that application of either recommended dose of fertilizers (RDF) or 75% of RDF along with 5 t FYM manure ha^{-1} or 75% of RDF + 2.5 t poultry manure ha^{-1} were at par with each other and all these treatments significantly improved growth, yield and nutrient uptake in mustard crop over rest of the treatments. However, the length of silliqua remained unaffected.

2.1.7 Weight of 1000-seeds (g)

Meitei and Bajpay (2019) carried out an experiment to evaluate the effect of organic manures with or without combination of inorganic fertilizers on transplanted Gobhi Sarson (*Brassica napus* L.) on various growth and yield attributing traits of transplanted Gobhi sarson. The effect of eight treatments *viz.*, (T_1) 20 t ha^{-1} Farm yard manure, (T_2) 10 t ha^{-1} Farm yard manure + ½ Nitrogen, (T_3) 10 t ha^{-1} Poultry manure, (T_4) 5 t ha^{-1} Poultry manure + ½ Nitrogen, (T_5) 5 t ha^{-1} Farm yard manure + 5 t ha^{-1} Poultry manure, (T_6) 5 t ha^{-1} Vermicompost, (T_7) 40:12 (Recommended Dose of Fertilizer) and (T_8) Control were studied on various growth and yield attributing parameters of *Brassica napus*. The findings revealed that upon various treatments combination, Treatment T_4: application of 5 t ha^{-1} Poultry manure + ½ Nitrogen produced significantly heavier weight of 1000-seeds (2.77 g).

Murali *et al*. (2018) conducted a field experiment to find out the effect of different levels of organic manure on the growth and yield of mustard (*Brassica juncea* L.) under Jatropha (*Jatropha circus* L.) based agroforestry system. The soil of experimental plot was sandy loam in texture, nearly neutral

in soil reaction (pH 6.7), low in organic carbon (0.35%), N (230 kg ha^{-1}), P (20 kg ha^{-1}) and K (98 kg ha^{-1}), The treatment comprised of 3 levels of Farm Yard Manure (FYM), Vermicompost (VC) and Poultry Manure (PM) viz. T_1 (control), T_2 (100% FYM), T_3 (100% PM), T_4 (100% VC), T_5 (50% FYM + 50% VC), T_6 (50% FYM + 50% PM), T_7 (50% FYM + 25% VC + 25% PM), T_8 (25% FYM + 25% VC + 50% PM), T_9 (25% FYM + 25% PM + 50% VC). The result showed that maximum weight of 1000-seeds (4.93 g) after harvest was recorded from treatment T_5 (50% FYM + 50% VC).

Reddy and Singh (2018) set up a field experiment during the Rabi season of 2017 on mustard crop (var. DHARA) to study the effect of integrated nitrogen management on growth and yield of mustard. The experiment consisted of 80 kg of nitrogen to mustard of which 50 kg of nitrogen was supplied by urea and 30 kg of nitrogen was supplied either by poultry manure or by farmyard manure or by vermicompost with and without *Azotobacter* seed inoculation; which was compared with 80 kg of nitrogen supplied through urea alone. The result showed that application of 50 kg nitrogen through urea + 30 kg nitrogen through poultry manure + *Azotobacter* (seed inoculation) gave significantly heavier weight of 1000-seeds (4.90 g).

Jamwal (2000) carried out a field experiment to study the effect of integrated nutrient management on growth, yield, quality, nutrient uptake and economics of mustard. The experimental soil was clay loam in texture, low in available N and organic malter, medium in available P and K contents with neutral soil reaction (pH). The experiment was laid out with nine (9) treatment combinations of organic and inorganic fertilizers. Mustard variety Pusa bold was sown in lines 30 cm apart using 5 kg seed ha^{-1}. The results revealed that application of either recommended dose of fertilizers (RDF) or 75% of RDF along with 5 t FYM manure ha^{-1} or 75% of RDF + 2.5 t poultry manure ha^{-1} were at par with each other and all these treatments significantly improved growth, yield and nutrient uptake in mustard crop over rest of the treatments. However, the weight of 1000-seeds remained unaffected.

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

Meitei and Bajpay (2019) carried out an experiment to evaluate the effect of organic manures with or without combination of inorganic fertilizers on transplanted Gobhi Sarson (*Brassica napus* L.) on various growth and yield attributing traits of transplanted Gobhi sarson. The effect of eight treatments *viz.*, (T_1) 20 t ha^{-1} Farm yard manure, (T_2) 10 t ha^{-1} Farm yard manure + ½ Nitrogen, (T_3) 10 t ha^{-1} Poultry manure, (T_4) 5 t ha^{-1} Poultry manure + ½ Nitrogen, (T_5) 5 t ha^{-1} Farm yard manure + 5 t ha^{-1} Poultry manure, (T_6) 5 t ha^{-1} Vermicompost, (T_7) 40:12 (Recommended Dose of Fertilizer) and (T_8) Control were studied on various growth and yield attributing parameters of *Brassica napus*. The findings revealed that upon various treatments combination, Treatment T_4: application of 5 t ha^{-1} Poultry manure + ½ Nitrogen produced significantly higher grain yield (2329.0 kg ha^{-1}).

Murali *et al*. (2018) conducted a field experiment to find out the effect of different levels of organic manure on the growth and yield of mustard (*Brassica juncea* L.) under Jatropha (*Jatropha circus* L.) based agroforestry system. The soil of experimental plot was sandy loam in texture, nearly neutral in soil reaction (pH 6.7), low in organic carbon (0.35%), N (230 kg ha^{-1}), P (20 kg ha^{-1}) and K (98 kg ha^{-1}), The treatment comprised of 3 levels of Farm Yard Manure (FYM), Vermicompost (VC) and Poultry Manure (PM), *viz*. T_1 (control), T_2 (100% FYM), T_3 (100% PM), T_4 (100% VC), T_5 (50% FYM + 50% VC), T_6 (50% FYM + 50% PM), T_7 (50% FYM + 25% VC + 25% PM), T_8 (25% FYM + 25% VC + 50% PM), T_9 (25% FYM + 25% PM + 50% VC). The result showed that maximum seed yield (1.49 t ha^{-1}) after harvest was recorded from treatment T_5 (50% FYM + 50% VC).

Reddy and Singh (2018) set up a field experiment during the Rabi season of 2017 on mustard crop (var. DHARA) to study the effect of integrated nitrogen management on growth and yield of mustard. The experiment consisted of 80 kg of nitrogen to mustard of which 50 kg of nitrogen was supplied by urea and

30 kg of nitrogen was supplied either by poultry manure or by farmyard manure or by vermicompost with and without *Azotobacter* seed inoculation; which was compared with 80 kg of nitrogen supplied through urea alone. The result showed that application of 50 kg nitrogen through urea + 30 kg nitrogen through poultry manure + *Azotobacter* (seed inoculation) gave significantly higher seed yield (2.37 t ha^{-1}).

Lim (2016) carried out an experiment on Two leafy vegetables i.e. leaf mustard (*Brassica juncea*) and lettuce (*Lactuca sativa*), which were grown on a coastal sandy soil (bris) with increasing rates of poultry manure (PM), with and without inorganic fertiliser (IF). The rates of PM applied were 0, 10, 20, 30 and 40 t ha^{-1} and IF ($N{:}P_2O_5{:}K_2O{:}MgO$ = 12:12:17:2) was applied at the rate of 1 t ha^{-1}, giving altogether 10 treatments. 10 t ha^{-1} PM gave higher yields than IF alone. Yields obtained with PM as the sole source of nutrients ranged from 62–96% of the yields with PM + IF for leaf mustard. Yield responses to increasing rates of organic fertiliser for leaf mustard showed a quadratic trend represented by the equation $Y = -0.0181x^2 + 1.0534x + 2.5537$. The optimum rate of poultry manure was 29.10 t ha^{-1} and the yield obtained was 17.90 t ha^{-1}. It was concluded that organic fertilisers as the sole source of nutrients can give good yields on bris soils.

Zamil *et al*. (2004) conducted 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 reared poultry manure, deep litter system reared poultry manure, cow dung and biogas slurry *viz*., 10 and 20 ton ha^{-1}, one control and one chemical fertilizer @ recommended dose (Urea: 200 kg ha^{-1}, TSP: 150 kg ha^{-1}, MoP: 70 kg ha^{-1}, Gypsum: 120 kg ha^{-1}, zinc: 5 kg ha^{-1}, Boric Acid: 10 kg ha^{-1} and decomposed cow dung: 10000 kg ha^{-1}). Cage system poultry manure @ 20-ton ha^{-1} significantly increased the seed yield of mustard and cow dung showed lower performance. In case of mustard seed, the highest uptake of N, P, K, Ca, Mg and S was obtained from cage system poultry manure @ 20 ton ha^{-1}. Protein

and oil content were also found higher in this treatment. Seed yield was found to be significantly and positively correlated with branch and effective pod per plant. Protein and oil contents of mustard seeds were increased with increasing level of animal manures though their effects were not significant. A positive and significant correlation was observed between protein and oil contents of mustard cv. Agrani. The overall results suggest that cage system poultry manure @ 20 ton ha^{-1} gave best performance among the parameters studied.

Jamwal (2000) carried out a field experiment to study the effect of integrated nutrient management on growth, yield, quality, nutrient uptake and economics of mustard. The experimental soil was clay loam in texture, low in available N and organic matter, medium in available P and K contents with neutral soil reaction (pH). The experiment was laid out with nine (9) treatment combinations of organic and inorganic fertilizers. Mustard variety Pusa bold was sown in lines 30 cm apart using 5 kg seed ha^{-1}. The results revealed that application of either recommended dose of fertilizers (RDF) or 75% of RDF along with 5 t FYM manure ha^{-1} or 75% of RDF + 2.5 t poultry manure ha^{-1} were at par with each other and all these treatments significantly improved growth, yield and nutrient uptake in mustard crop over rest of the treatments. The increase in seed yield was 80% with application of 75% of RDF + 5 t FYM ha^{-1} as compared to the treatment receiving only FYM @10 t ha^{-1}. The results have suggested that 25% nutrient requirement of mustard can be met through 5 t FYM ha^{-1} or 2.5 t poultry manure ha^{-1} for obtaining the yield at par with treatment receiving 100% recommended dose through chemical fertilizers.

Prasad *et al.* (1991) from the study on Indo-gangetic alluvial soil of Allahabad reported that incorporation of poultry manure as a source of organic matter @ 5 and 10 t ha^{-1} brought about significant increase in seed yield of mustard over control. It was recorded that application of 100 kg P_2O_5 in combination with 10 t ha^{-1} poultry manure significantly increased the grain yield of mustard.

Das *et al.* (1991) reported that poultry manure or piggery manure could be effectively used to increase the efficiency of P fertilizer in acid alfisol under the conditions of low organic matter soils. There was a marked increase in tissue concentration of P in mustard plants at flower initiation stage due to application of P fertilizer amended with organic manures. The researchers recorded the highest seed yield of mustard with the application of 5 t poultry manure ha^{-1} amended with 28 kg P ha^{-1}.

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

Meitei and Bajpay (2019) carried out an experiment to evaluate the effect of organic manures with or without combination of inorganic fertilizers on transplanted Gobhi Sarson (*Brassica napus* L.) on various growth and yield attributing traits of transplanted Gobhi sarson. The effect of eight treatments *viz.,* (T_1) 20 t ha^{-1} Farm yard manure, (T_2) 10 t ha^{-1} Farm yard manure + ½ Nitrogen, (T_3) 10 t ha^{-1} Poultry manure, (T_4) 5 t ha^{-1} Poultry manure + ½ Nitrogen, (T_5) 5 t ha^{-1} Farm yard manure + 5 t ha^{-1} Poultry manure, (T_6) 5 t ha^{-1} Vermicompost, (T_7) 40:12 (Recommended Dose of Fertilizer) and (T_8) Control were studied on various growth and yield attributing parameters of *Brassica napus*. The findings revealed that upon various treatments combination, Treatment T_4: application of 5 t ha^{-1} Poultry manure + ½ Nitrogen produced significantly higher stover yield (8592.2 kg ha^{-1}).

Murali *et al*. (2018) conducted a field experiment to find out the effect of different levels of organic manure on the growth and yield of mustard (*Brassica juncea* L.) under Jatropha (*Jatropha circus* L.) based agroforestry system. The soil of experimental plot was sandy loam in texture, nearly neutral in soil reaction (pH 6.7), low in organic carbon (0.35%), N (230 kg ha^{-1}), P (20 kg ha^{-1}) and K (98 kg ha^{-1}), The treatment comprised of 3 levels of Farm Yard Manure (FYM), Vermicompost (VC) and Poultry Manure (PM) viz. T_1 (control), T_2 (100% FYM), T_3 (100% PM), T_4 (100% VC), T_5 (50% FYM + 50% VC), T_6 (50% FYM + 50% PM), T_7 (50% FYM + 25% VC + 25% PM), T_8 (25% FYM + 25% VC + 50% PM), T_9 (25% FYM + 25% PM + 50% VC).

The result showed that maximum stalk yield (1.93 t ha^{-1}) was recorded from treatment T_5 (50% FYM + 50% VC).

Reddy and Singh (2018) set up a field experiment during the Rabi season of 2017 on mustard crop (var. DHARA) to study the effect of integrated nitrogen management on growth and yield of mustard. The experiment consisted of 80 kg of nitrogen to mustard of which 50 kg of nitrogen was supplied by urea and 30 kg of nitrogen was supplied either by poultry manure or by farmyard manure or by vermicompost with and without *Azotobacter* seed inoculation; which was compared with 80 kg of nitrogen supplied through urea alone. The result showed that application of 50 kg nitrogen through urea + 30 kg nitrogen through poultry manure + *Azotobacter* (seed inoculation) gave significantly higher stalk yield (6.62 t ha^{-1}).

Zamil *et al*. (2004) conducted 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 reared poultry manure, deep litter system reared poultry manure, Cowdung and biogas slurry *viz*., 10 and 20 ton ha^{-1}, one control and one chemical fertilizer @ recommended dose (Urea: 200 kg ha^{-1}, TSP: 150 kg ha^{-1}, MoP: 70 kg ha^{-1}, Gypsum: 120 kg ha^{-1}, zinc: 5 kg ha^{-1}, Boric Acid: 10 kg ha^{-1} and decomposed cow dung: 10000 kg ha^{-1}). Cage system poultry manure @ 20-ton ha^{-1} significantly increased the stover yield of mustard and Cowdung showed lower performance. In stover, the highest uptake of N, P, K, Ca, Mg and S was obtained from cage system poultry manure @ 20 ton ha^{-1}.

2.1.10 Harvest Index (%)

Meitei and Bajpay (2019) carried out an experiment to evaluate the effect of organic manures with or without combination of inorganic fertilizers on transplanted Gobhi Sarson (*Brassica napus* L.) on various growth and yield attributing traits of transplanted Gobhi sarson. The effect of eight treatments *viz.,* (T_1) 20 t ha^{-1} Farm yard manure, (T_2) 10 t ha^{-1} Farm yard manure + ½

Nitrogen, (T_3) 10 t ha^{-1} Poultry manure, (T_4) 5 t ha^{-1} Poultry manure + ½ Nitrogen, (T_5) 5 t ha^{-1} Farm yard manure + 5 t ha^{-1} Poultry manure, (T_6) 5 t ha^{-1} Vermicompost, (T_7) 40:12 (Recommended Dose of Fertilizer) and (T_8) Control were studied on various growth and yield attributing parameters of *Brassica napus*. The findings revealed that upon various treatments combination, Treatment T_4: application of 5 t ha^{-1} Poultry manure + ½ Nitrogen, produced significantly higher harvest index (23.6%).

Reddy and Singh (2018) set up a field experiment during the Rabi season of 2017 on mustard crop (var. DHARA) to study the effect of integrated nitrogen management on growth and yield of mustard. The experiment consisted of 80 kg of nitrogen to mustard of which 50 kg of nitrogen was supplied by urea and 30 kg of nitrogen was supplied either by poultry manure or by farmyard manure or by vermicompost with and without *Azotobacter* seed inoculation; which was compared with 80 kg of nitrogen supplied through urea alone. The result showed that application of 50 kg nitrogen through urea + 30 kg nitrogen through poultry manure + *Azotobacter* (seed inoculation) gave significantly higher harvest index (26.35%).

2.2 Effect of weeding

2.2.1 Plant height (cm)

Gupta *et al.* (2018) carried out a field experiment during two consecutive rabi seasons of 2013–14 and 2014–15 to study the effect of weed management practices on yield, weed dynamics and economics of mustard and to find out the most effective and economic weed management practice for mustard under semi-arid conditions of Rajasthan. The experiment consisted of 10 treatments *viz.* T_1: weedy check, T_2: Pendimethalian 30 EC @ 0.75 kg ha^{-1}, T_3: pendimethalian 38.7 CS @ 0.75 kg ha^{-1}, T_4: Oxadiargyl 6EC @ 0.09 kg ha^{-1}, T_5: Pendimethlian 30 EC + Imazethapyr 2 EC (ready mix) @ 0.75 kg ha^{-1}, T_6: Oxyflurofen 23.5 EC @ 0.15 kg ha^{-1}, T_7: Quizalofop-p-ethyl 5EC @ 0.06 kg ha^{-1}, T_8: Clodinafop-p-ethyl 15WP @ 0.06 kg ha^{-1}, T_9: one hand weeding

(HW) at 25–30 DAS and T_{10}: Two hand weeding at 25–30 and 40–45 DAS were evaluated in Randomized Block Design with three replications. The experiment revealed that the plant height of mustard improved slightly due to application of weed management treatments over weedy check. The mean maximum plant height of 165.4 cm was recorded under 2 HW, which was statistically at par with other treatments and significantly superior over treatment T_5 during both the years. The mean increases in plant height due to treatment T_3 were 8.4 and 54.7 cm, respectively over weedy check (T_1) and treatment T_5.

Akhter *et al.* (2016) set up an experiment to study the effects of sowing time and weed management on the yield and yield components of three varieties of rapeseed (*Brassica campestris* L.). The experiment was laid out in a split-split plot design with three replications. Each replicated field was divided into four main plots for sowing treatments (S_1 = 18 October, S_2 = 2 November, S_3 = 17 November, S_4 = 3 December). Each main plot was divided into three sub-plots for weeding treatment (W_0 = No weeding, W_1 = one hand weeding, W_2 = two hand weeding). They found that BINA Sarisha-6 possessed the maximum plant height (110.39 cm) while BARI Sarisha-14 had the minimum plant height (92.17 cm). Among the treatments, two hand-weeding plots had the highest plant height (101.94 cm) while plots with no weeding had the minimum plant height (96.92 cm).

Afroj (2015) set up a field experiment study the effect of source of nitrogen and weed control method on the performance of mustard cv. BARI Sarisha-14. The treatment consisted of four sources of nitrogen viz. N_0 = No nitrogen (Control), N_1 = Prilled urea, N_2 = NPK mixed fertilizer and N_3 = Urea super granule; and three different weeding methods viz. W_0 = No weeding, W_1 = Hand weeding and W_2 = Herbicidal weeding. The tallest plant (55.49 cm) of mustard was produced with hand weeding.

Awal and Fardous (2014) conducted an experiment to study the effect of a single weeding on the growth and yield of two species of mustard namely *Brassica napus* and *Brassica campestris.* The experiment comprised of 4 (four) treatments from the combination of those two species of mustard *viz.* (i) *Brassica napus* and (ii) *Brassica campestris*, represented by the cultivars BINA Sarisha-5 and BINA Sarisha-6, respectively along with two weeding regimes *viz.* (a) one hand weeding on 40 days after sowing (DAS) or (b) without weeding (i.e. control). They reported that the tallest mustard plant (137.53 cm) was obtained from weeding condition along with the species *Brassica campestris* whereas the shortest plant (85.03 cm) was found in interaction with or without weeding along with *Brassica napus*. The taller plants were observed from weeded plots compared to that at non-weeded plots throughout the growing period.

Kibria (2013) carried out an experiment to study the effect of irrigation and weeding on the yield components and yield of mustard (SAU sarisha-3). The treatment consisted of four irrigation viz. I_0 = No irrigation, I_1 = One irrigation at 20 DAS (just before flowering), I_2 = Two irrigation [1st at 20 DAS + 2nd at 40 DAS (during siliquae formation)], I_3 = Three irrigation [1st at 20 DAS + 2nd at 40 DAS + 3rd at 60 DAS (during seed maturation stage)] and three different weeding viz. W_0 = No weeding (Control), W_1 = One weeding at 10 DAS, W_2 = Two weeding [1st at 10 DAS + 2nd at 20 DAS]. The tallest plant (102.10 cm) was produced by two weedings. The shortest plant (97.73 cm) was produced by no weedings.

Sharma and Jain (2002) from their experiment on effect of herbicides on weed dynamics and seed yield of Indian mustard (*Brassica juncea*) reported that plant height was found to be taller in weeding condition in mustard crop field.

Gaffer (1984) observed that height of mustard plant was favourably increased with the spell of weed free periods by hand weeding.

2.2.2 Dry matter weight

Awal and Fardous (2014) from their experiment on the effect of a single weeding on the growth and yield of two species of mustard namely *Brassica napus* and *Brassica campestris* recorded that initial low accumulation of TDM increased rapidly till 85 DAS followed by a slower increase. Results showed that the higher TDM (484.42 g m^{-2}) obtained from the weeding condition along with species *Brassica campestris* whereas the lower TDM (375.45 g m^{-2}) was found in no weeding along with *Brassica napus*.

