EFFECT OF PLANTING GEOMETRY AND SOWING TIME ON GROWTH AND PRODUCTIVITY OF MUSTARD

SHARMILEE ISLAM

DEPARTMENT OF AGRONOMY

SHER-E-BANGLA AGRICULTURAL UNIVERSITY

DHAKA-1207

JUNE, 2021

EFFECT OF PLANTING GEOMETRY AND SOWING TIME ON GROWTH AND PRODUCTIVITY OF MUSTARD

By

SHARMILEE ISLAM

REGISTRATION NO.: 14-06210

A Thesis
submitted to the Faculty of Agriculture,
Sher-e-Bangla Agricultural University, Dhaka-1207,
in partial fulfilment of the requirements
for the degree of

MASTER OF SCIENCE (MS)

IN

AGRONOMY

SEMESTER: JANUARY-JUNE, 2021

APPROVED BY:

Prof. Dr. H. M. M. Tariq Hossain **Supervisor**	**Dr. Anisur Rahman** **Associate Professor** **Co-Supervisor**

Prof. Dr. Tuhin Suvra Roy
Chairman
Examination Committee

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

Ref…………………………… Date……………………………..

CERTIFICATE

This is to certify that the thesis entitled ***'EFFECT OF PLANTING GEOMETRY AND SOWING TIME ON GROWTH AND PRODUCTIVITY OF MUSTARD'*** *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* ***SHARMILEE ISLAM****, Registration number:* ***14-06210,*** *under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

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

Dated:
Place: Dhaka, Bangladesh

Prof. Dr. H. M. M. Tariq Hossain
Department of Agronomy
Supervisor

Dedicated to My

Beloved Parents

ACKNOWLEDGEMENTS

*Alhamdulillah, all praises are due to The Almighty **Allah Rabbul Al-Amin** for His gracious kindness and infinite mercy in all the endeavors the author to let her successfully completing the research work and the thesis leading to Master of Science in Agronomy degree.*

*The author would like to express her heartfelt gratitude and most sincere appreciations to her supervisor **Prof. Dr. H. M. M. Tariq Hossain**, Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka, for his valuable guidance, advice, immense help, encouragement and support throughout the study. Likewise grateful appreciation is conveyed to co-supervisor **Dr. Anisur Rahman**, Associate Professor, Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka, for his constant encouragement, cordial suggestions, constructive criticisms and valuable advice to complete the thesis.*

*It is highly appreciating words for **Prof. Dr. Tuhin Suvra Roy**, Chairman, Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka along with faculties of the Department of Agronomy, Sher-e-Bangla Agricultural University for their rendered novel services towards me as their student.*

The author wishes to express her deepest gratitude and respect to all of the respected teachers of the Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka, for their valuable teaching, sympathetic cooperation, and inspirations throughout the course of this study and research work.

The author wishes to extend her special thanks to her classmates and friends for their keen help as well as heartiest co-operation and encouragement during experimentation.

The author is deeply indebted and grateful to her parents, and relatives; without whose love, affection, inspiration and sacrifice this work would have not been completed.

Finally the author appreciates the assistance rendered by the staff members of the Department of Agronomy, Sher-e-Bangla Agricultural University Farm staff, Dhaka, who have helped her during the period of study.

The Author

EFFECT OF PLANTING GEOMETRY AND SOWING TIME ON GROWTH AND PRODUCTIVITY OF MUSTARD

ABSTRACT

The experiment was conducted in the experimental field of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka to find out the effect of planting geometry and sowing time on growth and productivity of mustard during the period from October 2019 to March 2020. The experiment consisted of two factors; Factor A: Three sowing times *viz.*, S_1: Sowing on 25th October, S_2: Sowing on 10th November and S_3: Sowing on 30th November, 2019; Factors B: Four planting geometries *viz.*, G_1= Random geometry, G_2= 25 cm × 5 cm, G_3= 30 cm × 5 cm and G_4= 35 cm × 5 cm. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Plant height, leaves plant^{-1}, branches plant^{-1}, dry matter weight plant^{-1}, siliquae plant^{-1}, seeds siliqua^{-1}, length of siliqua, 1000 seed weight, seed yield, stover yield, biological yield and harvest index were compared among the combinations and individual effects of treatments. Results indicated that, sowing time and planting geometry had significant influence on most of the growth, yield and yield contributing characters of mustard. The maximum seed yield (2.16 t ha^{-1}) was obtained from S_2 and the minimum seed yield (1.68 t ha^{-1}) was obtained from S_3. In the case of planting geometry, the maximum seed yield (2.00 t ha^{-1}) was obtained from G_3 and the minimum seed yield (1.82 t ha^{-1}) was obtained from G_1. Thus, it was revealed that when mustard was sown on 10th November with 30 cm × 5 cm geometric pattern resulted with the highest seed yield (2.24 t ha^{-1}). The lowest seed yield (1.58 t ha^{-1}) was obtained from the 30th November sowing with random geometry. So, it may be recorded that mustard sowing on 10th November with 30 cm × 5 cm planting geometry (S_2G_3) could be the most suitable combination for the potential yield improvement in Bangladesh.