Hamzei *et al.* (2007) carried out an experiment on critical period of weed control in three winter oilseed rape (*Brassica napus* L.) cultivars reported that Total Dry Matter (TDM) was larger in weed free condition as compared to un-weedy situation. A single weeding had significant effect on TDM accumulation. Irrespective of the species, higher TDM was obtained from weeding condition than that of no weeding condition.

Roebuck *et al.* (1978) conducted an experiment on weed control of winter oilseed rape and observed that effective weed control on the autumn increased the total crop dry weight at the start of flowering by 80–90%.

2.2.3 Number of branches $plant^{-1}$

Akhter *et al.* (2016) from their experiment on the effects of sowing time and weed management on the yield and yield components of three varieties of rapeseed (*Brassica campestris* L.) found that BINA Sarisha-5 produced the highest number of branches $plant^{-1}$ (5.54) followed by BARI Sarisha-14 (4.22) and BINA Sarisha-6 (3.83). Comparison of the treatment means reflected that maximum number of branches $plant^{-1}$ (5.39) was recorded from the plots where two weeding were conducted; while minimum number of branches $plant^{-1}$ (3.39) was counted in the plots with no weeding.

Afroj (2015) set up a field experiment study the effect of source of nitrogen and weed control method on the performance of mustard cv. BARI Sarisha-14. The

treatment consisted of four sources of nitrogen viz. N_0 = No nitrogen (Control), N_1 = Prilled urea, N_2 = NPK mixed fertilizer and N_3 = Urea super granule; and three different weeding methods viz. W_0 = No weeding, W_1 = Hand weeding and W_2 = Herbicidal weeding. The maximum number of branches per plant (4.63) was obtained from hand weeding.

Awal and Fardous (2014) from their experiment on the effect of a single weeding on the growth and yield of two species of mustard namely *Brassica napus* and *Brassica campestris* reported that the number of branches plant^{-1} increased gradually with time. The interaction effect of weeding and species was found significant but the trend was irregular. However, the highest number of branches (11.07) was obtained at weeding treatment with *Brassica napus* plants and the lowest number (6.40) from no weeding along with *Brassica campestris*. Weeding gave the higher number of branches as compared to that of no weeding treatment.

Kibria (2013) carried out an experiment to study the effect of irrigation and weeding on the yield components and yield of mustard (SAU sarisha-3). The treatment consisted of four irrigation viz. I_0 = No irrigation, I_1 = One irrigation at 20 DAS (just before flowering), I_2 = Two irrigation [1st at 20 DAS + 2nd at 40 DAS (during siliquae formation)], I_3 = Three irrigation [1st at 20 DAS + 2nd at 40 DAS + 3rd at 60 DAS (during seed maturation stage)] and three different weeding viz. W_0 = No weeding (Control), W_1 = One weeding at 10 DAS, W_2 = Two weeding [1st at 10 DAS + 2nd at 20 DAS]. The maximum number of branches per plant (7.90) was produced by two weedings. The minimum number of branches per plant (7.16) was produced by no weedings.

Ray (2013) carried out a research work to compare the performance of different recommended managements on the growth and yield of mustard var. BARI Sharisha-13. The experimental treatments included T_1 = Control (no modern managements), T_2 = Fertilizer, irrigation, weeding, fungicide, mulching, insecticide, row arrangement), T_3 = All managements except irrigation T_4 = All

managements except weeding, T_5 = All managements except line sowing, T_6 = All managements except mulching, T_7 = All managements except insecticide, T_8 = All managements except fungicide, T_9 = All managements except fertilizers, T_{10} = All managements except insecticide and fungicide, T_{11} = All managements except irrigation and weeding, T_{12} = All managements except irrigation, weeding and fertilizer, T_{13} = All managements except mulching and weeding, T_{14} = All managements except weeding and fertilizer, T_{15} = All managements except insecticide, fungicide and irrigation and T_{16} = All managements except irrigation, weeding and insecticide. Results showed that treatment T_6 gave significantly the maximum number of secondary branches (5.1). Treatment T_7 gave the maximum number of primary branches (4.4).

Singh and Sinsinwar (2002) reported from their experiment on effect of cultural and chemical methods of weed control in Indian mustard (*Brassica juncea*) that hand weeding twice gave the maximum number of branches per plant in mustard. Weeding in mustard field gave the higher number of branches per plant as compared to no weeding treatment.

Gaffer (1984) observed that primary branches plant^{-1} of mustard were favourably increased with the spell of weed free periods.

2.2.4 Number of siliquae plant^{-1}

Gupta *et al.* (2018) carried out field experiments during two consecutive rabi seasons of 2013–14 and 2014–15 to study the effect of weed management practices on yield, weed dynamics and economics of mustard and to find out the most effective and economic weed management practice for mustard. They recorded that number of siliquae plant^{-1} was influenced significantly due to weed management practices during both the years. The maximum number of siliquae plant^{-1} (156.80) was observed in T_{10}: two hand weeding at 25–30 DAS and 40–45 DAS and the minimum number of siliquae plant^{-1} (117.80) was seen from T_5 [Pendimethlian 30 EC + Imazethapyr 2 EC (ready mix) @ 0.75 kg ha^{-1}] treatment.

Akhter *et al.* (2016) from their experiment on the effects of sowing time and weed management on the yield and yield components of three varieties of rapeseed (*Brassica campestris* L.) recorded that BINA Sarisha-5 had the highest number of siliquae plant^{-1} (65.67) followed by BARI Sarisha-14 (50.78) and BINA Sarisha-6 (46.22). The highest number of siliquae plant^{-1} (65.61) was recorded in the plots which received two hand weeding while the lowest number of siliquae plant^{-1} (44.44) was noted in plots with no weeding.

Afroj (2015) set up a field experiment study the effect of source of nitrogen and weed control method on the performance of mustard cv. BARI Sarisha-14. The treatment consisted of four sources of nitrogen viz. N_0 = No nitrogen (Control), N_1 = Prilled urea, N_2 = NPK mixed fertilizer and N_3 = Urea super granule; and three different weeding methods *viz.* W_0 = No weeding, W_1 = Hand weeding and W_2 = Herbicidal weeding. The maximum number of siliquae per plant (22.75) was obtained from hand weeding.

Awal and Fardous (2014) from their experimental results on the effect of a single weeding on the growth and yield of two species of mustard namely *Brassica napus* and *Brassica campestris* recorded that the highest siliquae plant^{-1} (82.53) was obtained from the weeding condition along with species *Brassica campestris*; whereas, the lowest siliquae plant^{-1} (62.42) was found in no weeding along with *Brassica napus*.

Kibria (2013) carried out an experiment to study the effect of irrigation and weeding on the yield components and yield of mustard (SAU sarisha-3). The treatment consisted of four irrigation viz. I_0 = No irrigation, I_1 = One irrigation at 20 DAS (just before flowering), I_2 = Two irrigation [1st at 20 DAS + 2nd at 40 DAS (during siliquae formation)], I_3 = Three irrigation [1st at 20 DAS + 2nd at 40 DAS + 3rd at 60 DAS (during seed maturation stage)] and three different weeding viz. W_0 = No weeding (Control), W_1 = One weeding at 10 DAS, W_2 = Two weeding [1st at 10 DAS + 2nd at 20 DAS]. The maximum

number of siliquae per plant (131.50) was produced by two weedings. The minimum number of siliquae per plant (117.50) was produced by no weedings.

Ray (2013) carried out a research work to compare the performance of different recommended managements on the growth and yield of mustard var. BARI Sharisha-13. The experimental treatments included T_1 = Control (no modern managements), T_2 = Fertilizer, irrigation, weeding, fungicide, mulching, insecticide, row arrangement), T_3 = All managements except irrigation T_4 = All managements except weeding, T_5 = All managements except line sowing, T_6 = All managements except mulching, T_7 = All managements except insecticide, T_8 = All managements except fungicide, T_9 = All managements except fertilizers, T_{10} = All managements except insecticide and fungicide, T_{11} = All managements except irrigation and weeding, T_{12} = All managements except irrigation, weeding and fertilizer, T_{13} = All managements except mulching and weeding, T_{14} = All managements except weeding and fertilizer, T_{15} = All managements except insecticide, fungicide and irrigation and T_{16} = All managements except irrigation, weeding and insecticide. Results showed that treatment T_6 gave significantly the maximum number of siliquae plant^{-1} (169).

Omprakash (2002) conducted an experiment on weed management in Indian mustard (*Brassica juncea*) and recorded that the weeding gave the higher number of siliquae per plant in mustard.

Singh and Singh (2001) from their field study on effect of weed management on nutrient uptake in *Brassica* species observed that the weeding gave the greater number of siliquae per plant in mustard.

Yadav *et al.* (1999) observed that siliquae yields of rapeseed were significantly increased by removing weeds at 2, 4, 6 and 8 week after sowing (WAS). Further delayed on weed removal had little effect on production of siliquae.

Bowerman (1990) from his experimental results on weed control in winter oilseed rape reported that the weeding gave the greater number of siliquae per plant in mustard.

2.2.5 Number of seeds siliqua^{-1}

Gupta *et al.* (2018) conducted field experiments during two consecutive rabi seasons of 2013–14 and 2014–15 to study the effect of weed management practices on yield, weed dynamics and economics of mustard and to find out the most effective and economic weed management practice for mustard under semi-arid conditions of Rajasthan. Their experiments revealed that the highest number of seeds siliquae^{-1} (13.07) was observed in two hand weeding and the lowest number of seeds siliquae^{-1} (9.32) from T_5 [Pendimethlian 30 EC + Imazethapyr 2 EC (ready mix) @ 0.75 kg ha^{-1}] treatment which was statistically similar with T_1 (weedy check) treatment.

Akhter *et al.* (2016) set up a field experiment to study the effects of sowing time and weed management on the yield and yield components of three varieties of rapeseed (*Brassica campestris* L.). They recoded that BINA Sarisha-5 produced the maximum number of seeds siliquae^{-1} (26.61) followed by BARI Sarisha-14 (19.22) and BINA Sarisha-6 (18.39). The maximum number of seeds siliquae^{-1} (22.36) obtained from two hand-weeding treatment, while the lowest number of seeds siliquae^{-1} (20.44) was found in no weeding treatment.

Afroj (2015) set up a field experiment study the effect of source of nitrogen and weed control method on the performance of mustard cv. BARI Sarisha-14. The treatment consisted of four sources of nitrogen viz. N_0 = No nitrogen (Control), N_1 = Prilled urea, N_2 = NPK mixed fertilizer and N_3 = Urea super granule; and three different weeding methods viz. W_0 = No weeding, W_1 = Hand weeding

and W_2 = Herbicidal weeding. The maximum number of seeds per silliqua (26.31) was obtained from hand weeding.

Awal and Fardous (2014) experimental results to assess the effect of a single weeding on crop growth and yield of two mustard species, *Brassica napus* and *Brassica campestris* revealed that the maximum number of seeds siliqua^{-1} (21.04) obtained from the weeding condition along with species *Brassica campestris* whereas the minimum number of seeds siliqua^{-1} (18.31) was found in no-weeding along with *Brassica campestris*.

Kibria (2013) carried out an experiment to study the effect of irrigation and weeding on the yield components and yield of mustard (SAU sarisha-3). The treatment consisted of four irrigation viz. I_0 = No irrigation, I_1 = One irrigation at 20 DAS (just before flowering), I_2 = Two irrigation [1st at 20 DAS + 2nd at 40 DAS (during siliquae formation)], I_3 = Three irrigation [1st at 20 DAS + 2nd at 40 DAS + 3rd at 60 DAS (during seed maturation stage)] and three different weeding viz. W_0 = No weeding (Control), W_1 = One weeding at 10 DAS, W_2 = Two weeding [1st at 10 DAS + 2nd at 20 DAS]. The maximum number of seeds per silliqua (20.02) was produced by two weedings. The minimum number of seeds per silliqua (18.82) was produced by no weedings.

Chemale and Fleck (1984) carried out an experiment on mustard cultivars on competition with *Euphorbia microphylla*. They observed that the number of seeds siliqua^{-1} decreased with increasing weed density.

2.2.6 Weight of 1000-seeds

Gupta *et al.* (2018) carried out field experiment during two consecutive Rabi seasons of 2013–14 and 2014–15 to study the effect of weed management practices on yield, weed dynamics and economics of mustard and to find out the most effective and economic weed management practice for mustard. The experiment consisted of 10 treatments *viz.* T_1: weedy check, T_2: Pendimethalian 30 EC @ 0.75 kg ha^{-1}, T_3: pendimethalian 38.7 CS @ 0.75 kg ha^{-1}, T_4: Oxadiargyl 6EC @ 0.09 kg ha^{-1}, T_5: Pendimethlian 30 EC + Imazethapyr 2 EC

(ready mix) @ 0.75 kg ha^{-1}, T_6: Oxyflurofen 23.5 EC @ 0.15 kg ha^{-1}, T_7: Quizalofop-p-ethyl 5EC @ 0.06 kg ha^{-1}, T_8: Clodinafop-p-ethyl 15WP @ 0.06 kg ha^{-1}, T_9: one hand weeding (HW) at 25–30 DAS and T_{10}: Two hand weeding at 25–30 and 40–45 DAS were evaluated in Randomized Block Design with three replications. They recorded that the maximum weight of 1000 seeds (4.33 g) was observed in T_{10} (two hand weeding) treatment and the minimum weight of 1000 seeds (3.97 g) was observed from T_1 (Weedy check) treatment.

Akhter *et al.* (2016) from their experiment on the effects of sowing time and weed management on the yield and yield components of three varieties of rapeseed (*Brassica campestris* L.) recorded that the highest weight of 1000 seeds was produced by BINA Sarisha-5 (3.14 g) while the lowest weight of 1000 seeds was found in BINA Sharisha-6 (2.84 g) in both growing seasons. Among the weeding treatments, the maximum weight of 1000 seeds (3.14 g) was obtained from two hand-weeding plots while the minimum weight of 1000 seeds (2.80 g) was obtained from plots with no weeding.

Awal and Fardous (2014) experimental results to assess the effect of a single weeding on crop growth and yield of two mustard species, *Brassica napus* and *Brassica campestris* showed that the maximum weight of 1000 seeds (2.98 g) obtained from the weeding condition along with species *Brassica napus* whereas the minimum weight of 1000 seeds (2.52 g) was found in no weeding along with *Brassica campestris*.

2.2.7 Grain yield

Gupta *et al.* (2018) conducted field experiments during two consecutive rabi seasons of 2013–14 and 2014–15 to study the effect of weed management practices on yield, weed dynamics and economics of mustard and to find out the most effective and economic weed management practice for mustard. Their experimental results revealed that the highest seed yield (16.96 q ha^{-1}) was observed in T_{10} (two hand weeding) treatment and the lowest seed yield (9.67 q

ha^{-1}) was reported from T_5 (Pendimethlian 30 EC + Imazethapyr 2 EC (ready mix) @ 0.75 kg ha^{-1}) treatment which was statistically similar with T_1 (weedy check) treatment.

Paul (2018) conducted an experiment to study the performance of different weed management techniques affecting growth and yield of different mustard varieties. The experiment comprised of two factors *viz*., (i) three mustard varieties - V_1 = BARI Sharisha-14, V_2 = BARI Sharisha-15 and V_3= BARI Sharisha-17 and (ii) Five Weed managements *viz*., W_0 = No weeding (control), W_1 = One hand weeding at 10 DAS, W_2 = Two hand weeding at 10 and 20 DAS, W_3 = Panida 33EC (Pendemethylin) @ 2000 ml ha^{-1} at 5 DAS and W_4 = Whipsuper (Fenoxaprop-p-ethyl) 9EC @ 750 ml ha^{-1} at 21 DAS. Among the mustard varieties 'BARI Sharisha-17' performed superior than other varieties and it produced (1.61 t ha^{-1}) seed which was 96.34% higher than BARI Sharisha-14 (0.82 t ha^{-1}). In case of weed managements, two hand weeding at 10 and 20 DAS (W_2) resulted better than other treatments and the estimated seed yield (1.61 t ha^{-1}) was recorded which was 69.47% higher than no weeding treatment (0.95 t ha^{-1}). Similar trend was observed in interaction of variety and weed managements. BARI Sharisha-17 (V_3) along with two hand weeding at 10 and 20 DAS (W_2) produced maximum seed yield (1.89 t ha^{-1}) which was 329.54% higher than BARI Sharisha-14 (V_1) along with no weeding treatment. BARI Sharisha-17 along with two hand weeding at 10 and 20 DAS was found to be a better mustard cultivation package in cultivating mustard.

Bamboriya *et al.* (2017) carried out field investigation to evaluate the effect of different weed management practices on yield and nutrient uptake of mustard. The experiment comprises of 10 treatments, which were i) weedy check, ii) one hand weeding at 20 DAS, iii) two hand weeding at 20 and 40 DAS, iv) fenoxaprop-p-ethyl 0.075 kg ha^{-1} at 10 DAS, v) fluazifop-p-butyl 0.055 kg ha^{-1} at 10 DAS, vi) quizalofop-p-ethyl 0.050 kg ha^{-1} at 30 DAS, vii) fenoxaprop-p-ethyl 0.075 kg ha^{-1} at 10 DAS + one hoeing at 40 DAS, viii) fluazifop-p-butyl 0.055 kg ha^{-1} at 10 DAS + one hoeing at 40 DAS, ix) isoproturon 1.25 kg ha^{-1}

at 30 DAS and x) weed free check. They reported that the maximum seed yield (1955.25 kg ha^{-1}) was recorded from two hand-weeding treatment except weed free check and was at par with fluazifop-p-butyl 0.055 kg ha^{-1} 10 DAS + hoeing 40 DAS and fenoxaprop-p-ethyl 0.075 kg ha^{-1} 10 DAS + hoeing 40 DAS, while the minimum seed yield (1166.75 kg ha^{-1}) was recorded from weedy check treatment.

Akhter *et al.* (2016) set up an experiment to study the effects of sowing time and weed management on the yield and yield components of three varieties of rapeseed (*Brassica campestris* L.). Their experimental results revealed that among the varieties, BINA Sarisha-5 gave the highest seed yield (840 kg ha^{-1}) and BINA Sarisha-6 produced the lowest seed yield (609 kg ha^{-1}). The maximum seed yield (898.50 kg ha^{-1}) was produced from the plots that received two hand-weeding; while the minimum seed yield (515 kg ha^{-1}) was obtained from no weeding treatment.

Afroj (2015) set up a field experiment study the effect of source of nitrogen and weed control method on the performance of mustard cv. BARI Sarisha-14. The treatment consisted of four sources of nitrogen viz. N_0 = No nitrogen (Control), N_1 = Prilled urea, N_2 = NPK mixed fertilizer and N_3 = Urea super granule; and three different weeding methods *viz*. W_0 = No weeding, W_1 = Hand weeding and W_2 = Herbicidal weeding. The highest seed yield (1040.00 kg ha^{-1}) was obtained from hand weeding. The interaction effect of nitrogen and weeding had significant effect on almost all parameter. The highest seed yield (1382.00 kg ha^{-1}) was obtained from prilled urea with hand weeding interaction treatment.

Awal and Fardous's (2014) trial to assess the effect of a single weeding on crop growth and yield of two mustard species, *Brassica napus* and *Brassica campestris* revealed that the highest seed yield (1.52 t ha^{-1}) obtained from the weeding condition along with species *Brassica campestris* whereas the lowest seed yield (1.06 t ha^{-1}) was found in no weeding along with *Brassica napus.*

Kibria (2013) carried out an experiment to study the effect of irrigation and weeding on the yield components and yield of mustard (SAU sarisha-3). The treatment consisted of four irrigation viz. I_0 = No irrigation, I_1 = One irrigation at 20 DAS (just before flowering), I_2 = Two irrigation [1st at 20 DAS + 2nd at 40 DAS (during siliquae formation)], I_3 = Three irrigation [1st at 20 DAS + 2nd at 40 DAS + 3rd at 60 DAS (during seed maturation stage)] and three different weeding viz. W_0 = No weeding (Control), W_1 = One weeding at 10 DAS, W_2 = Two weeding [1st at 10 DAS + 2nd at 20 DAS]. The maximum seed yield (1.88 t ha^{-1}) was produced by two weedings. The minimum seed yield (1.60 t ha^{-1}) was produced by no weedings. The combinations of irrigation and weeding had significant effect on almost all parameters. The highest yield of seed per hectare (2.88 t) was obtained from two weedings and two irrigations treatment combination (I_2W_2). The control combination of irrigation and weeding (I_0W_0) produced the lowest seed yield per hectare (1.28 t).

According to Singh *et al.* (2013), many biotic stresses such as weeds cause severe yield losses up to 45% in rapeseed-mustard. Many of the weeds are specific to crop and / or location. *Orobanche aegyptiaca* is becoming great menace in rain-fed areas of Rajasthan, Madhya Pradesh and Haryana, whereas, *Chenopodium, Asphodelus, Melilotus* and *Trianthema spp*. cause serious yield losses in other areas. Unlike other oilseed crops, mustard suffers more from weed competition in early growth stages especially between 20–40 days after sowing. The weed management in mustard is done by both cultural and herbicidal approaches. Different di-nitroaniline herbicides are commonly used to eliminate weed species and most of these are effective against only narrow range of weed species. Thus, integration of herbicide at critical growth stages with one or two hand weeding at proper time for improving the weed suppressing effect of crop gives significant improvement in crop yield. Economic analysis revealed that fluchloralin and pendimethalin alone or in

combination with hand weeding at 30 days after sowing was the most economical practice.

Singh *et al.* (2009) from their experiment on effect of fertilizer placement and weed management practice on weed dynamics and yield of rain-fed mustard (*Brassica juncea* L.) observed that mustard seed yield was found to be the highest in weed free condition.

Rashid (2006) conducted an experiment to study the response of rapeseed line SAU-C-F7 in respect of yield, yield attributes and oil yield to different nitrogen levels and number of weeding. The treatment comprised of four (4) levels of nitrogen and three (3) levels of weeding. Different N level were 0 kg N ha^{-1} (N_0), 90 kg N ha^{-1} (N_1), 120 kg N ha^{-1} (N_2) and 150 kg N ha^{-1} (N_3). The weeding treatments were no weeding (W_0), one weeding at 20 DAS (W_1) and two weedings at 20 and 45 DAS (W_2). The results revealed that nitrogen at the rate of 120 kg ha^{-1} showed the best performance regarding to yield components and yields. The maximum seed yield ha^{-1} (2343.4 kg ha^{-1}) with 120 kg N ha^{-1} was 194.28%, 71.11% and 6.87% higher than the yield obtained from 0 kg, 90 kg and 150 kg N ha^{-1}, respectively. In case of weeding, it was observed that two hand weeding resulted in maximum production of yield and yield attributes as well as seed and oil yields. Two hand-weeding increased the seed yield by 17.66% over control. The interaction effect of nitrogen levels and number of weeding revealed that 120 kg N ha^{-1} along with two hand-weeding showed the best performance in producing the yield attributes and yields. Number of branches per plant, number of siliquae per plant, number of seeds per plant, 1000-seed weight has a significant correlation with seed yield per plant with the R-values of 0.91, 0.97, 0.88 and 0.96, respectively.

Roy (2006) carried out an experiment to study the influence of variety and number of weeding on the growth and yield of rapeseed. The treatment comprised of three varieties and four levels of weeding. The varieties were improved Tori-7, BARI sarisha-12 and SAU sarisha-1. The weeding treatments

were no weeding, one weeding at 20 DAS, two weedings at 20 and 30 DAS and three weedings at 20, 30 and 40 DAS. The growth behaviour of the three studied varieties was different and hence weeding recommendation varied. The variety SAU sarisha-1 showed the highest yield (1.57 t ha^{-1}) response with one weeding that followed by the same variety with two weedings (1.55 t per ha^{-1}) but BARI sarisha-12 responded better with two weedings. No weeding was needed for improved Tori-7 probably due to its earlier better growth coverage.

Sharma *et al.* (2005) set up a field experiment on weed management in Indian mustard (*Brassica juncea*) and observed that mustard seed yield was recorded the highest in weed free condition.

Tekale *et al.* (2005) from their study on effect of weed management practices on growth and yield contributing parameters of Indian mustard and their correlation with yield. The weed free management through timely manual weeding like hand weeding was found as the most effective treatment in improving the yield attributes with maximum seed yields in mustard.

Bazzaz *et al.* (2003) conducted an experiment in two successive rabi seasons (1998–1999 and 1999–2000) to find out the effective herbicide for weed control in mustard. Performance of Ronstar and Setoff were tested against one hand weeding at 25 days after sowing and unweeded control plots using three mustard varieties (Daulat, Dhali and Tori-7). Application of Ronstar gave 10 and 30% higher grain yield of mustard compared to hand weeding and unweeded control plots, respectively. Setoff reduced plant stand and yield attributes of mustard that causes 60–75% yield reduction compared to unweeded control plot. This indicates that Setoff is detrimental to weeds as well as mustard. Yield difference of the varieties was significant. Among the varieties, Daulat gave the highest grain yield. Interaction effect of varieties and weed control measures was significant. Across the seasons, Ronstar effectively reduced weed growth and consequently gave higher grain yield of mustard regardless of variety.

Pandey and Mishra (2003) set up an experiment involving 5 weed control treatments viz. weedy control, hand weeding, chemical, cultural, and chemical + cultural, in a rice-Indian mustard-mungbean cropping system. Hand weeding in rice was done at 30 days after transplanting, while in Indian mustard and mungbean at 20 DAS. In the cultural treatment, a hand-driven wooden hand plough was run between the line 35 DAS. Weed competition in the rice-Indian mustard-mungbean cropping system lowered the total grain productivity by 32%. The maximum decrease in grain productivity of rice, Indian mustard and mungbean was 35.3, 19.3 and 45.6%, respectively. Weed control treatments caused a significant increase in grain yield of crops in both years. Chemical + cultural and hand weeding caused a significant increase in grain yield of rice, while hand weeding and chemical treatments did that in mustard and mungbean.

Singh *et al.* (1999) conducted a field study on productivity and economics of Indian mustard (*Brassica juncea*) as influenced by varieties and weed control treatments and reported that *Chenopodium album* and *Chenopodium murale* made up 82% of the weed flora. One weeding at 30 DAS was effective and resulted the largest reduction of weed population and dry weight of weeds. The higher seed yields (18.41 and 17.68 q ha^{-1}) were also obtained from weeded treatment compared to the un-weeded control.

Yadav *et al.* (1999) from their study on weed control in Indian mustard (*Brassica juncea*) recorded that a single weeding from 20 to 40 DAS can minimize yield loss of mustard.

Joshi *et al.* (1991) studied the effect of weeding and weed free conditions on the growth and yield of mustard (*Brassica juncea*). They found that the maximum reduction in seed yield due to weed occurred between 20 and 40 days of growth in mustard.

Bowerman (1990) from his experiment on weed control in winter oilseed rape reported that significant yield increase could be achieved mainly where the level of weed control is high.

Chemale and Fleck (1984) set up an experiment to study the nature and magnitude of crop weed competition in intercropped chickpeas cv. Radhey and mustard cv. Varuna (4:1 row ratio). The loss of seed yield caused by crop competition with weeds until the time of crop maturity was 34% in mustard.

2.2.8 Stover yield

Gupta *et al.* (2018) carried out field experiments during two consecutive rabi seasons of 2013–14 and 2014–15 to study the effect of weed management practices on yield, weed dynamics and economics of mustard and to find out the most effective and economic weed management practice for mustard. They found that the highest stover yield (53.08 q ha^{-1}) was observed in T_{10} (two hand weeding) treatment and the lowest stover yield (31.25 q ha^{-1}) from T_5 (Pendimethlian 30 EC + Imazethapyr 2 EC (ready mix) @ 0.75 kg ha^{-1}) treatment which was statistically similar with T_1 (weedy check) treatment.

Bamboriya *et al.* (2017) from their field experiment to evaluate the effect of different weed management practices on yield and nutrient uptake of mustard noted that the maximum stover yield (5568.25 kg ha^{-1}) was recorded from two hand weeding treatment while the minimum stover yield (3943.00 kg ha^{-1}) was recorded from weedy check treatment.

Ray (2013) carried out a research work to compare the performance of different recommended managements on the growth and yield of mustard var. BARI Sharisha-13. The experimental treatments included T_1 = Control (no modern managements), T_2 = Fertilizer, irrigation, weeding, fungicide, mulching, insecticide, row arrangement), T_3 = All managements except irrigation T_4 = All managements except weeding, T_5 = All managements except line sowing, T_6 = All managements except mulching, T_7 = All managements except insecticide, T_8 = All managements except fungicide, T_9 = All managements except

fertilizers, T_{10} = All managements except insecticide and fungicide, T_{11} = All managements except irrigation and weeding, T_{12} = All managements except irrigation, weeding and fertilizer, T_{13} = All managements except mulching and weeding, T_{14} = All managements except weeding and fertilizer, T_{15} = All managements except insecticide, fungicide and irrigation and T_{16} = All managements except irrigation, weeding and insecticide. Results showed that treatment T_6 gave significantly the maximum chaff weight (3.1 t ha^{-1}). Treatment T_7 gave the maximum stover yield (5.7 t ha^{-1}).

2.2.9 Biological yield

Bamboriya *et al.* (2017) conducted a field experiment to evaluate the effect of different weed management practices on yield and nutrient uptake of mustard. The results of their experiment showed that the highest biological yield (7523.50 kg ha^{-1}) was recorded from two hand weeding treatment while the lowest biological yield (5109.75 kg ha^{-1}) was seen in weedy check treatment.

Awal and Fardous (2014) carried out a field experiment to assess the effect of a single weeding on crop growth and yield of two mustard species, *Brassica napus* and *Brassica campestris*. Results showed that the highest biological yield (4.84 t ha^{-1}) obtained from the weeding condition along with species *Brassica campestris* whereas the lowest biological yield (3.75 t ha^{-1}) was found in no weeding along with *Brassica napus.*

Ray (2013) carried out a research work to compare the performance of different recommended managements on the growth and yield of mustard var. BARI Sharisha-13. The experimental treatments included T_1 = Control (no modern managements), T_2 = Fertilizer, irrigation, weeding, fungicide, mulching, insecticide, row arrangement), T_3 = All managements except irrigation T_4 = All managements except weeding, T_5 = All managements except line sowing, T_6 = All managements except mulching, T_7 = All managements except insecticide, T_8 = All managements except fungicide, T_9 = All managements except fertilizers, T_{10} = All managements except insecticide and fungicide, T_{11} = All

managements except irrigation and weeding, T_{12} = All managements except irrigation, weeding and fertilizer, T_{13} = All managements except mulching and weeding, T_{14} = All managements except weeding and fertilizer, T_{15} = All managements except insecticide, fungicide and irrigation and T_{16} = All managements except irrigation, weeding and insecticide. Treatment T_{13} gave the maximum biological yield (9.56 t ha^{-1}).

2.2.10 Harvest index (%)

Awal and Fardous (2014) field trial to assess the effect of a single weeding on crop growth and yield of two mustard species, *Brassica napus* and *Brassica campestris* showed that the highest harvest index (33.88 %) obtained from the weeding condition along with species *Brassica napus* whereas the lowest harvest index (27.81%) was found in no weeding along with *Brassica campestris*.

Singh *et al.* (2000) from their field experiment on integrated weed management in Indian mustard (*Brassica juncea*) reported that harvest index was higher in weed free condition as compared to un-weeded control.

2.3 Weed parameters

2.3.1 Weed Population

Bamboriya *et al.* (2017) carried out a field investigation to evaluate the effect of different weed management practices on yield and nutrient uptake of mustard. Use of post emergence herbicides of 'fop' group such as fluazifop-p-butyl, quizalofop-p-ethyl, fenoxaprop-p -ethyl (which are mostly used in soybean and groundnut crop) in Indian mustard found most effective in controlling grassy weeds in early stage whereas at latterly, one hoeing 40 DAS was found effective in controlling grassy as well as broad leaved weeds under irrigated conditions.

Kaur *et al*. (2013) conducted an experiment to study the effect of different weed control treatments on growth and yield of rapeseed. Eight herbicide treatments, *viz*. trifluralin at 0.48 kg and 0.60 kg ha^{-1} (pre-plant and pre-emergence), pendimethalin at 0.56 kg and 0.75 kg ha^{-1} (pre-emergence), pendimethalin at 0.75 kg ha^{-1} (pre-plant) and oxyfluorfen at 0.25 kg ha^{-1} (pre-emergence), two hand weeding (25 and 45 days after sowing) and unweeded control were kept. Two hand weeding, pre-plant application of trifluralin at 0.60 kg ha^{-1} and pre-plant and pre-emergence application of pendimethalin at 0.70 kg ha^{-1} significantly decreased dry weight of associated weeds as compared to unweeded control. Weed control efficiency recorded similar trend as of dry matter of weeds.

Tekale *et al.* (2005) from their study on effect of weed management practices on growth and yield contributing parameters of Indian mustard and their correlation with yield stated that one hand weeding in mustard field at 25 DAS gave the lowest weed count, weed dry weight and weed growth rate.

Pandey and Mishra (2003) set up an experiment involving 5 weed control treatments viz. weedy control, hand weeding, chemical, cultural, and chemical + cultural, in a rice-Indian mustard-mungbean cropping system. Hand weeding in rice was done at 30 days after transplanting, while in Indian mustard and mungbean at 20 DAS. In the cultural treatment, a hand-driven wooden hand plough was run between the line 35 DAS. The principal weed species that competed were *Echinochloa colonum* (*E. colona*) and *E. crusgalli* in rice, *Phalaris minor* in Indian mustard and *Trianthema portulacastrum* in mungbean. In all the three crops, with all weed control treatments, weed population and dry weight of weed were recorded significantly lower compared to the weedy control. Chemical + cultural, hand weeding and chemical treatments resulted in a marked decrease in weeds, the decreases being higher in the former two treatments.

Chapter 3

Materials & Methods

CHAPTER III

MATERIALS AND METHODS

This chapter presents a brief description about experimental period, site description, climatic condition, crop or planting materials, treatments, experimental design, crop growing procedure, fertilizer application, uprooting of seedlings, intercultural operations, data collection and statistical analysis.

3.1 Location of the experimental field

The field experiment was conducted at the research field of Sher-e- Bangla Agricultural University Farm, Dhaka during the period from November 2018 to February 2019. The experimental area was located at 23.74° N latitude and 90.35° E longitude with an elevation of 8.2 m from the sea level. The location of the experimental site has been shown in Appendix I.

3.2 Soil of the experimental field

Soil of the experimental site was silty clay loam in texture belonging to Tejgaon series. The area represents the Agro-Ecological Zone of Madhupur tract (AEZ No. 28) with pH 5.8–6.5, ECE-25–28. The selected plot was above flood level and sufficient sunshine was available having available irrigation and drainage system during the experimental period. The analytical data of the soil sample collected from the experimental area were determined in the Soil Testing Laboratory of Soil Resources Development Institute (SRDI), Khamarbari, Dhaka and have been presented in Appendix II.

3.3 Climate of the experimental field

The experimental area was under the subtropical climate and was characterized by high temperature, high humidity and heavy precipitation with occasional gusty winds but scanty rainfall associated with moderately low temperature prevailed during the period from March to August (Idris *et al*., 1979). The

climate of the locality is subtropical which is characterized by high temperature and heavy rainfall during *kharif* season (April–September) and scanty rainfall during Rabi season (October–March) associated with moderately low temperature. The detailed meteorological data in respect of air temperature, relative humidity, rainfall and sunshine hour recorded by the meteorology centre, Dhaka for the period of experimentation have been presented in Appendix III.

3.4 Plant materials and features

Mustard cv. BARI Sharisha-14 was used as plant material for the present study. This variety is recommended for *Rabi* season. The features of this variety are presented below:

BARI Sharisha-14 (*Brassica campestris*) was released by Oil Seed Research Centre of Bangladesh Agricultural Institute in 1997 crossing 'Tori 7' with 'Sonali sorisha' by hybridization technique and released as BARI Sharisha-14 variety in 2006 by National Seed Board. It can produce 25–30% more mustard than 'Tori 7'. The characteristics of BARI Sharisha-14 are as follows:

Plant height	:	75–85 cm
Leaf	:	Light green
Maturity	:	75–80 days
Siliquae plant^{-1}	:	80–100
Seeds siliquae^{-1}	:	22–26
Seed colour	:	Yellow
Weight of 1000-seeds	:	3.5–3.8 g
Yield	:	1.40–1.60 t ha^{-1}

3.5 Collection of plant materials

The seeds of mustard cv. BARI Sharisha-14 were collected from the Agronomy Division, Bangladesh Agricultural Research Institute, Gazipur, Bangladesh.

The seeds were healthy, vigorous, well matured and free from other crop seeds and inert materials.

3.6 Experimental treatments

The experiment consisted of two factors as mentioned below:

Factor A: Fertilizer management: 4 levels

P_0 : Recommended dose of fertilizer

P_1 : Recommended dose of fertilizer + recommended dose of poultry manure

P_2 : 25 % reduction of recommended dose of fertilizer + recommended dose of poultry manure

P_3 : 50 % reduction of recommended dose of fertilizer + recommended dose of poultry manure

The recommendation followed in this experiment was as per BARI, 2006 as mentioned in Table 1.

Factor B: Mechanical weed control: 3 levels

M_0 : No weed control

M_1 : Mechanical weed control once (at 20 DAS)

M_2 : Mechanical weed control twice (at 15 and 30 DAS)

3.6.1 Treatment combinations

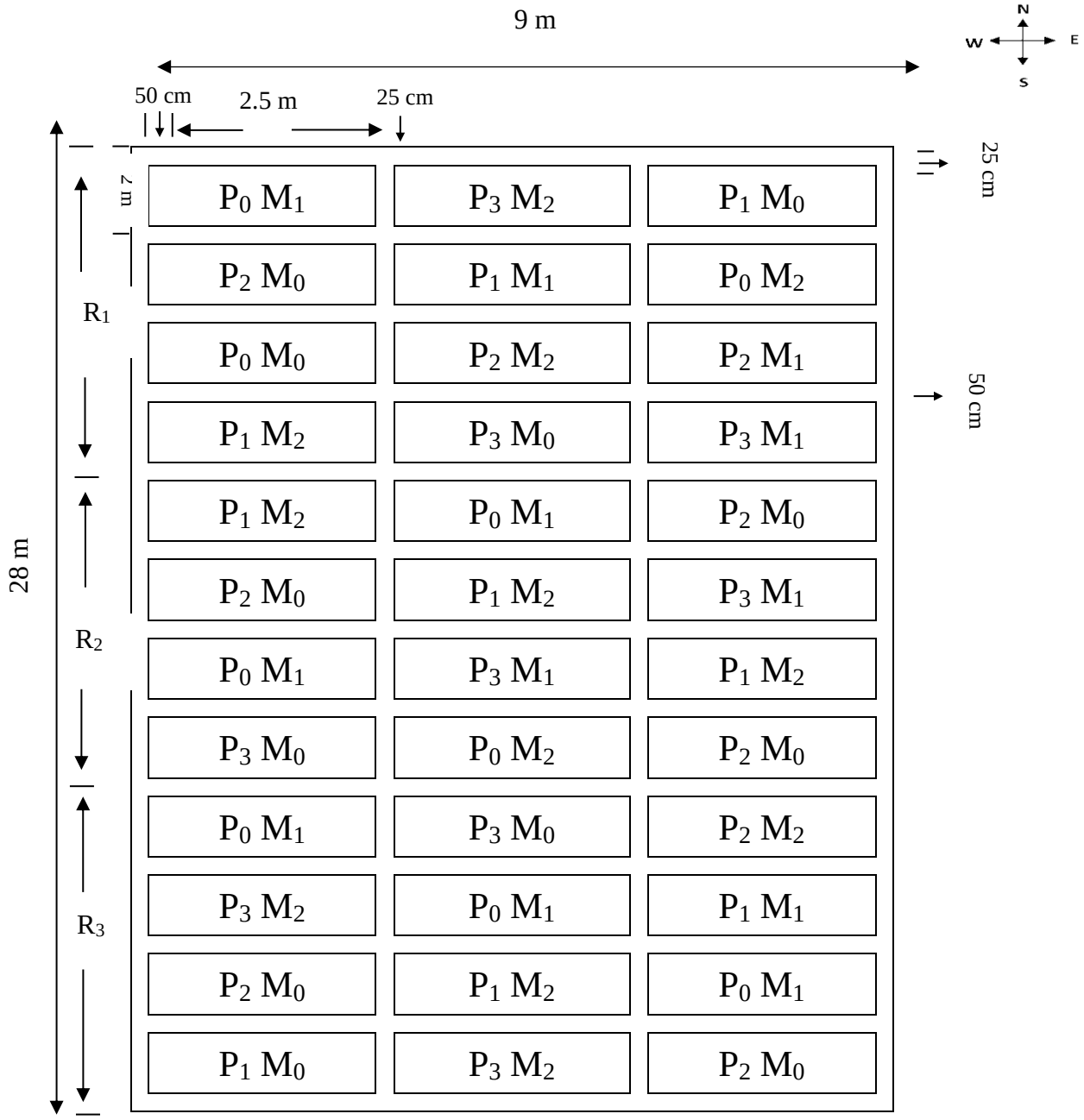
Based on the above mentioned two treatment factors, the experiment consists of 12 treatment combinations as P_0M_0, P_0M_1, P_0M_2, P_1M_0, P_1M_1, P_1M_2, P_2M_0, P_2M_1, P_2M_2, P_3M_0, P_3M_1 and P_3M_2.

3.6.2 Experimental design and layout

The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. The size of the individual plot was 4.0 m × 2.5 m and total number of plots was 36. There were 12 treatment combinations. Layout of the experiment was done on 01 November 2018 with inter-plot spacing of 0.50 m and inter-block spacing of 1 m (Figure 1).

3.7 Land preparation

Power tiller was used to open the experimental field first time on 01 November 2018. Then it was exposed to the sunshine for 7 days prior to the next ploughing. Thereafter, the land was ploughed and cross-ploughed with the help of power tiller to obtain good tilth. Deep ploughing was done to produce a good tilth, which was necessary to get better yield of this crop. Laddering was done in order to break the clods into small pieces followed by each ploughing. All the weeds and stubble were removed from the experimental field. The plots were spaded one day before planting and the whole amount of fertilizers were incorporated thoroughly before planting according to fertilizer recommendation of BARI (2006). At final land preparation Furadan 5G was applied in the field @ 8 kg ha^{-1} to protect young plants from the attack of mole cricket, ants and cutworms. Land preparation was completed on 08 November 2018 and was ready for sowing seeds.



Unit Plot Size = 4.0 m × 2.5 m Plot Spacing = 0.25 m Between replication = 0.50 m

P_0 : Recommended dose of fertilizer,
P_1 : Recommended dose of fertilizer + recommended dose of poultry manure,
P_2 : 25 % reduction of recommended dose of fertilizer + recommended dose of poultry manure,
P_3 : 50 % reduction of recommended dose of fertilizer + recommended dose of poultry manure.

M_0 : No weed control,
M_1 : Mechanical weeding once (20 DAS) and
M_2 : Mechanical weeding twice (15 DAS and 30 DAS).

Figure 1: Field layout of the experiment in Randomized Complete Block design (RCBD)

3.8 Manures and fertilizers

The calculated entire amount of all manures and fertilizers were applied during final plot preparation according to the design and treatment. The applied manures were mixed properly with the soil in the plot using a spade. The dose and time of application of organic and inorganic fertilizers are shown in below:

Table 1: Recommended doses of organic and inorganic fertilizers and their application modes in mustard field (BARI, 2006).

Manure and Fertilizers	Dose (ha^{-1})	Application (%)	
		Basal	1st instalment
Urea	220 kg	66.66	33.33
TSP	180 kg	100	-
MoP	85 kg	100	-
Gypsum	150 kg	100	-
Zinc oxide	5 kg	100	-
Boric acid	6 kg	100	-
Poultry manure	10 ton	100	-

3.9 Seed treatment

Before sowing seeds were treated with Provex-200 @ 0.25 % to prevent seeds from the attack of soil borne disease.

3.10 Sowing of seeds

Seeds were sown at the rate of 7 kg ha^{-1} in the furrow on 10 November 2018 and the furrows were covered with the soils soon after seeding. The line-to-line (furrow-to-furrow) distance was 30 cm.

3.11 Intercultural operations

3.11.1 Thinning out

Emergence of seedlings was completed within 7 days after sowing. Thinning was done maintaining 10 cm plant-to-plant distance at 20 November 2018 to remove unhealthy and lineless seedlings.

3.11.2 Water management

Pre-sowing irrigation in rows was given to ensure the maximum germination percentage. Three irrigations were applied in the field at 10, 25, and 45 days after sowing (DAS). Proper drainage system was also developed for draining out excess water.

3.11.3 Weeding

Weed control was done as per experimental treatments.

3.11.4 Disease and pest management

The experimental crop was not infected with any disease and no fungicide was used. Hairy caterpillars attacked the young plants and accumulated on the lower surface of leaves where they usually sucked juice of green leaves. Borers also attacked the crop plants. They attacked at the early growing stages of seedlings. To control these pests, the infected leaves were removed from the stem and destroyed together with the insects by hand picking. Besides, pyriphos and triel @ 20 ml were also applied to control these insects. To control aphid Malathion 57 EC @ 2 ml L^{-1} was applied 2 times at 10 DAS interval. The insecticide was sprayed whenever it needed.

3.12 Harvesting and processing

The crop was harvested manually depending upon the maturity from each plot starting from 02 February 2019. For collecting yield, data plants of central 4 m^2 areas of the plots were harvested. During harvest, randomly selected 10 plants of each plot were cut at the ground level with sickle, bundled, and tagged carefully for recording some necessary morphological and yield contributing parameters data. The harvested plants of pre-demarcated 4 m^2 area of each treatment plots were brought to the cleaned threshing floor. Thereafter siliquae and seeds were separated from plants by hand and allowed them for drying well under bright sunlight. Finally, seeds or grain yield was taken on individual plot basis at moisture content of 14 % and converted into t ha^{-1}.

3.13 Data Collection

Ten (10) plants from each plot were selected at random and were tagged for the data collection. Some data were collected from sowing to harvesting with 10 days interval and some data were collected at harvest. The sample plants were uprooted prior to harvest and dried properly in the sun. The seed yield and stover yield per plot were recorded after cleaning and drying those properly in the sun. Data were collected on the following parameters:

A. Crop growth parameters

i. Plant height (cm)

ii. Leaves plant^{-1} (no.)

iii. Branches plant^{-1} (no.)

iv. Dry weight plant^{-1} (g)

B. Yield and yield components

i. Siliqua plant^{-1} (no.)

ii. Seeds silliqua^{-1} (no.)

iii. Length of silliqua (cm)

iv. Weight of 1000-seeds (g)

v. Grain yield (t ha^{-1})

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

vii. Biological yield (t ha^{-1})

viii. Harvest index (%)

C. Weed parameters

Weed population (No. m^{-2})

3.13.1 Crop Growth parameters

a) Plant height (cm)

Plant height was measured in centimetre by a meter scale at 20, 35, 50, 65 DAS (Days after sowing) and at harvest period. Data were recorded as the average of

randomly selected 10 plants from the inner rows of each plot. Plant height from the ground surface to the top of the main shoot and the mean height were expressed in cm.

b) Number of leaves plant^{-1}

Number of leaves plant^{-1} was recorded from 10 plants of each treatment at 20, 35, 50, 65 DAS (Days after sowing) and at harvest period and mean value was calculated.

c) Branches plant^{-1} (no.)

Number of branches plant^{-1} data was also recorded at 35, 50, 65 DAS (Days after sowing) and at harvest where all the primary and secondary branches were considered in each plant.

d) Dry weight plant^{-1} (g)

The plant dry matter weight was measured by oven dry method. Ten plants were uprooted randomly from each plot at 35, 50, 65 DAS and at harvest, and were gently washed to remove sand and dust particles adhered to the plants. Then the water adhered to the plants were soaked with paper towel. Thereafter the samples were kept in an oven at 70˚C for 72 hours to attain constant weight. When the plant samples were attained at constant weight, the dry weights of the date were recorded.

3.13.2 Yield and yield components

a) Siliqua plant^{-1} (no.)

Siliqua collected from ten randomly selected plants of each plot were counted at 50, 65 DAS and at harvest and then the average number of silliqua for each plant was determined.

b) Seeds silliqua^{-1} (no.)

Total number of seed was counted from the selected 20 siliquae of ten randomly selected plants of each plot and averaged them to have number of seeds siliqua^{-1}.

c) Length of silliqua (cm)

Siliqua length was recorded from the base to the apex of each silliqua from randomly selected 20 silliqua of ten randomly selected plants of each plot and then means value was calculated.

d) Weight of 1000-seeds (g)

One thousand clean sun dried seeds were counted from the seed stock obtained from the sample plants, weighed by electronic balance and expressed in gram.

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

Total mustard plants were collected from pre-selected area (4 m^2) of the middle of each plot. The plants were cut, threshed and dried. Final grain yield was adjusted at 14% moisture. The dried grains were weighed. The grain yield t ha^{-1} was measured by the following formula:

$$\text{Grain yield (t ha}^{-1}\text{)} = \frac{\text{Grain yield per unit plot (kg)} \times 10000}{\text{Area of unit plot in square meter} \times 1000}$$

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

Stover obtained from each unit plot was sun-dried and weighed carefully. The dry weight of stover of central 4 m^2 area was used to record the final stover yield plot^{-1} which was finally converted to t ha^{-1}. The stover yield t ha^{-1} was measured by the following formula:

$$\text{Stover yield (t ha}^{-1}) = \frac{\text{Stover yield per unit plot (kg)} \times 10000}{\text{Area of unit plot in square meter} \times 1000}$$

g) Biological yield (t ha^{-1})

Grain and stover yields were altogether regarded as biological yield. The biological yield was calculated with the following formula-

$$\text{Biological yield (t ha}^{-1}) = \text{Grain yield (t ha}^{-1}) + \text{Straw yield (t ha}^{-1})$$

h) Harvest index (%)

Harvest index is the ratio of economic yield to biological yield and was calculated with the following formula-

$$\text{Harvest Index (\%)} = \frac{\text{Economic Yield (Grain weight)}}{\text{Biological Yield (Total weight)}} \times 100$$

3.13.3 Weed parameters

Weed population (No. m^{-2})

The data on weed infestation as well as density were collected from each treated plot at harvest period. A plant quadrate of 1.0 m^2 was placed at three different spots of 5 m^2 of the plot. The middle quadrate was remained undisturbed for yield data. The infesting species of weeds within the first and third quadrate were identified and their number was counted.

3.14 Statistical Analyses

The recorded data on different parameters were compiled and subjected to statistical analysis. Analyses of variance were done following a split plot design relating with MSTAT-C (Russell, 1986). The significant differences among the treatment means were compared by Least Significant Difference (LSD) at 5% levels of probability (Gomez and Gomez, 1984).

Chapter 4

Results and Discussion

CHAPTER IV

RESULTS AND DISCUSSION

This chapter comprises presentation and discussion of the results obtained from a study to investigate the performance of different fertilizer doses and weed management techniques affecting growth and yield of mustard. The results of the crop characters and weed parameters as influenced by different fertilizer doses and weed management techniques have been presented and discussed in this chapter.

4.1 Crop Growth parameters

4.1.1 Plant height (cm)

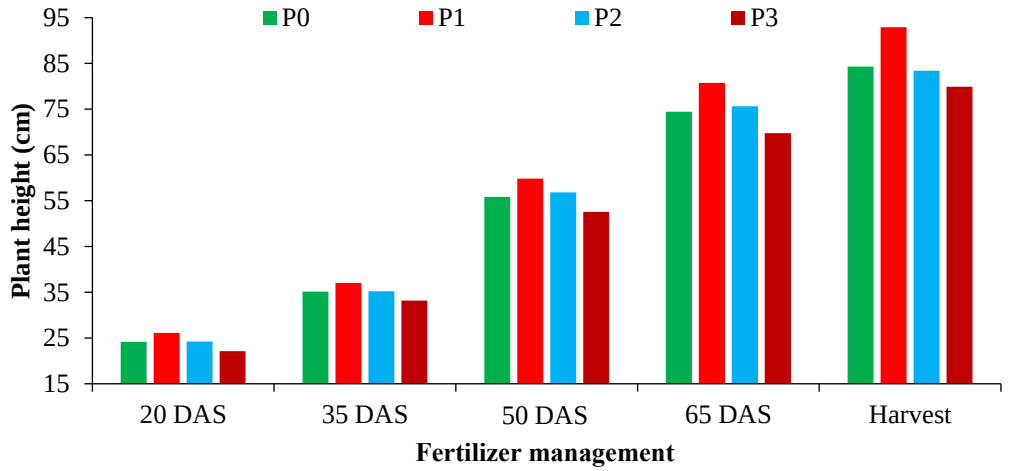
Effect of fertilizer management

Fertilizer doses significantly increased the plant height (Figure 2 and Appendix IV). Plant height was progressively increased with the increase of fertilizer doses. The tallest plant (26.08, 37.03, 59.83, 80.76 and 92.89 cm at 20, 35, 50, 65 DAS and at harvest, respectively) recorded from P_1 (Recommended dose of fertilizer + recommended dose of poultry manure) treatment. 50 % less fertilizer dose with poultry manure (P_3) treatment scored the shortest plant (22.12, 33.18, 52.53, 69.74 and 79.90 cm at 20, 35, 50, 65 DAS and at harvest, respectively). The increment of plant height with increased fertilizer doses was due to more expansion of plant cells rendering the elongation of tissues. These findings are in agreement with those of Singh *et al.* (2003), Tripathi and Tripathi (2003). Singh *et al.* (2002) and Tarafder and Mondal (1990).

Effect of mechanical weeding

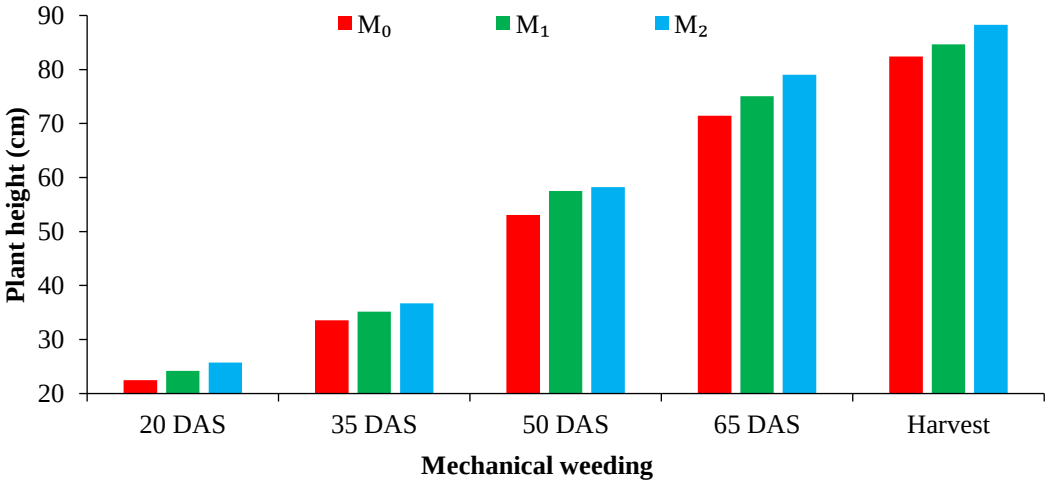
Plant height of the mustard cv. BARI Sharisha−14 was also influenced by the mechanical weeding (Figure 3 and Appendix IV). The tallest plants (25.72, 36.70, 58.22, 79.00 and 88.29 cm at 20, 35, 50, 65 DAS and at harvest,

respectively) were produced with two weeding at 15 and 30 DAS (M_2) treatment which was followed by one weeding treatment.



P_0 : Recommended dose of fertilizer without poultry manure, P_1 : Recommended dose of fertilizer with poultry manure, P_2 : 25 % less fertilizer dose with poultry manure and P_3 : 50 % less fertilizer dose with poultry manure.

Figure 2: Effect of Fertilizer management on plant height of mustard at different days after sowing (DAS) and at harvest (LSD value = 0.53, 1.55, 2.47, 0.93 and 1.91 at 20, 35, 50, 65 DAS and harvest, respectively).



M_0 : No weed control, M_1 : Mechanical weeding once (20 DAS) and M_2 : Mechanical weeding twice (15 DAS and 30 DAS).

Figure 3: Effect of mechanical weeding on plant height of mustard at different days after sowing (DAS) and at harvest (LSD value = 0.46, 1.35, 2.14, 0.81 and 1.65 at 20, 35, 50, 65 DAS and harvest, respectively).

The plant height was found minimum (22.48, 33.54, 53.08, 71.44 and 82.43 cm at 20, 35, 50, 65 DAS and at harvest, respectively) with no weeding. Weeding facilitates the plants to have more resources which rendering the increased plant height in this experiment. Paul (2018), Yadav *et al.* (1999) and Kibria (2013) also concluded that better growth and development of the crop under competition free environment with effective control of weeds due to different weed control treatments showed influence on the attaining higher plant height. The results are in agreement with those reported by Jangir *et al.* (2017), Awal and Fardous, (2014), Kumar *et al.* (2012), Rashid (2006), Singh (2006), Chauhan *et al.* (2005) and Sharma and Jain (2002) who exposed that plant height was found to be taller in weeding condition in mustard crop.

Interaction effect

The interaction effect between fertilizer doses and mechanical weeding on plant height was significant (Table 1 and Appendix IV). The tallest plant (27.70, 38.60, 62.76, 83.62 and 95.33 cm at 20, 35, 50, 65 DAS and at harvest, respectively) was recorded from the combination of Recommended dose of fertilizer with poultry manure and two mechanical weeding at 15 and 30 DAS (P_1M_2) which was statistically similar with P_1M_1 (37.20 and 60.35 cm at 35 and 50 DAS, respectively) and P_2M_2 (37.20 cm at 35 DAS) whereas, the shortest (20.35, 31.49, 48.05, 65.39 and 76.98 cm at 20, 35, 50, 65 DAS and at harvest, respectively) was obtained from 50 % less fertilizer dose with poultry manure and no weeding combination (P_3M_0).

Table 2: Interaction effect of Fertilizer management and mechanical weeding on plant height of mustard at different days after sowing (DAS) and at harvest

Treatment combination	Plant height (cm)				
	20 DAS	35 DAS	50 DAS	65 DAS	Harvest
P_0M_0	22.47 f	33.49 f	53.48 f	70.49 h	82.58 ef
P_0M_1	24.48 d	35.49 cd	56.70 c-e	73.48 f	84.35 de
P_0M_2	25.44 c	36.47 bc	57.40 cd	79.48 c	85.97 d
P_1M_0	24.27 d	35.28 c-e	56.39 c-e	77.39 d	90.81 bc
P_1M_1	26.28 b	37.20 ab	60.35 ab	81.25 b	92.52 b
P_1M_2	27.70 a	38.60 a	62.76 a	83.62 a	95.33 a
P_2M_0	22.84 f	33.90 ef	54.39 ef	72.49 g	79.34 h
P_2M_1	23.51 e	34.52 d-f	57.72 c	75.89 e	81.52 fg
P_2M_2	26.25 b	37.20 ab	58.35 bc	78.55 c	89.36 c
P_3M_0	20.35 g	31.49 g	48.05 g	65.39 j	76.98 i
P_3M_1	22.50 f	33.52 f	55.20 d-f	69.48 i	80.22 gh
P_3M_2	23.51 e	34.52 d-f	54.35 ef	74.35 f	82.49 ef
$LSD_{(0.05)}$	**0.53**	**1.55**	**2.47**	**0.94**	**1.91**
CV (%)	**10.30**	**8.61**	**8.59**	**6.73**	**7.32**

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

P_0 : Recommended dose of fertilizer without poultry manure, P_1 : Recommended dose of fertilizer with poultry manure, P_2 : 25 % less fertilizer dose with poultry manure and P_3 : 50 % less fertilizer dose with poultry manure.

M_0 : No weed control, M_1 : Mechanical weeding once (20 DAS) and M_2 : Mechanical weeding twice (15 DAS and 30 DAS).

4.1.2 Number of leaves plant^{-1}

Effect of Fertilizer management

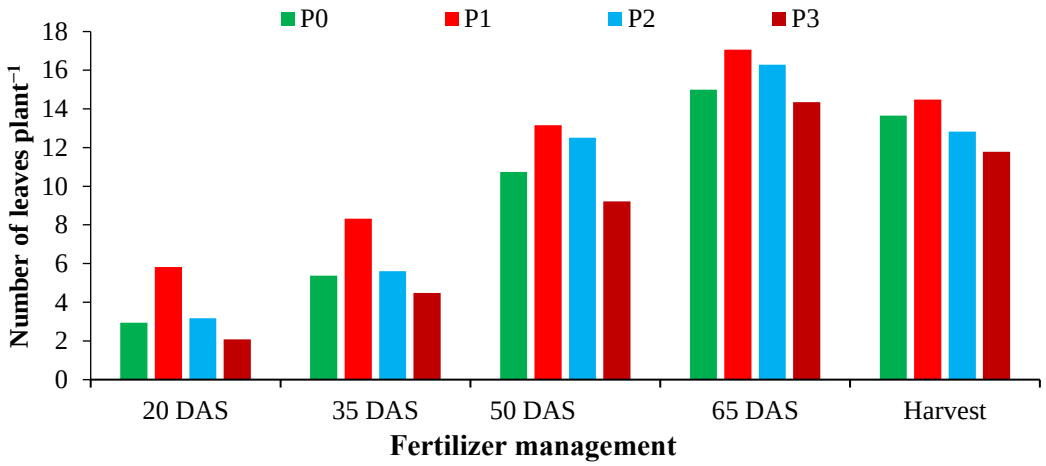
Significant difference in the number of leaves plant^{-1} was noted due to variation in fertilizer management (Figure 4 and Appendix V). Application of recommended dose of fertilizer with poultry manure (P_1) gave significantly highest (5.82, 8.33, 13.15, 17.06 and 14.48 at 20, 35, 50, 65 DAS and at harvest, respectively) number of leaves plant^{-1} whereas, the lowest (2.09, 4.49, 9.21, 14.35 and 11.78 at 20, 35, 50, 65 DAS and at harvest, respectively) was obtained from 50% less fertilizer dose with poultry manure (P_3).

Effect of mechanical weeding

Significant difference in the number of leaves plant^{-1} was noted due to variation in mechanical weeding (Figure 5 and Appendix V). Two weeding at 15 and 30 DAS (M_2) treatment gave significantly highest (3.07, 5.50, 10.55, 14.92 and 12.43 at 20, 35, 50, 65 DAS and at harvest, respectively) number of leaves plant^{-1} whereas, the lowest (3.53, 5.98, 11.50, 15.49 and 13.05 at 20, 35, 50, 65 DAS and at harvest, respectively) was obtained from no weeding (M_0).

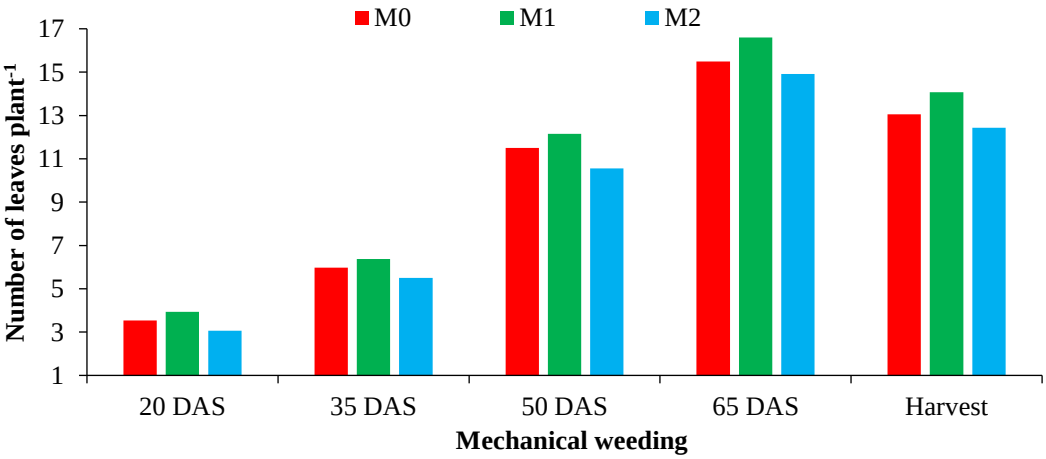
Interaction effect

The interaction effect between fertilizer doses and mechanical weeding on number of leaves plant^{-1} was significant (Table 2 and Appendix V). The highest number of leaves plant^{-1} (6.47, 9.00, 14.00, 18.89 and 16.73 at 20, 35, 50, 65 DAS and at harvest, respectively) was recorded from the combination of Recommended dose of fertilizer with poultry manure and two mechanical weeding at 15 and 30 DAS (P_1M_2) whereas, the lowest (1.81, 4.20, 8.34, 13.26 and 10.40 at 20, 35, 50, 65 DAS and at harvest, respectively) was obtained from 50 % less fertilizer dose with poultry manure and no weeding combination (P_3M_0).



P_0 : Recommended dose of fertilizer without poultry manure, P_1 : Recommended dose of fertilizer with poultry manure, P_2 : 25 % less fertilizer dose with poultry manure and P_3 : 50 % less fertilizer dose with poultry manure.

Figure 4: Effect of Fertilizer management on number of leaves plant^{-1} of mustard at different days after sowing (DAS) and at harvest (LSD value = 0.25, 0.05, 0.38, 0.38 and 0.23 at 20, 35, 50, 65 DAS and harvest, respectively).



M_0 : No weed control, M_1 : Mechanical weeding once (20 DAS) and M_2 : Mechanical weeding twice (15 DAS and 30 DAS).

Figure 5: Effect of mechanical weeding on number of leaves plant^{-1} of mustard at different days after sowing (DAS) and at harvest (LSD value = 0.22, 0.05, 0.33, 0.33 and 0.20 at 20, 35, 50, 65 DAS and harvest, respectively).

Table 3: Interaction effect of fertilizer dose and mechanical weeding on number of leaves plant^{-1} of mustard at different days after sowing (DAS) and at harvest

Treatment combination	Number of leaves plant^{-1}				
	20 DAS	35 DAS	50 DAS	65 DAS	Harvest
P_0M_0	3.20 d	5.64 f	10.78 f	14.48 g	13.29 c
P_0M_1	3.36 cd	5.80 e	11.34 e	15.48 e	14.39 b
P_0M_2	2.29 fg	4.70 i	10.10 g	15.00 f	13.29 c
P_1M_0	5.59 b	8.10 b	12.93 c	16.37 c	14.17 b
P_1M_1	6.47 a	9.00 a	14.00 a	18.89 a	16.73 a
P_1M_2	5.39 b	7.89 c	12.52 d	15.93 d	12.53 d
P_2M_0	3.23 d	5.67 f	12.80 cd	16.34 c	12.48 de
P_2M_1	3.50 c	5.95 d	13.48 b	17.01 b	12.49 de
P_2M_2	2.79 e	5.21 g	11.24 e	15.49 e	13.49 c
P_3M_0	1.81 h	4.20 k	8.34 i	13.26 h	10.40 f
P_3M_1	2.37 f	4.78 h	9.78 gh	15.02 f	12.67 d
P_3M_2	2.10 g	4.50 j	9.50 h	14.76 fg	12.27 e
$LSD_{(0.05)}$	**0.25**	**0.05**	**0.38**	**0.38**	**0.22**
CV (%)	**4.26**	**6.50**	**7.99**	**7.44**	**7.03**

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

P_0 : Recommended dose of fertilizer without poultry manure, P_1 : Recommended dose of fertilizer with poultry manure, P_2 : 25 % less fertilizer dose with poultry manure and P_3 : 50 % less fertilizer dose with poultry manure.

M_0 : No weed control, M_1 : Mechanical weeding once (20 DAS) and M_2 : Mechanical weeding twice (15 DAS and 30 DAS).

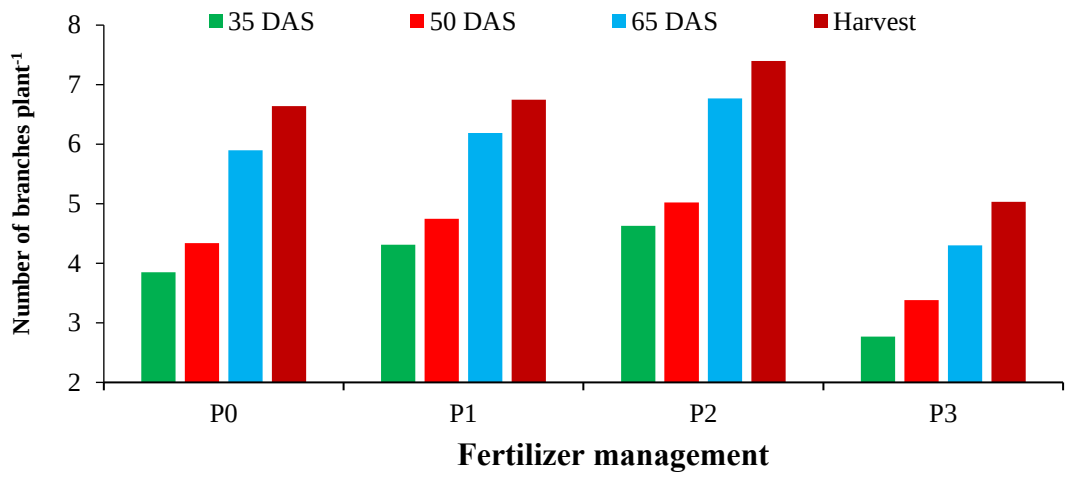
4.1.3 Number of branches plant^{-1}

Effect of Fertilizer management

The effect of fertilizer doses on number of branches plant^{-1} was found significant (Figure 6 and Appendix VI). The maximum number of branches plant^{-1} (4.63, 5.02, 6.77 and 7.40 at 35, 50, 65 DAS and at harvest, respectively) was recorded at 25 % less fertilizer dose with poultry manure (P_2) and the minimum (2.77, 3.38, 4.30 and 5.03 at 35, 50, 65 DAS and at harvest, respectively) was found in 50 % less fertilizer dose with poultry manure (P_3). The result of the present investigation was similar to the findings reported by Patil *et al*. (1996), Khanpara *et al*. (1992) and Murtuza and Paul (1989).

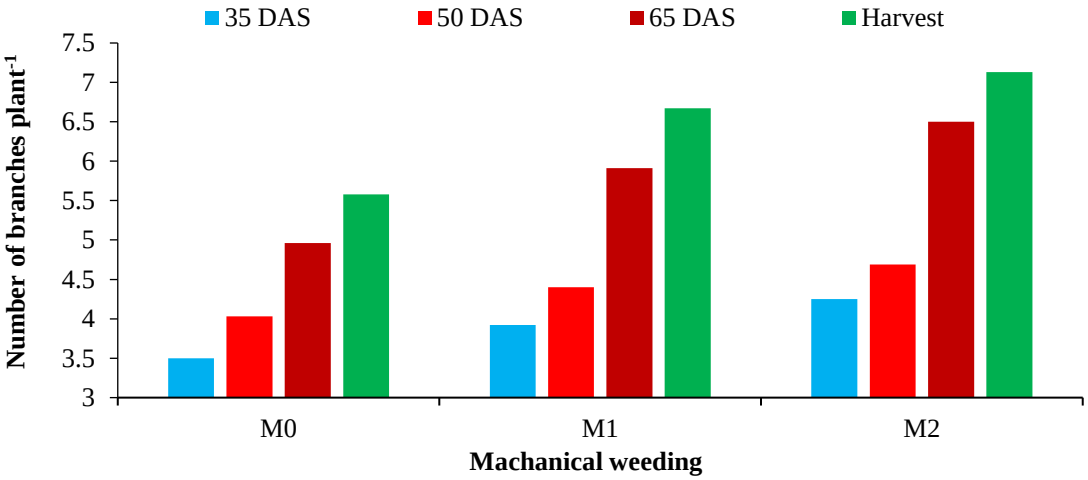
Effect of mechanical weeding

Different mechanical weed managements had significant effect on branches plant^{-1} over time (Figure 6 and Appendix VI). The results revealed that, M_2 produced maximum branches plant^{-1} (4.25, 4.69, 6.50 and 7.13 at 35, 50, 65 DAS and harvest, respectively) and the minimum (3.50, 4.03, 4.96 and 5.58 at 35, 50, 65 DAS and harvest, respectively) were produced by M_0. Under weed free condition, the plant growth was vigorous and plant produced more branches because there was no crop weed competition for natural resources (light, water, essential plant nutrients etc.). On the other hand, plant grown under no weeding plot competed with weed. Singh and Sinsinwar (2002) who observed that, hand weeding twice gave the greatest number of branches per plant in mustard. Weeding gave the higher number of branches as compared to no weeding treatment. Similar results were reported by Jangir *et al.* (2017), Awal and Fardous (2014), Kumar *et al.* (2012), Singh (2006) and Chauhan *et al.* (2005) in mustard crop.



P_0 : Recommended dose of fertilizer without poultry manure, P_1 : Recommended dose of fertilizer with poultry manure, P_2 : 25 % less fertilizer dose with poultry manure and P_3 : 50 % less fertilizer dose with poultry manure.

Figure 5: Effect of Poultry manure on number of branches plant^{-1} of mustard at different days after sowing (DAS) and at harvest (LSD value = 0.25, 0.05, 0.05 and 0.32 at 35, 50, 65 DAS and harvest, respectively).



M_0 : No weed control, M_1 : Mechanical weeding once (20 DAS) and M_2 : Mechanical weeding twice (15 DAS and 30 DAS).

Figure 6: Effect of mechanical weeding on number of branches plant^{-1} of mustard at different days after sowing (DAS) and at harvest (LSD value = 0.22, 0.05, 0.05 and 0.28 at 35, 50, 65 DAS and harvest, respectively).

Table 4: Interaction effect of Fertilizer management and mechanical weeding on number of branches plant^{-1} of mustard at different days after sowing (DAS) and at harvest

Treatment combination	Number of branches plant^{-1}			
	35 DAS	50 DAS	65 DAS	Harvest
P_0M_0	3.50 f	4.03 g	4.80 g	5.57 ef
P_0M_1	3.86 e	4.35 f	6.00 e	6.74 d
P_0M_2	4.20 cd	4.65 d	6.89 c	7.62 b
P_1M_0	3.98 de	4.45 e	5.01 f	5.73 e
P_1M_1	4.37 bc	4.80 c	6.45 d	7.13 c
P_1M_2	4.59 b	4.99 b	7.10 b	7.40 bc
P_2M_0	4.16 cd	4.61 d	5.98 e	6.69 d
P_2M_1	4.61 b	5.01 b	6.89 c	7.43 bc
P_2M_2	5.11 a	5.45 a	7.45 a	8.07 a
P_3M_0	2.35 h	3.01 j	4.04 j	4.31 g
P_3M_1	2.85 g	3.45 i	4.30 i	5.36 f
P_3M_2	3.10 g	3.67 h	4.56 h	5.42 ef
$LSD_{(0.05)}$	**0.25**	**0.05**	**0.05**	**0.32**
CV (%)	**8.38**	**7.56**	**7.42**	**9.97**

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

P_0 : Recommended dose of fertilizer without poultry manure, P_1 : Recommended dose of fertilizer with poultry manure, P_2 : 25 % less fertilizer dose with poultry manure and P_3 : 50 % less fertilizer dose with poultry manure.

M_0 : No weed control, M_1 : Mechanical weeding once (20 DAS) and M_2 : Mechanical weeding twice (15 DAS and 30 DAS).

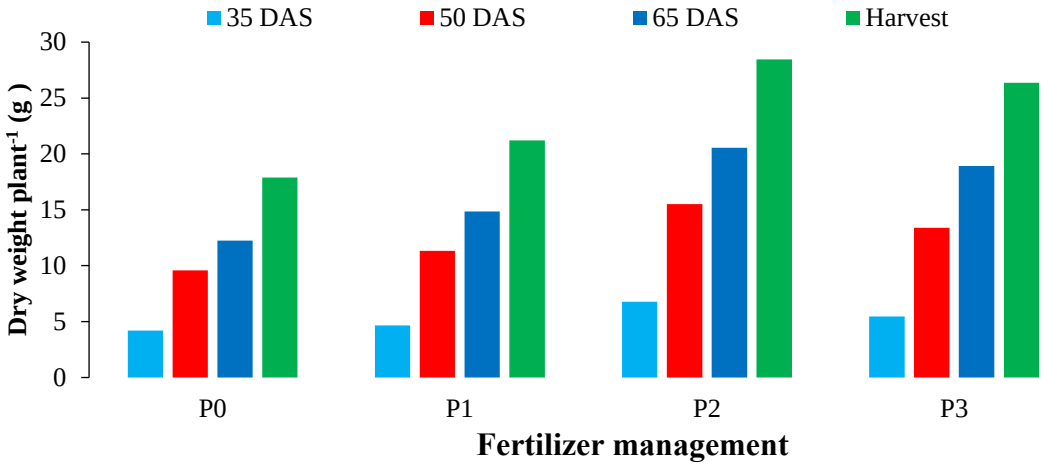
Interaction effect

A significant variation in the number of branches plant^{-1} was found with the interaction of fertilizer doses and mechanical weeding (Table 3 and Appendix VI). The maximum number of branches plant^{-1} (5.11, 5.45, 7.45 and 8.07 at 35, 50, 65 DAS and harvest, respectively) was found in combined use of 25 % less fertilizer dose with poultry manure and two times weeding (P_2M_2) treatment, whereas the minimum number of branches plant^{-1} (2.35, 3.01, 4.40 and 4.31 at 35, 50, 65 DAS and harvest, respectively) was found in 50 % less fertilizer dose with poultry manure and no weeding treatment (P_3M_0).

4.1.4 Dry weight plant^{-1} (g)

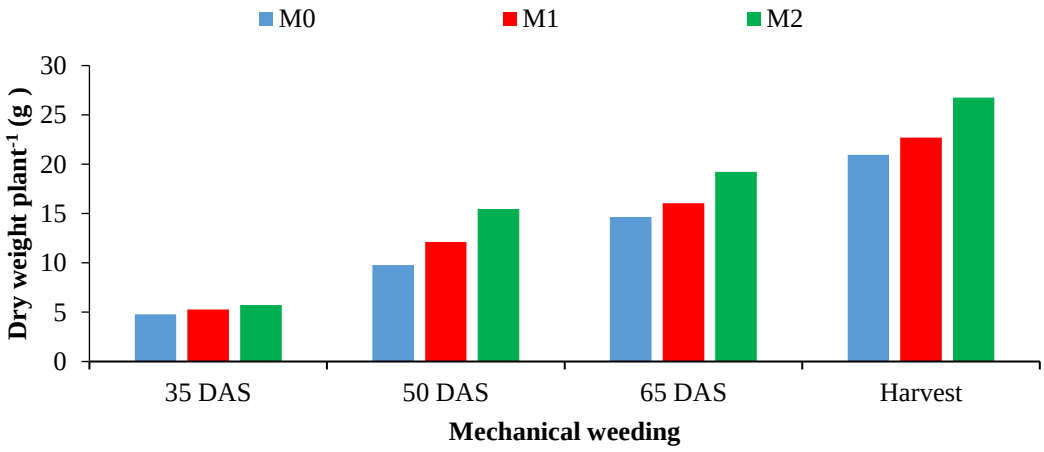
Effect of fertilizer

Significant variation was found in dry weight plant^{-1} due to the effect of different doses of fertilizer at different days after sowing and the analysis of variance has been shown in Appendix VII. Figure 8 showed that, the highest dry weight plant^{-1} (6.77, 15.51, 20.56 and 28.45 g at 35, 50, 65 DAS and at harvest, respectively) was taken from the treatment P_2 (25 % less fertilizer dose with poultry manure) which was closely followed by P_3 (50 % less fertilizer dose with poultry manure) (5.45, 13.40, 18.92 and 26.35 g at 35, 50, 65 DAS and at harvest, respectively). Significantly, the lowest dry weight plant^{-1} (4.21, 9.57, 12.24 and 17.88 g at 35, 50, 65 DAS and at harvest, respectively) was found in recommended dose of fertilizer without poultry manure (P_0) treatment. These results were supported by Saikia *et al.* (2002) and Patil *et al.* (1997).They found that application of poultry manure increased the total dry weight of mustard plant.



P_0 : Recommended dose of fertilizer without poultry manure, P_1 : Recommended dose of fertilizer with poultry manure, P_2 : 25 % less fertilizer dose with poultry manure and P_3 : 50 % less fertilizer dose with poultry manure.

Figure : 7. Effect of Fertilizer management on dry weight plant^{-1} of mustard at different days after sowing (DAS) and at harvest (LSD value = 0.05, 0.41, 0.19 and 0.50 at 35, 50, 65 DAS and harvest, respectively).



M_0 : No weed control, M_1 : Mechanical weeding once (20 DAS) and M_2 : Mechanical weeding twice (15 DAS and 30 DAS).

Figure 8: Effect of mechanical weeding on dry weight plant^{-1} of mustard at different days after sowing (DAS) and at harvest (LSD value = 0.05, 0.35, 0.16 and 0.43 at 35, 50, 65 DAS and harvest, respectively).

Effect of mechanical weeding

Dry weight plant^{-1} was significantly affected by different mechanical weed managements (Figure 8 and Appendix VII). From the early stages distinct differences were noticed among the weed managements in respect of dry matter production. The lowest dry weight plant^{-1} (4.80, 9.77, 14.66 and 20.95 g at 35, 50, 65 DAS and at harvest, respectively) throughout the growing period was observed in no weeding treatment (M_0). On the other hand, the highest dry weight plant^{-1} (5.73, 15.45, 19.24 and 26.77g at 35, 50, 65 DAS and at harvest, respectively) were observed in M_2 treatment. Under weed free condition the crop plant got facility to uptake more nutrients due to the suppression of weed growth that might have been the driving force behind higher dry matter and nutrient uptake in mustard under these weed control treatments especially two hand weeding. Such higher uptake might be attributed to higher seed yield production under better weed management treatments. Jangir *et al.* (2017) also reported that both the herbicide and hand weeding treatments suppressed the weed growth efficiently which is supplemented at the crucial stage of crop growth which checks the weed growth and resulted in better plant growth and increased the dry matter content of plant. The results were in agreement with those reported by Bamboriya *et al*. (2017), Awal and Fardous (2014), Mukherjee (2014), Chander *et al*. (2013), Kumar *et al.* (2012), Hamzei *et al.* (2007), Singh (2006) and Chauhan *et al.* (2005) who reported that dry matter weight of plant was larger in weed free condition as compared to un-weedy situation.

Interaction effect

The interaction effect between fertilizer doses and mechanical weeding on dry weight plant^{-1} was significant (Table 5 and Appendix VII). The highest dry weight plant^{-1} (7.29, 18.50, 21.68 and 29.87 g at 35, 50, 65 DAS and at harvest, respectively) was recorded from the combination of 25 % less fertilizer dose with poultry manure and two mechanical weeding at 15 and 30 DAS (P_2M_2) whereas, the lowest (3.97, 6.47, 8.20 and 12.75 g at 35, 50, 65 DAS and

at harvest, respectively) was obtained from recommended dose of fertilizer without poultry manure and no weeding combination (P_0M_0).

Table 5: Interaction effect of Fertilizer management and mechanical weeding on dry weight plant^{-1} of mustard at different days after sowing (DAS) and at harvest

Treatment combination	Dry weight plant^{-1} (g)			
	35 DAS	50 DAS	65 DAS	Harvest
P_0M_0	3.97 i	6.47 i	8.20 k	12.75 j
P_0M_1	4.21 h	8.75 h	10.25 j	15.37 i
P_0M_2	4.45 g	13.48 d	18.25 e	25.51 d
P_1M_0	4.20 h	9.75 g	12.84 i	18.64 h
P_1M_1	4.76 f	10.87 f	14.84 h	21.18 g
P_1M_2	4.98 e	13.36 d	16.89 g	23.79 f
P_2M_0	6.25 c	12.34 e	19.83 c	27.51 b
P_2M_1	6.78 b	15.68 c	20.18 b	27.97 b
P_2M_2	7.29 a	18.50 a	21.68 a	29.87 a
P_3M_0	4.78 f	10.52 f	17.77 f	24.90 e
P_3M_1	5.35 d	13.20 d	18.84 d	26.25 c
P_3M_2	6.21 c	16.47 b	20.14 b	27.91 b
$LSD_{(0.05)}$	**0.05**	**0.41**	**0.19**	**0.50**
CV (%)	**8.42**	**9.94**	**8.65**	**7.25**

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

P_0 : Recommended dose of fertilizer without poultry manure, P_1 : Recommended dose of fertilizer with poultry manure, P_2 : 25 % less fertilizer dose with poultry manure and P_3 : 50 % less fertilizer dose with poultry manure.

M_0 : No weed control, M_1 : Mechanical weeding once (20 DAS) and M_2 : Mechanical weeding twice (15 DAS and 30 DAS).

4.2 Yield and yield components

4.2.1 Number of siliqua plant^{-1}

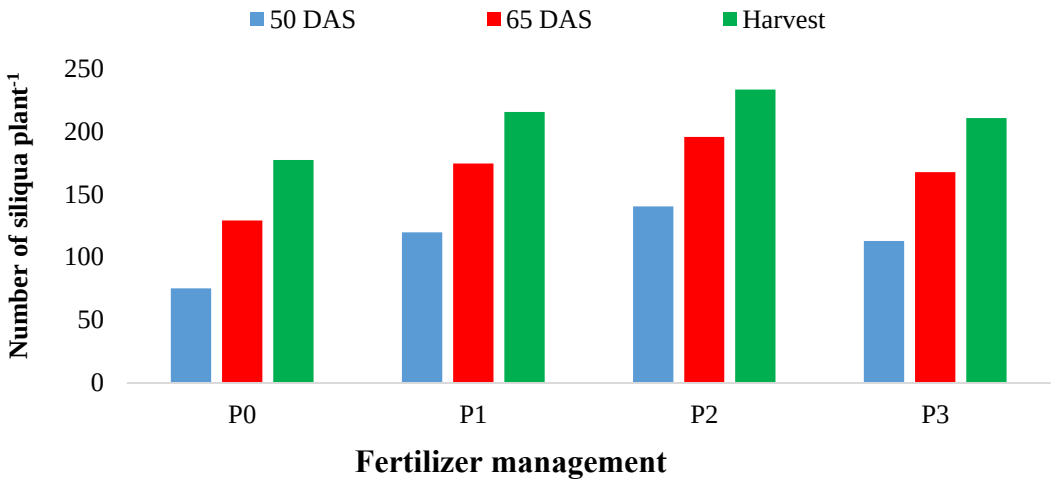
Effect of Fertilizer management

Application of different doses of fertilizer significantly influenced the number of siliqua plant^{-1} (Figure 9 and Appendix VIII). The maximum numbers of siliqua plant^{-1} (140.40, 195.50 and 233.20 at 50 and 65 DAS and at harvest, respectively) was obtained from the 25 % less fertilizer dose with poultry manure (P_2) treatment. The minimum number of siliqua plant^{-1} (75.24, 129.10 and 177.30 at 50 and 65 DAS and at harvest, respectively) was obtained from recommended dose of fertilizer without poultry manure (P_0). Similar findings were reported by Deekshitula and Subbaiah (1997) and Bhagwan *et al*. (1996).

Effect of mechanical weeding

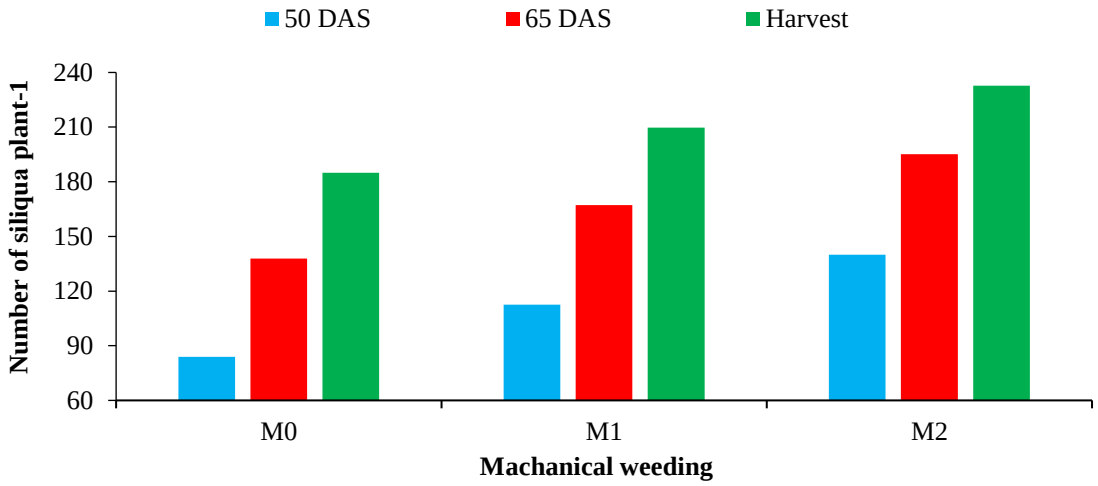
Significant variation was found in siliqua plant^{-1} due to the effect of mechanical weed control (Figure 10 and Appendix VIII). The maximum siliqua plant^{-1} (139.90, 195.10 and 232.80 at 50 and 65 DAS and at harvest, respectively) was obtained from the effect of M_2 and the minimum siliqua plant^{-1} (83.82, 137.80 and 184.90 at 50 and 65 DAS and at harvest, respectively) was obtained from no weeding treated plot (M_0). Two hand weeding at 15 DAS and 30 DAS (M_2) gave 25.91 % more siliqua plant^{-1} than no weeding (M_0). The increases in siliqua plant^{-1} under hand weeding might be due to better suppression of weeds, which might have maintained greater availability of nutrients and moisture content due to less removal by weeds. This might have increased nutrient and water uptake by crops leading to increase rate of photosynthesis and ultimately better supply of photo synthates to various sinks resulting increased the siliqua plant^{-1}. Similar findings have also been reported (Gupta *et al.*, 2018; Awal and Fardous, 2014; Tekale *et al*., 2005; Omprakash, 2002; Singh and Singh, 2001 and Bowerman, 1990) who

observed that the weeding gave the greater number of siliqua plant^{-1} in mustard.



P_0 : Recommended dose of fertilizer without poultry manure, P_1 : Recommended dose of fertilizer with poultry manure, P_2 : 25 % less fertilizer dose with poultry manure and P_3 : 50 % less fertilizer dose with poultry manure.

Figure 9: Effect of Fertilizer management on number of silliqua plant^{-1} of mustard at different days after sowing (DAS) and at harvest (LSD value = 2.00, 3.71 and 4.35 at 50, 65 DAS and harvest, respectively)



M_0 : No weed control, M_1 : Mechanical weeding once (20 DAS) and M_2 : Mechanical weeding twice (15 DAS and 30 DAS).

Figure 10: Effect of mechanical weeding on number of silliqua plant^{-1} of mustard at different days after sowing (DAS) and at harvest (LSD value = 2.00, 3.71 and 4.35 at 50, 65 DAS and harvest, respectively)

Table 6: Interaction effect of Fertilizer management and mechanical weeding on number of silliqua plant^{-1} of mustard at different days after sowing (DAS) and at harvest

Treatment combination	Number of silliqua plant^{-1}		
	50 DAS	65 DAS	Harvest
P_0M_0	53.20 j	106.60 j	158.50 j
P_0M_1	73.03 i	126.90 i	175.20 i
P_0M_2	99.50 f	153.90 f	198.20 f
P_1M_0	92.50 g	146.50 g	192.20 g
P_1M_1	122.90 d	177.70 d	218.10 d
P_1M_2	144.00 c	199.30 c	236.30 bc
P_2M_0	109.80 e	164.30 e	207.40 e
P_2M_1	142.80 c	198.00 c	235.10 c
P_2M_2	168.50 a	224.20 a	257.10 a
P_3M_0	79.82 h	133.80 h	181.50 h
P_3M_1	111.50 e	166.20 e	210.90 e
P_3M_2	147.50 b	203.10 b	239.50 b
$LSD_{(0.05)}$	**2.00**	**3.71**	**4.35**
CV (%)	**7.05**	**10.31**	**8.23**

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

P_0 : Recommended dose of fertilizer without poultry manure, P_1 : Recommended dose of fertilizer with poultry manure, P_2 : 25 % less fertilizer dose with poultry manure and P_3 : 50 % less fertilizer dose with poultry manure.

M_0 : No weed control, M_1 : Mechanical weeding once (20 DAS) and M_2 : Mechanical weeding twice (15 DAS and 30 DAS).

Interaction effect

A significant variation was found in the treatment combinations of fertilizer doses and weeding on number of siliqua plant^{-1} on mustard (Table 5 and Appendix VIII). The maximum number of siliqua plant^{-1} (168.50, 224.20 and 257.10 at 50 and 65 DAS and at harvest, respectively) was found in P_2M_2 treatment, which was statistically higher than all other values obtained by the rest treatment combinations whereas the minimum number of siliqua plant^{-1} (53.20, 106.60 and 158.50 at 50 and 65 DAS and at harvest, respectively) was found in P_0M_0 treatment combination.

4.2.2 Number of seeds silliqua^{-1}

Effect of Fertilizer management

There was significant effect of fertilizer doses on number of seeds siliqua^{-1} (Table 7 and Appendix XI). Application of 25 % less fertilizer dose with poultry manure produced the highest number of seeds siliqua^{-1} (13.81) which was statistical identical with P_1 (13.60) and P_3 (13.46) treatment. On the contrary, application of recommended dose of fertilizer without poultry manure produced lowest number of seeds siliqua^{-1} (11.99). The present results confirmed the report of Deekshitula and Subbaiah (1997). Singh (2002), Sukla *et al.* (2002), Tarafder and Mondal (1990) and Mondal and Gaffer (1983) observed significant effect of organic and inorganic fertilizer on number of seeds siliqua^{-1}.

Effect of mechanical weeding

Significant variation was observed in seeds siliqua^{-1} due to different mechanical weed managements (Table 6 and Appendix XI). The highest seeds siliqua^{-1} (13.65) was obtained from the effect of M_2 whereas, the lowest seeds siliqua^{-1} (12.80) was obtained from no weeding treated plot (M_0). Two mechanical weeding at 15 DAS and 30 DAS (M_2) gave 9.61 % more seeds

siliqua^{-1} than no weeding (M_0). From this study it was observed that two mechanical weeding produced the maximum number of seeds siliqua^{-1}. This result is also supported by Paul (2018), Kibria (2013), Rashid (2006) and Sarkar and Mondal (1985).

Interaction effect

Interaction between fertilizer doses and mechanical weeding has also a great influence on the number of seeds siliqua^{-1} in this experiment (Table 7 and Appendix XI). The highest (14.22) number of seeds siliqua^{-1} was observed from P_2M_2 (25 % less fertilizer dose with poultry manure and two mechanical weeding at 15 DAS and 30 DAS) which was statistically similar P_1M_2 (14.08), P_2M_1 (13.89) and P_3M_2 (13.72). The lowest (11.50) number of seeds siliqua^{-1} was observed from P_0M_0 (Recommended dose of fertilizer without poultry manure and no mechanical weeding) which was statistically identical P_0M_1 (11.90). The maximum number of seeds siliqua^{-1} was probably resultant effect of increased siliquae length that accommodated more number of seeds.

4.2.3 Length of silliqua (cm)

Effect of Fertilizer management

Fertilizer doses had significant effect on the length of siliqua of mustard (Table 6 and Appendix XI). The tallest siliqua (23.00 cm) was found from 25 % less fertilizer dose with poultry manure (P_2) treatment. The control plot without poultry manure produced the shortest (20.99 cm) siliqua in this study. Singh (2002), Singh *et al.* (2002), Shukla and Kumar (1997) reported the highest length of siliqua following organic and inorganic fertilizer combination.

Effect of mechanical weeding

There was significant difference among the weeding treatments in the length of silliqua (Table 7 and Appendix XI). The tallest silliqua (22.51 cm) was produced in M_2 treatment and the shortest silliqua (21.72 cm) was produced in M_0 condition.

Table 7: Effect of Fertilizer management, mechanical weeding and their interaction on number of seeds siliqua^{-1}, silliqua length and 1000-seed weight of mustard

Treatment	No. of seeds siliqua^{-1}	Siliqua length (cm)	1000-seed weight (g)
Poultry manure			
P_0	11.99 b	20.99 d	2.84 c
P_1	13.60 a	22.33 b	3.04 b
P_2	13.81 a	23.00 a	3.22 a
P_3	13.46 a	22.08 c	3.03 b
$LSD_{(0.05)}$	**0.43**	**0.09**	**0.09**
Mechanical weeding			
M_0	12.80 c	21.72 c	2.87 c
M_1	13.20 b	22.08 b	3.00 b
M_2	13.65 a	22.51 a	3.23 a
$LSD_{(0.05)}$	**0.37**	**0.08**	**0.08**
Interaction effect			
P_0M_0	11.50 g	20.19 j	2.51 f
P_0M_1	11.90 g	21.09 i	2.81 e
P_0M_2	12.58 f	21.70 h	3.19 b
P_1M_0	13.21 e	22.01 f	2.91 d
P_1M_1	13.51 cde	22.31 e	2.99 cd
P_1M_2	14.08 ab	22.67 d	3.21 b
P_2M_0	13.33 de	22.78 c	3.15 b
P_2M_1	13.89 abc	22.90 b	3.20 b
P_2M_2	14.22 a	23.33 a	3.32 a
P_3M_0	13.17 e	21.90 g	2.91 d
P_3M_1	13.50 cde	22.00 f	3.01 c
P_3M_2	13.72 bcd	22.33 e	3.18 b
$LSD_{(0.05)}$	**0.43**	**0.09**	**0.09**
CV (%)	**12.10**	**8.26**	**9.84**

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

P_0 : Recommended dose of fertilizer without poultry manure, P_1 : Recommended dose of fertilizer with poultry manure, P_2 : 25 % less fertilizer dose with poultry manure and P_3 : 50 % less fertilizer dose with poultry manure.

M_0 : No weed control, M_1 : Mechanical weeding once (20 DAS) and M_2 : Mechanical weeding twice (15 DAS and 30 DAS).

Interaction effect

Length of silliqua indicated a significant variation among the treatment combinations of fertilizer doses and mechanical weeding (Table 6 and Appendix XI). The tallest silliqua (23.33 cm) which was found in P_2M_2 (25 % less fertilizer dose with poultry manure and two mechanical weeding at 15 DAS and 30 DAS) treatment combination whereas, the shortest silliqua (20.19 cm) was found in P_0M_0 (Recommended dose of fertilizer without poultry manure and no mechanical weeding) treatment.

4.2.4 Weight of 1000-seed (g)

Effect of Fertilizer management

Weight of 1000-seed exerted significant difference due to the effect of different fertilizer combinations (Table 6 and Appendix XI). The maximum 1000-seed weight (3.22 g) was recorded in P_2 (25 % less fertilizer dose with poultry manure) all chemical fertilizer applied which was followed by P_1 (Recommended dose of fertilizer with poultry manure) and P_3 (50 % less fertilizer dose with poultry manure) (3.04 and 3.03 g, respectively). The minimum value (2.84 g) was found in the recommended dose of fertilizer without poultry manure treatment.

Effect of mechanical weeding

Effect of mechanical weed management showed significant variation in 1000-seed weight (Appendix XI). Results of the investigation showed that, two mechanical weeding at 15 DAS and 30 DAS (M_2) gave the maximum 1000-seed weight (3.23 g) (Table 6). The minimum 1000-seed weight (2.87 g) was found from no weeding (M_0). In our investigation two mechanical weeding at 15 and 30 DAS performed better to control weed population and the plot was

weed free which facilitated better uptake of nutrient, light and moisture trigger the plant growth and development, increased the photosynthesis rate and more partitioning of photosynthates from source to sink, thus produced the seed with higher weight. On the other hand under no weeding condition in the earlier growth period weed population severely affected crop plant and plant could not compete with weed for those natural resources consequently drastically reduced the growth and development as well as crop yield. These results were in conformity with those reported by Gupta *et al.* (2018), Awal and Fardous (2014), Khan *et al.* (2008), Amin *et al.* (2003), Singh *et al.* (2000), Yadav *et al.* (1999) and Raghavan and Hariharan (1991) who stated that seed weight increases in weed management condition compare to that of no weeding condition.

Interaction effect

The interaction between fertilizer doses and mechanical weeding significantly affected the weight of 1000-seed (Table 6 and Appendix XI). From this study, it was found that the interaction between 25 % less fertilizer dose with poultry manure and two mechanical weeding at 15 DAS and 30 DAS produced the maximum 1000-seed weight (3.32 g). The minimum 1000-seed weight (2.51 g) was observed from the combination treatment of P_0M_0 (Recommended dose of fertilizer without poultry manure and no mechanical weeding).

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

Effect of Fertilizer management

Applied fertilizer had the positive effect on grain yield ha^{-1} (Table 7 and Appendix X). In general, application of fertilizer at different combination significantly enhanced grain yield over control. The highest grain yield (1.43 t ha^{-1}) was obtained from the plants treated with 25 % less fertilizer dose with poultry manure and the lowest was obtained from recommended dose of fertilizer without poultry manure (0.97 t ha^{-1}). This indicated that the fertilizer

dose must be optimum to achieve the highest grain yield. The higher grain yield ha^{-1} was also obtained with same fertilizer rate reported by Singh and Prasad (2003), Singh *et al.* (2003), Sukla *et al.* (2002), Singh (2002), Singh *et al.* (2002), Shukla and Kumar (1997) and Shamsuddin *et al.* (1987). On the other hand, Highest grain yield ha^{-1} obtained by Singh (2004), Sharma and Jain (2002), Khan *et al.* (2003), Singh *et al.* (1998) and Thakuria and Gogoi (1996) at the rate of recommended dose of fertilizer with poultry manure.

Effect of mechanical weeding

Weeding had also an important role in increasing the grain yield ha^{-1} in this experiment (Table 8 and Appendix X). Grain yield was increased with the increasing of weeding operation. The highest grain yield (1.38 t ha^{-1}) was obtained from two hand weeding at 15 and 30 DAS (M_2) where M_0 (no mechanical weeding) gave the lowest (1.13 t ha^{-1}). One weeding at 20 DAS gave 1.26 t ha^{-1} grain yield which was statistically different than other treatments. The grain yield with two weeding and one weeding were 22.12 % and 11.50 % higher than the control. The remarkable increase in grain yield might be due to effective control of weeds, lower dry weight of weeds and higher weed control efficiency as well as lower weed index which cumulatively facilitated the crop to utilize more nutrients and water for better growth and development in terms of various growth attributing characters and yield attributing characters. On the other hand, the lowest value of yield attributes and yield maybe due to severe competition by weeds for resources, which made the crop plant incompetent to take up more moisture and nutrients, consequently growth was adversely affected. Poor growth of nutrients in weedy check might have produced less photosynthates and partitioned less assimilates to numerous metabolic sink and ultimately poor development of yield components and seed yield. Reduced crop-weed competition under thus saved a substantial amount of nutrients for crop that led to profuse growth enabling the crop to utilize more soil moisture and nutrients from deeper soil layers, ultimately increased the photosynthesis rate which leaded to more partitioning

of photosynthates from source to sink and produced more seed (Bijarnia *et al*., 2017; Singh *et al.,* 2015 and Kour *et al*., 2014) reported that twice hand weeding at 20 and 40 DAS treatment controlled all types of weeds very effectively and minimized the weed competition. As a result, it produced more grain yield (1.95 t ha^{-1}) compare to that of no weeding treatment (1.17 t ha^{-1}). Yadav *et al.* (2017) reported that improvement in yield contributing characters and thereby seed yield under weed control treatments may be attributed to low weed pressure. Weedy check had lowest seed yield due to higher weed density and dry matter accumulation. Weed in untreated check reduced seed yield of mustard by 49.24%. These findings were in close agreement with those reported by (Gupta *et al.,* 2018; Bamboriya *et al*., 2017; Jangir *et al.,* 2017; Kumar and Kaur, 2015; Adhikary and Ghosh, 2014; Awal and Fardous, 2014; Mukherjee, 2014; Kumar *et al.,* 2012; Bijanzadeh *et al.,* 2010; Miri and Rahimi, 2009; Singh *et al.,* 2009; Khan *et al.,* 2008; Rathi *et al.,* 2007; Sarkar *et al.,* 2005 and Sharma *et al.,* 2005) who observed that the mustard seed yield was found highest in weed free condition compare to that of no weeding condition.

Interaction effect of

Interaction of fertilizer doses and mechanical weeding had significant effect on the grain yield ha^{-1} (Table 8 and Appendix X). In this experiment, the highest grain yield (1.57 t ha^{-1}) was obtained from the combination of 25 % less fertilizer dose with poultry manure and two mechanical weeding at 15 and 30 DAS (P_2M_2). The combination of recommended dose of fertilizer without poultry manure and no mechanical weeding (control) gave the lowest grain yield (0.90 t ha^{-1}). The highest yield with P_2M_2 was 74.44 % higher than the control (P_0M_0).

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

Effect of Fertilizer management

Effect of different fertilizer combinations effect on stover yield showed significant variation (Table 8 and Appendix X). Significantly the maximum stover yield was found in P_0 treatment (4.06 t ha^{-1}), the second highest stover was found in P_3 (3.93 t ha^{-1}) and P_1 (3.91 t ha^{-1}) and minimum stover yield (3.73 t ha^{-1}) as observed in P_2 treatment. These findings were in agreement with that of Singh and Prasad (2003) and Singh *et al.* (2002). But, Meena *et al.* (2002) observed lowest stover yield of mustard at the control treatment.

Effect of mechanical weeding

Significant variation was observed for stover yield due to different mechanical weed managements (Table 8 and Appendix X). The maximum stover yield (4.03 t ha^{-1}) was produced from no mechanical weeding treatment (M_0) and the minimum stover yield (3.75 t ha^{-1}) was produced when the plot done with two mechanical weeding at 15 DAS and 30 DAS (M_2). The remarkable increase in stover yield might be due to effective control of weeds, lower dry weight of weeds and higher weed control efficiency as well as lower weed index which cumulatively facilitated the crop to utilize more nutrients and water for better growth and development which facilitated more biomass production and finally stover yield of mustard. These findings were in close agreement with those reported by (Jangir *et al.,* 2017; Adhikary and Ghosh, 2014; Kumar *et al.,* 2012; Rathi *et al.,* 2007 and Sarkar *et al.,* 2005).

Interaction effect

The combined effect of fertilizer doses and mechanical weeding was significant on yield of stover ha^{-1} (Table 8 and Appendix X). The maximum stover yield (4.22 t ha^{-1}) obtained from P_0M_0 treatment and second maximum P_0M_1 (4.05 t ha^{-1}) was statistically similar to 4.02 t ha^{-1}, 4.01 t ha^{-1}, 3.98 t ha^{-1}, 3.95 t ha^{-1} and 3.90 t ha^{-1}, respectively obtained from P_3M_0, P_1M_0, P_1M_1, P_3M_1 and P_0M_2. The minimum yield of stover (3.54 t ha^{-1}) was obtained from P_2M_2 treatment.

4.2.7 Biological yield (t ha^{-1})

Effect of Fertilizer management

Significant difference was observed on biological yield due to the effect of different fertilizer combination treatments (Appendix X). The highest biological yield (5.27 t ha^{-1}) was found in recommended dose of fertilizer with poultry manure and the lowest biological yield was recorded in recommended dose of fertilizer without poultry manure (5.03 t ha^{-1}). On the other hand, the second

Table 8: Effect of Fertilizer management, mechanical weeding and their interaction on grain yield, stover yield, biological yield and harvest index of mustard

Treatment	Grain yield (t ha^{-1})	Stover yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest Index (%)
Poultry manure				
P_0	0.97 d	4.06 a	5.03 c	19.31 d
P_1	1.35 b	3.91 b	5.27 a	25.70 b
P_2	1.43 a	3.73 c	5.15 b	27.64 a
P_3	1.27 c	3.93 b	5.20 b	24.08 c
$LSD_{(0.05)}$	**0.05**	**0.05**	**0.05**	**1.01**
Mechanical weeding				
M_0	1.13 c	4.03 a	5.15 b	21.84 c
M_1	1.26 b	3.94 b	5.21 a	23.91 b
M_2	1.38 a	3.75 c	5.13 b	26.80 a
$LSD_{(0.05)}$	**0.05**	**0.05**	**0.05**	**0.88**

Interaction effect

P_0M_0	0.90 i	4.22 a	5.12 c	17.58 g
P_0M_1	0.97 h	4.05 b	5.02 d	19.32 f
P_0M_2	1.04 g	3.90 ef	4.94 e	21.04 e
P_1M_0	1.21 e	4.01 bc	5.22 b	23.18 d
P_1M_1	1.38 c	3.98 cd	5.36 a	25.75 c
P_1M_2	1.47 b	3.75 i	5.22 b	28.16 b
P_2M_0	1.28 d	3.85 fg	5.13 c	24.95 c
P_2M_1	1.43 bc	3.79 hi	5.22 b	27.39 b
P_2M_2	1.57 a	3.54 j	5.11 c	30.58 a
P_3M_0	1.11 f	4.02 bc	5.13 c	21.64 e
P_3M_1	1.26 de	3.95 de	5.21 b	23.18 d
P_3M_2	1.44 b	3.81 gh	5.25 b	27.42 b
$LSD_{(0.05)}$	**0.05**	**0.05**	**0.05**	**1.01**
CV (%)	**6.29**	**5.32**	**5.38**	**7.47**

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

P_0 : Recommended dose of fertilizer without poultry manure, P_1 : Recommended dose of fertilizer with poultry manure, P_2 : 25 % less fertilizer dose with poultry manure and P_3 : 50 % less fertilizer dose with poultry manure.

M_0 : No weed control, M_1 : Mechanical weeding once (20 DAS) and M_2 : Mechanical weeding twice (15 DAS and 30 DAS).

highest biological (5.20 t ha^{-1} and 5.15 t ha^{-1}) was recorded from the treatment P_3 and P_2 (Table 8).

Effect of mechanical weeding

The biological yield varied significantly due to different mechanical weeding shown in Table 8 and Appendix X. Treatment M_1 gave the highest biological yield (5.21 t ha^{-1}). M_2 treatment gave the lowest biological yield (5.13 t ha^{-1}) where was statistically identical M_0 (5.15 t ha^{-1}) treatment.

Interaction effect

Table 8 showed that the combined effect of fertilizer doses and mechanical weeding influenced the biological yield in the present study. The treatment P_1M_1 produced the maximum biological yield (5.36 t ha^{-1}) and the treatment P_0M_2 produced the lowest biological yield (4.94 t ha^{-1}).

4.2.8 Harvest index (%)

Effect of Fertilizer management

Different fertilizer doses effect on harvest index showed significant variation (Table 8 and Appendix X). Harvest index completely responsible on grain yield and stover yield of any crop. Harvest index ranged from 19.31 to 27.64 %, where the maximum harvest index was recorded in P_2 (27.64 %) and the minimum harvest index was observed in P_0 (19.31 %). Similar result was also observed by Shukla and Kumar (1997) at the same organic and inorganic fertilizer.

Effect of mechanical weeding

Significant variation was observed in harvest index due to the effect of mechanical weeding (Table 8 and Appendix X). The maximum harvest index (26.80 %) was found due to the effect of M_2. No mechanical weeding (M_0) scored the lowest harvest index (21.84 %). Similar result was found by Jangir *et al.* (2017), Awal and Fardous (2014), Mishra and Kurchania (2001) and Singh *et al.* (2000) who reported that harvest index was higher in weed free condition than un-weeded control. While, contradictory result was recorded in this regard by Arya (2004).

Interaction effect

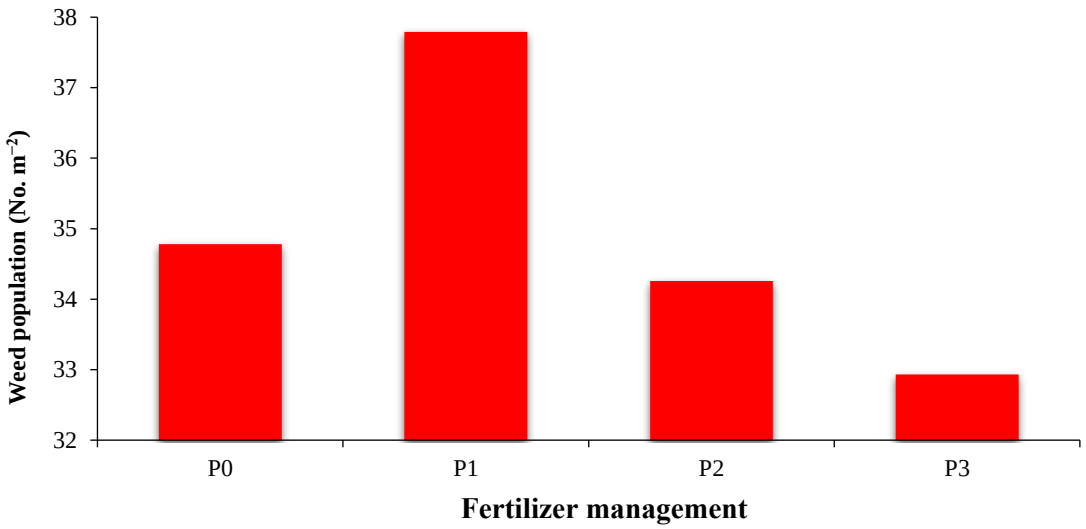
Harvest index was influenced by different combination of fertilizer doses and mechanical weeding (Table 8 and Appendix X). The maximum harvest index (30.58 %) was observed from the treatment P_2M_2. The treatment P_0M_0 gave the minimum harvest index (17.58 %).

4.3 Weed parameters

4.3.1 Weed population (no. m^{-2})

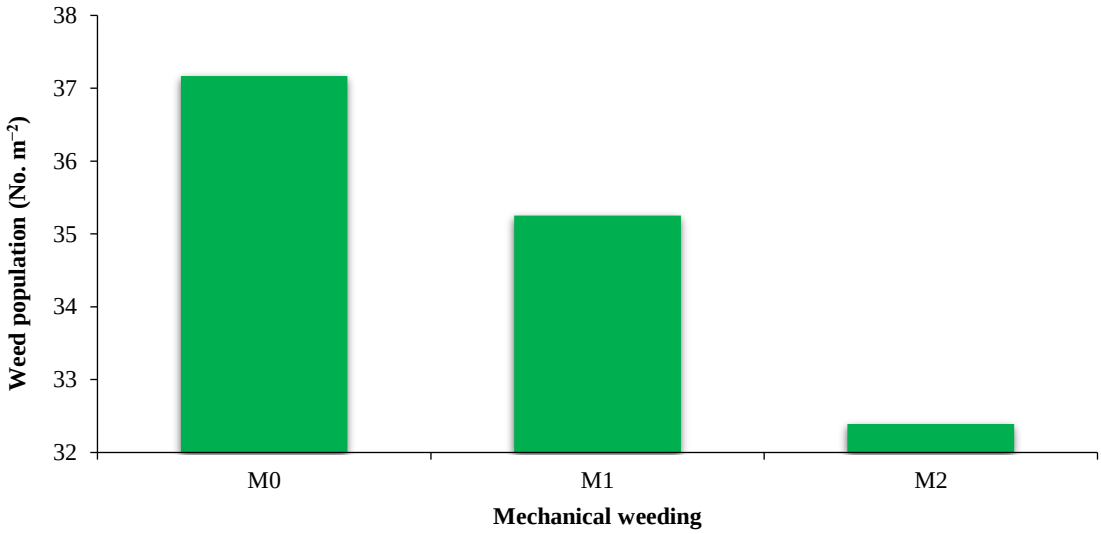
Effect of Fertilizer management

In this study, the number of weed population m^{-2} was significantly increased with the increment of fertilizer doses (Figure 12 and Appendix X). The maximum number of population (37.79 m^{-2}) were found from recommended dose of fertilizer with poultry manure which was statistically superior then other fertilizer doses. The plots 50% reduce fertilizer dose with poultry manure produced the minimum number of population (32.93 m^{-2}) in this experiment. The maximum number of plant produced by P_1 was 29.33 % higher than P_3 treatment. The higher number of weed population produced by higher fertilizer doses was due to more protein synthesis and increased vigour facilitated by nitrogen. Murtuza and Paul (1989) also found similar result.



P_0 : Recommended dose of fertilizer without poultry manure, P_1 : Recommended dose of fertilizer with poultry manure, P_2 : 25 % less fertilizer dose with poultry manure and P_3 : 50 % less fertilizer dose with Fertilizer management.

Figure 11: Effect of Fertilizer management on weed population of mustard (LSD value=1.97)

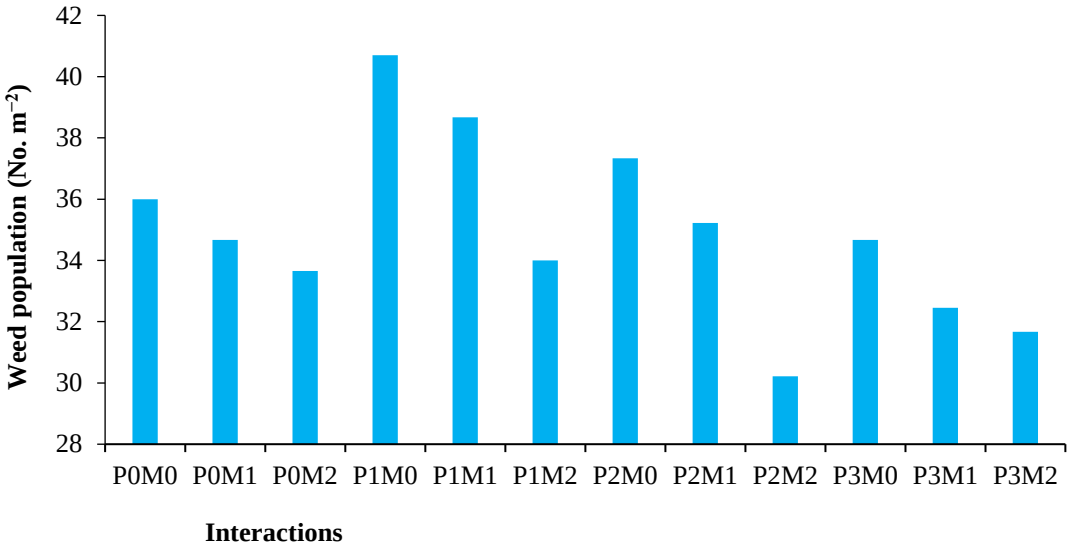


M_0 : No weed control, M_1 : Mechanical weeding once (20 DAS) and M_2 : Mechanical weeding twice (15 DAS and 30 DAS).

Figure 12: Effect of mechanical weeding on weed population of mustard (LSD value = 1.70)

Effect of mechanical weeding

Significant variation was observed on weed population m^{-2} throughout the growing period for mechanical weed management (Figure 12 and Appendix X). The maximum weed population (37.17 m^{-2}) was observed in no mechanical weeding (M_0) whereas, the minimum (32.39 m^{-2}) was observed in two hand weeding at 15 DAS and 30 DAS (M_2). The variability in weed population in different treatments can be attributed to the fact that mechanical weeding are more effective for weed control than the others. These findings are in close conformity with those of Gupta *et al.*, 2018; Yadav *et al.* (2017), Awal and Fardous (2014), Patel *et al.* (2013), Kumar *et al*. (2012), Bijanzadeh *et al.* (2010) and Khan *et al.* (2008).



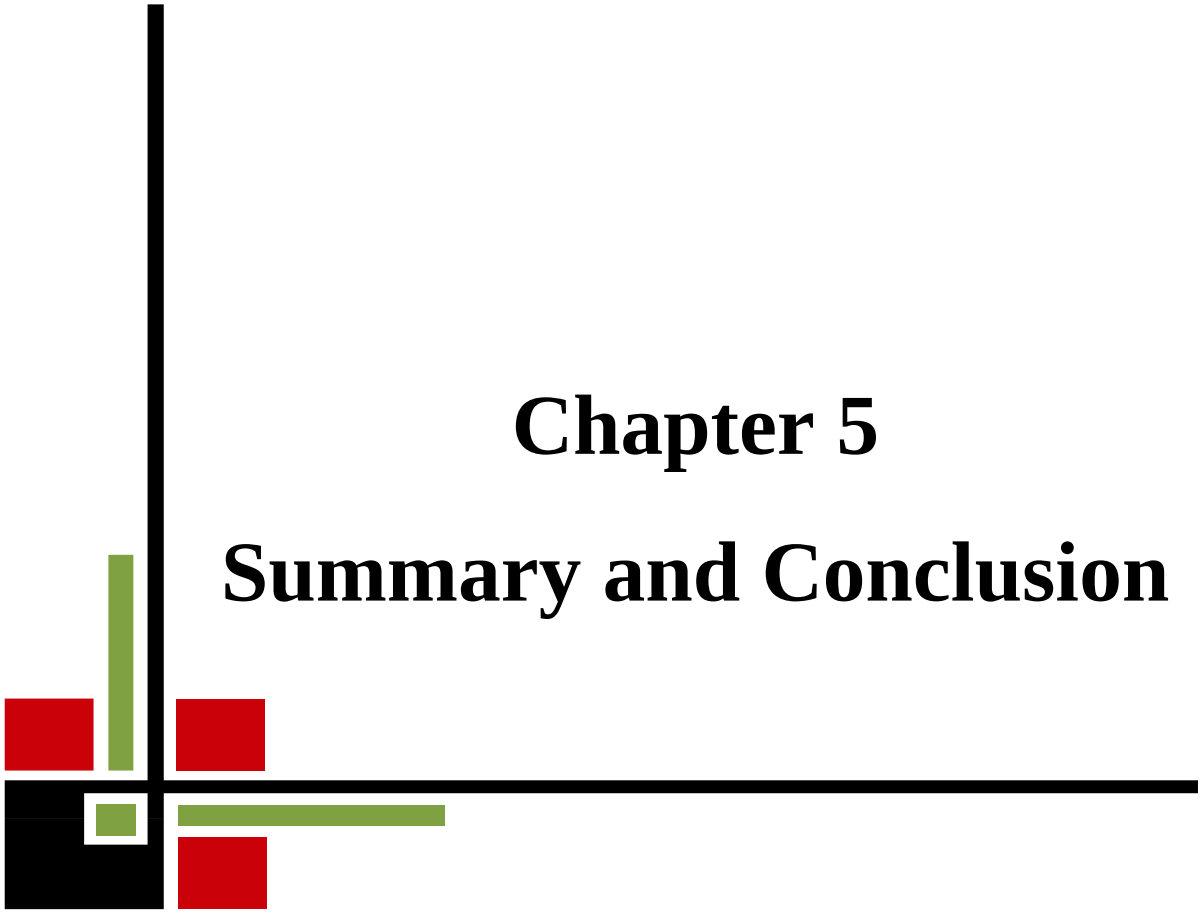
P_0 : Recommended dose of fertilizer without poultry manure, P_1 : Recommended dose of fertilizer with poultry manure, P_2 : 25 % less fertilizer dose with poultry manure and P_3 : 50 % less fertilizer dose with poultry manure.

M_0 : No weed control, M_1 : Mechanical weeding once (20 DAS) and M_2 : Mechanical weeding twice (15 DAS and 30 DAS).

Figure 13: Interaction effect of fertilizer dose and mechanical weeding on weed population of mustard (LSD value =1.97)

Interaction effect

The effect of fertilizer doses and mechanical weeding on number of weed population m^{-2} was statistically significant (Figure 13 and Appendix X). The maximum number of weed population (40.70 m^{-2}) was found from P_1M_0 (Recommended dose of fertilizer with poultry manure and no mechanical weeding) and the minimum (31.67 m^{-2}) from 50 % less fertilizer dose with poultry manure and two mechanical weeding at 15 DAS and 30 DAS (P_3M_2).



Chapter 5

Summary and Conclusion

CHAPTER V

SUMMARY AND CONCLUSION

A field experiment was conducted at the Agronomy field, Sher-e-Bangla Agricultural University (SAU), during from November 2018 to February 2019 with view to finding out the performance of mustard as affected by the fertilizer management and weed control method. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. The size of the individual plot was 4.0 m × 2.5 m and total number of plots were 36. There were 12 treatment combinations. Fertilizer management *viz*: P_0 - Recommended dose of fertilizer without poultry manure, P_1 - Recommended dose of fertilizer with recommended dose of poultry manure, P_2 - 25 % reduction of recommended dose of fertilizer with recommended dose of poultry manure and P_3 - 50 % reduction of recommended dose of fertilizer with recommended dose of poultry manure. Weed control methods *viz*: M_0 - No mechanical weed control, M_1 - Mechanical weed control once (at 20 DAS) and M_2 - Mechanical weed control twice (at 15 and 30 DAS).

Data were collected on the following parameters: plant height (cm), leaves plant^{-1} (no.), branches plant^{-1} (no.), dry weight plant^{-1} (g), silliqua plant^{-1} (no.), seeds silliqua^{-1} (no.), length of silliqua (cm), weight of 1000-seeds (g), grain yield (t ha^{-1}), stover yield (t ha^{-1}), biological yield (t ha^{-1}), harvest index (%) and weed population (No. m^{-2}). The collected data were analysed by computer package program MSTAT-C software. The significant differences among the treatment means were compared by Least Significant Difference (LSD) at 5% levels of probability.

Different fertilizer management showed significant variation on plant height, leaves plant^{-1}, branches plant^{-1}, dry weight plant^{-1}, siliqua plant^{-1}, seeds silliqua^{-1}, length of silliqua, weight of 1000-seeds, grain yield, stover yield, biological yield, harvest index and weed population. Recommended dose of fertilizer with poultry manure (P_1) scored the tallest plant (26.08, 37.03, 59.83,

80.76 and 92.89 cm at 20, 35, 50, 65 DAS and at harvest, respectively), highest number of leaves plant^{-1} (5.82, 8.33, 13.15, 17.06 and 14.48 at 20, 35, 50, 65 DAS and at harvest, respectively), highest biological yield (5.27 t ha^{-1}) and maximum number of weed population (37.79 m^{-2}). The maximum number of branches plant^{-1} (4.63, 5.02, 6.77 and 7.40 at 35, 50, 65 DAS and at harvest, respectively), highest dry matter weight plant^{-1} (6.77, 15.51, 20.56 and 28.45 g at 35, 50, 65 DAS and at harvest, respectively), maximum numbers of silliqua plant^{-1} (140.40, 195.50 and 233.20 at 50 and 65 DAS and at harvest, respectively), highest number of seeds siliqua^{-1} (13.81), tallest siliqua (23.00 cm), maximum weight of 1000-seeds (3.22 g), highest grain yield (1.43 t ha^{-1}), maximum harvest index (27.64 %) was recorded at 25 % less fertilizer dose with poultry manure (P_2) treatment.

Different mechanical weed control method showed significant variation on plant height, leaves plant^{-1}, branches plant^{-1}, dry weight plant^{-1}, siliqua plant^{-1}, seeds silliqua^{-1}, length of silliqua, weight of 1000-seeds, grain yield, stover yield, biological yield, harvest index and weed population. The tallest plants (25.72, 36.70, 58.22, 79.00 and 88.29 cm at 20, 35, 50, 65 DAS and at harvest, respectively), highest number of leaves plant^{-1} (3.07, 5.50, 10.55, 14.92 and 12.43 at 20, 35, 50, 65 DAS and at harvest, respectively), maximum branches plant^{-1} (4.25, 4.69, 6.50 and 7.13 at 35, 50, 65 DAS and harvest, respectively), the highest dry matter weight plant^{-1} (5.73, 15.45, 19.24 and 26.77g at 35, 50, 65 DAS and at harvest, respectively), maximum siliqua plant^{-1} (139.90, 195.10 and 232.80 at 50 and 65 DAS and at harvest, respectively), highest seeds siliqua^{-1} (13.65), tallest silliqua (22.51 cm), maximum weight of 1000-seeds (3.23 g), the highest grain yield (1.38 t ha^{-1}) and maximum harvest index (26.80 %) were produced with two weeding at 15 and 30 DAS (M_2) treatment. The maximum weed population (37.17 m^{-2}) was observed in no mechanical weeding (M_0) whereas, the minimum (32.39 m^{-2}) was observed in two hand weeding at 15 DAS and 30 DAS (M_2).

Combined effect of fertilizer management and mechanical weed control method showed significant variation in plant height, leaves plant^{-1}, branches plant^{-1}, dry weight plant^{-1}, siliqua plant^{-1}, seeds silliqua^{-1}, length of siliqua, weight of 1000-seeds, grain yield, stover yield, biological yield, harvest index and weed population. The tallest plant (27.70, 38.60, 62.76, 83.62 and 95.33 cm at 20, 35, 50, 65 DAS and at harvest, respectively), highest number of leaves plant^{-1} (6.47, 9.00, 14.00, 18.89 and 16.73 at 20, 35, 50, 65 DAS and at harvest, respectively) was recorded from the combination of Recommended dose of fertilizer with poultry manure and two mechanical weeding at 15 and 30 DAS (P_1M_2) treatment. The maximum number of branches plant^{-1} (5.11, 5.45, 7.45 and 8.07 at 35, 50, 65 DAS and harvest, respectively), highest dry matter weight plant^{-1} (7.29, 18.50, 21.68 and 29.87 g at 35, 50, 65 DAS and at harvest, respectively), maximum number of siliqua plant^{-1} (168.50, 224.20 and 257.10 at 50 and 65 DAS and at harvest, respectively), highest number of seeds siliqua^{-1} (14.22), maximum weight of 1000-seed (3.32 g), highest grain yield (1.57 t ha^{-1}) and maximum harvest index (30.58 %) was found in combined use of 25 % less fertilizer dose with poultry manure and two times weeding (P_2M_2) treatment. The maximum number of weed population (40.70 m^{-2}) was found from P_1M_0 (Recommended dose of fertilizer with poultry manure and no mechanical weeding) and the minimum (31.67 m^{-2}) from 50 % less fertilizer dose with poultry manure and two mechanical weeding at 15 DAS and 30 DAS (P_3M_2).

Conclusion

1. It may be concluded from the results that poultry manure with recommended fertilizer and mechanical weed control treatment is very much promising for mustard yield.
2. 25% less fertilizer dose with poultry manure and two times weeding showed better performance on growth and yield under the present study.

Recommendations

The present experiment was conducted only one season at a single location. Therefore, it is difficult to recommend this finding without further study. By considering the results of the present experiment, further studies in the following areas are suggested below:

1. Studies of similar nature could be carried out at different Agro Ecological Zones (AEZ) in different seasons of Bangladesh for the evaluation of zonal adaptability.
2. Different fertilizer combination and weed control methods should be studied for optimum yield of mustard.

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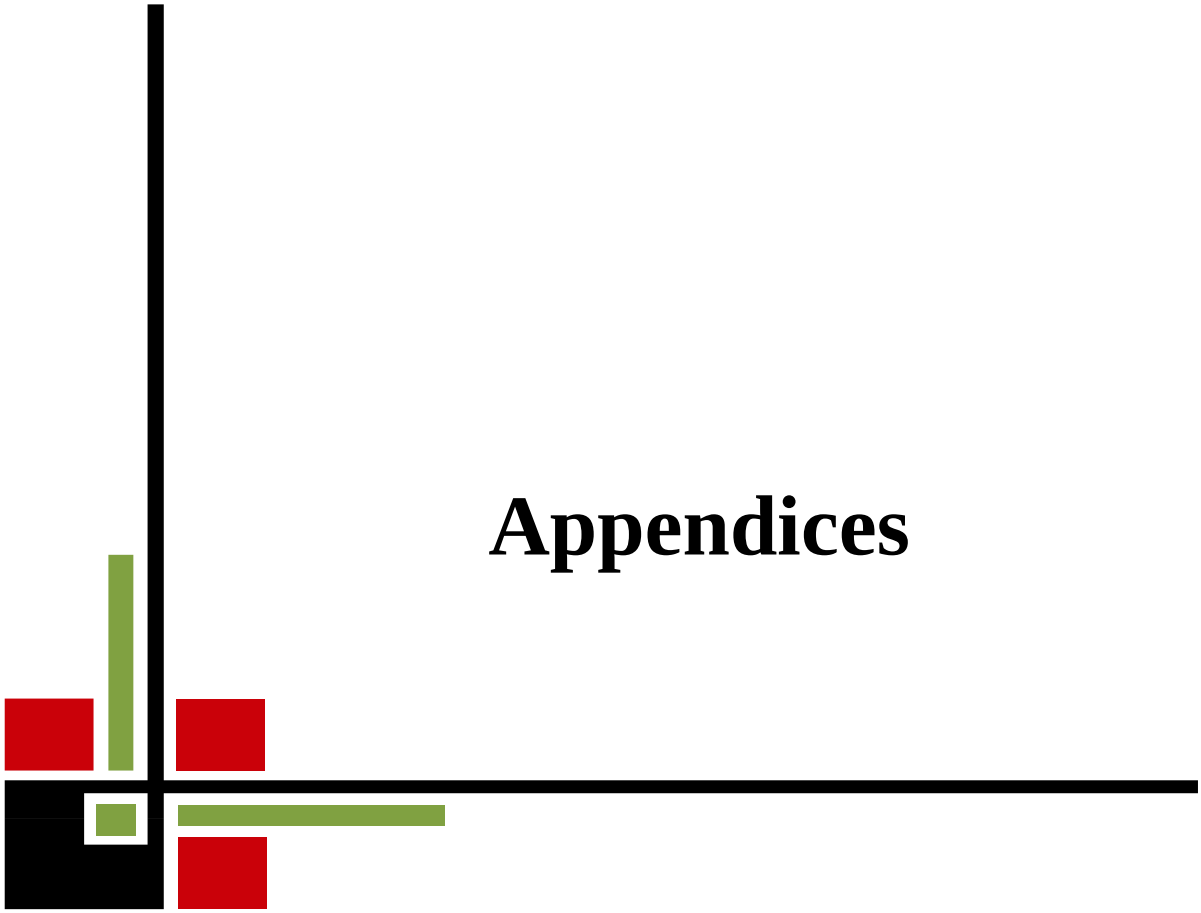
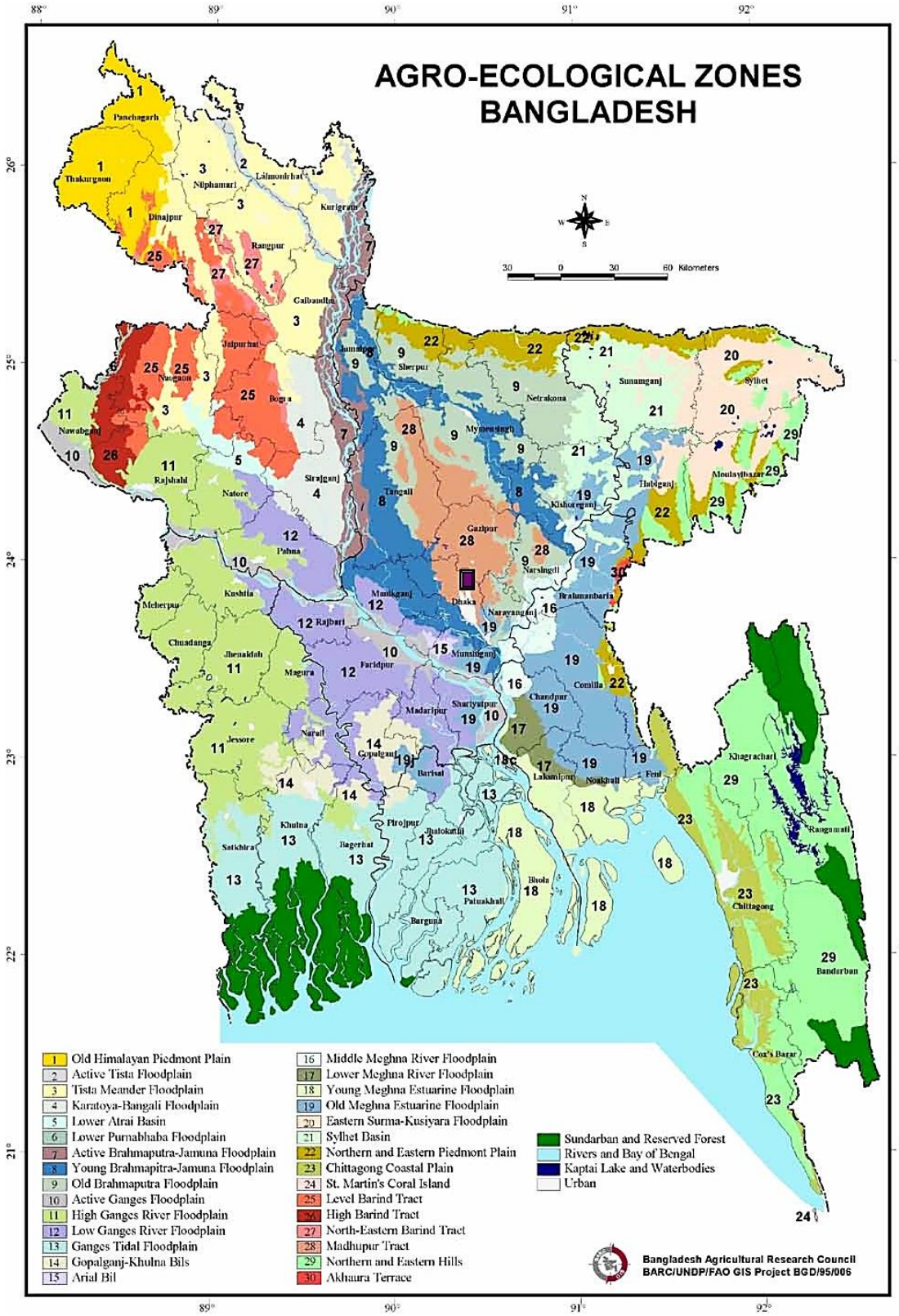


Appendices

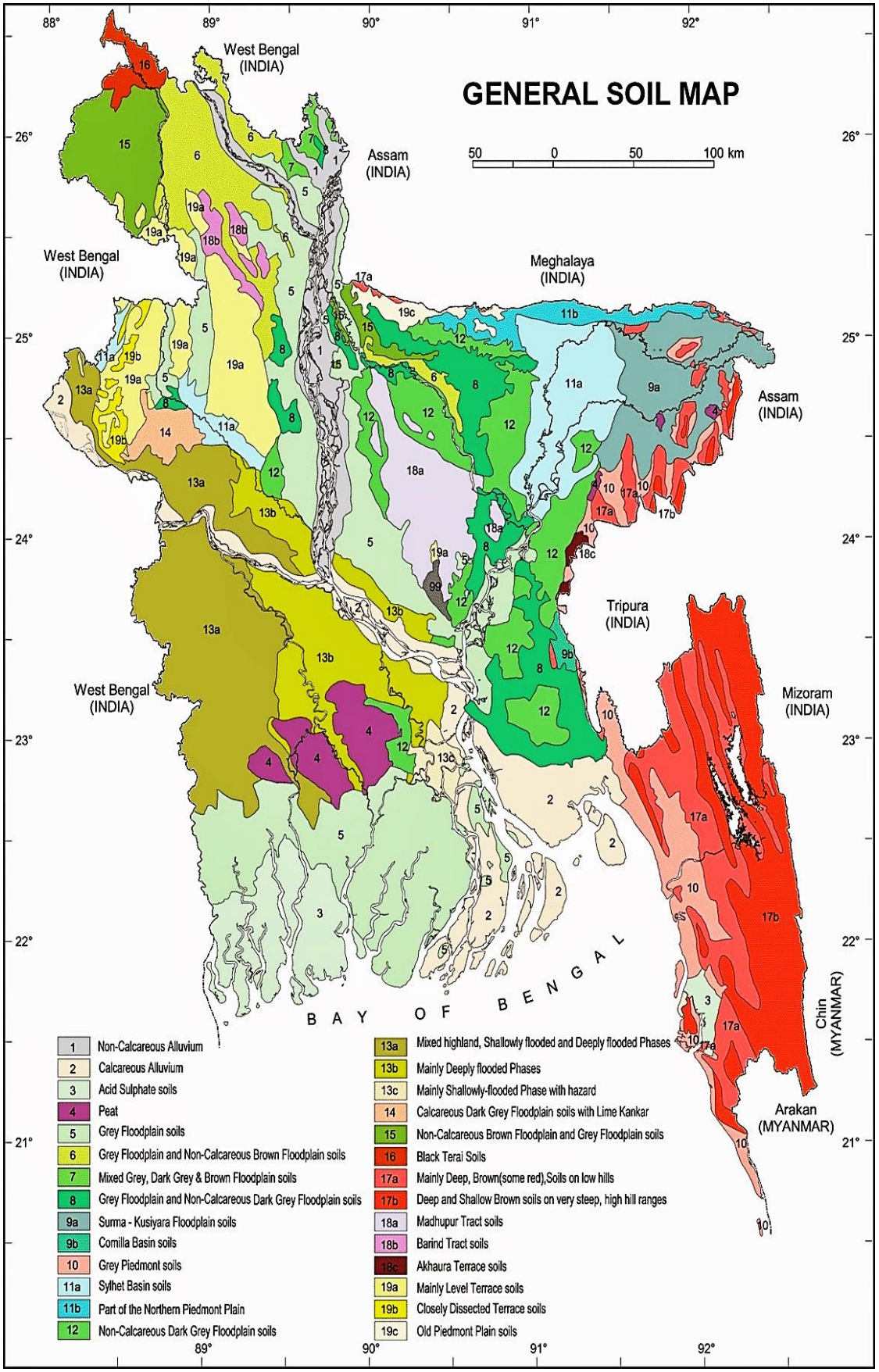
APPENDICES

Appendix I: (A) Map showing the experimental sites under study



■ The experimental site under study

Appendix I (B): Map showing the general soil sites under study



Appendix II. Characteristics of Agronomy Farm soil is analyzed by Soil Resources Development Institute (SRDI), Khamarbari, Farmgate, Dhaka

A. Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Agronomy Ferm, SAU, Dhaka
AEZ	Madhupur 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	Potato-Aus rice-Aman rice

B. Physical properties of the initial soil

Characteristics	Value
%Sand	27
%Silt	43
%clay	30

C. Chemical properties of the initial soil

Characteristics	Value
Textural class	Silty-clay
pH	5.6
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total N (%)	0.077
Available P (ppm)	20.00
Exchangeable K (mel 1 00 g soil)	0.10
Available S (ppm)	45

Source: Soil Resource Development Institute (SRDI)

Appendix III. Monthly average temperature, relative humidity and total rainfall of the experimental site during the period from November, 2018 to February, 2019

Month	Air temperature (^{0}C)		R. H. (%)	Total rainfall (mm)
	Maximum	Minimum		
November, 2018	21.20	14.25	52	35
December, 2018	20.82	12.04	47	12
January, 2019	18.40	10.50	45	8
February, 2019	18.25	11.20	49	22

Source: Bangladesh Metrological Department (Climate and weather division) Agargaon, Dhaka.

Appendix IV. Mean sum- square values for plant height of mustard at different days after sowing (DAS) and at harvest as influenced by fertilizer dose, mechanical weeding and their interaction

Source of variation	df	Plant height				
		20 DAS	35 DAS	50 DAS	65 DAS	Harvest
Replication	2	0.522	7.809	15.098	6.057	8.353
Fertilizer dose (A)	3	23.581*	22.255*	81.412*	184.095*	273.619*
Mechanical weeding (B)	2	31.558*	29.909*	92.664*	171.724*	105.107*
A × B	6	0.611**	0.568**	3.567**	2.986**	8.516*
Errror	22	0.099	0.843	2.125	0.302	1.263

*Significant at 5% level of probability

** Significant at 1% level of probability; df = Degrees of freedom

Appendix V. Mean sum- square values for number of leaves plant^{-1} of mustard at different days after sowing (DAS) and at harvest as influenced by fertilizer dose, mechanical weeding and their interaction

Source of variation	df	Number of leaves plant^{-1}				
		20 DAS	35 DAS	50 DAS	65 DAS	Harvest
Replication	2	0.055	0.002	0.314	0.191	0.059
Fertilizer dose (A)	3	23.264*	24.680*	28.620*	13.582*	11.985*
Mechanical weeding (B)	2	2.197**	2.342**	7.772*	8.785*	8.246*
A × B	6	0.138**	0.144**	0.282**	1.364**	3.942**
Errror	22	0.022	0.001	0.051	0.051	0.018

*Significant at 5% level of probability

** Significant at 1% level of probability; df = Degrees of freedom

Appendix VI. Mean sum- square values for number of branches plant^{-1} of mustard at different days after sowing (DAS) and at harvest as influenced by fertilizer dose, mechanical weeding and their interaction

Source of variation	df	Number of branches plant^{-1}			
		35 DAS	50 DAS	65 DAS	Harvest
Replication	2	0.095	0.003	0.005	0.114
Fertilizer dose (A)	3	5.955*	4.668**	10.067*	9.125*
Mechanical weeding (B)	2	1.708**	1.335**	7.269*	7.625*
A × B	6	0.020**	0.016**	0.439**	0.186**
Errror	22	0.022	0.001	0.001	0.036

*Significant at 5% level of probability

** Significant at 1% level of probability; df = Degrees of freedom

Appendix VII. Mean sum- square values for dry weight plant^{-1} of mustard at different days after sowing (DAS) and at harvest as influenced by fertilizer dose, mechanical weeding and their interaction

Source of variation	df	Dry weight plant^{-1}			
		35 DAS	50 DAS	65 DAS	Harvest
Replication	2	0.453	0.002	0.403	0.087
Fertilizer dose (A)	3	208.598*	11.410*	59.432*	129.465*
Mechanical weeding (B)	2	107.087*	2.609**	97.821*	66.353*
A × B	6	20.193*	0.138**	1.985**	12.572*
Errror	22	0.087	0.001	0.058	0.012

*Significant at 5% level of probability

** Significant at 1% level of probability; df = Degrees of freedom

Appendix VIII. Mean sum- square values for number of siliqua plant^{-1} of mustard at different days after sowing (DAS) and at harvest as influenced by fertilizer dose, mechanical weeding and their interaction

Source of variation	df	Number of siliqua plant^{-1}		
		50 DAS	65 DAS	Harvest
Replication	2	6.181	33.348	31.589
Fertilizer dose (A)	3	6649.373*	6912.132*	4902.365*
Mechanical weeding (B)	2	9429.056*	9851.195*	6882.151*
A × B	6	80.393*	85.043*	56.471*
Errror	22	1.396	4.802	6.594

*Significant at 5% level of probability

** Significant at 1% level of probability; df = Degrees of freedom

Appendix XI. Mean sum- square values for number of seeds siliqua^{-1}, siliqua length and 1000-seeds weight of mustard as influenced by fertilizer dose, mechanical weeding and their interaction

Source of variation	df	Number of seeds siliqua^{-1}	Siliqua length	1000-seeds weight
Replication	2	0.172	0.007	0.009
Fertilizer dose (A)	3	6.180*	6.282*	0.224**
Mechanical weeding (B)	2	2.141**	1.866**	0.386**
A × B	6	0.053**	0.198**	0.038**
Errror	22	0.065	0.003	0.003

*Significant at 5% level of probability

** Significant at 1% level of probability; df = Degrees of freedom

Appendix X. Mean sum- square values for grain yield, stover yield, biological yield, harvest index and weed population m^{-2} of mustard as influenced by fertilizer dose, mechanical weeding and their interaction

Source of variation	df	Grain yield	Stover yield	Biological yield	Harvest Index	Weed population m^{-2}
Replication	2	0.001	0.001	0.004	0.031	3.023
Fertilizer dose (A)	3	0.362**	0.166**	0.092**	113.866*	37.951*
Mechanical weeding (B)	2	0.195**	0.239**	0.017**	74.571*	69.652*
A × B	6	0.006**	0.005**	0.016**	1.275**	5.714*
Errror	22	0.001	0.001	0.001	0.357	1.351

*Significant at 5% level of probability

** Significant at 1% level of probability; df = Degrees of freedom

Data Collection

Maturity Stage

Harvesting