LIST OF CONTENTS

LIST OF CONTENTS (Cont'd)

LIST OF CONTENTS (Cont'd)

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES (Cont'd)

LIST OF APPENDICES

LIST OF ACRONYMS

Acronym		Full meaning
AEZ	=	Agro-Ecological Zone
%	=	Percent
^0C	=	Degree Celsius
BARI	=	Bangladesh Agricultural Research Institute
cm	=	Centimeter
CV%	=	Percentage of coefficient of variance
cv.	=	Cultivar
DAS	=	Days after sowing
et al.	=	And others
FAO	=	Food and Agriculture Organization
g	=	Gram
ha^{-1}	=	Per hectare
kg	=	Kilogram
LSD	=	Least Significant Difference
MoP	=	Muriate of Potash
N	=	Nitrogen
No.	=	Number
NPK	=	Nitrogen, Phosphorus and Potassium
SAU	=	Sher-e-Bangla Agricultural University
SRDI	=	Soil Resource and Development Institute
t	=	Ton
TSP	=	Triple Super Phosphate
viz.	=	Videlicet (namely)
Wt.	=	Weight

CHAPTER I

INTRODUCTION

CHAPTER I

INTRODUCTION

Edible oil is highly important in human nutrition. Edible oils are important for meeting calorie requirements because they are a high-energy component of food. Each gram of oil/fat contains approximately 9 kilocalories of energy, whereas each gram of carbohydrate/protein usually contains 4 kilocalories of energy (Stryer, 1980). Fats and oils are also the sources of essential fatty acids. The main essential fatty acids of vegetable oils are linoleic and linolenic acids. Fats and oils are used to synthesize phospholipid, which are important components of active tissues *viz*., brain, nerve, and liver of human beings and other animals. The current dietary pattern of the people of Bangladesh is highly imbalanced due to an excess consumption of carbohydrates in the form of cereal that exceeds the body’s requirement. Carbohydrates represent approximately 86% of total calorie requirements, while fats and oils contribute only 5-15% (Ullah, 1989). In Bangladesh, the average availability of oils and fats per capita per year is 3.8 kg (10.55 g/head/day) compared to the requirement of 11 kg, while most developed countries consume around 20 kg. For several decades, Bangladesh has been suffering from a severe shortage of edible oil. Our internal production can only meet about 21% of our needs (8 g/day/head). The remaining 79% is met by imports (Begum *et al.*, 2012). Due to insufficient production, a large amount of foreign exchange (over 160 million US dollars) is spent each year in Bangladesh for the importation of edible oils (Rahman, 2002).

Mustard (*Brassica spp*.) is one of the most important oil yielding crops of the world after soybean and groundnut (FAO, 2012). The genus *Brassica* of the family Crucifereae has mainly three edible oil producing species, namely *Brassica napus*, *B. campestris*, and *B. juncea*. Worldwide the total annual production of rapeseed along with mustard is 71.16 million tons of seed from an area of 42.81 million hectares (FAO, 2019). But it occupies the first position in respect of area and production among the oil crop grown in Bangladesh (DAE, 2015). In Bangladesh the edible oil production is 3,76,000 metric tons of which mustard *(Brassica spp*.) covers 62% of the total annual oil (MOA, 2006). Bangladesh occupying 0.270 million ha and the production was 0.312 million Mt and yield 0.115 million Mt ha^{-1} in 2018-19 (BBS, 2020). It is an important source of cooking oil in Bangladesh meeting one third of the edible oil requirement of the country (Ahmed, 2008). It is not only a high energy food but also a carrier of fat soluble vitamins (A, D, E and K) in the body.

The average per hectare yield of mustard in this country is alarmingly very poor compared to that of advanced countries like Germany, France, UK and Canada producing 6667 kg ha^{-1}, 5070 kg ha^{-1}, 3264 kg ha^{-1}, 3076 kg ha^{-1}, respectively (Mamun *et al.*, 2014). The low average yield of mustard is due to the cultivation of traditional varieties, the scarcity of seeds from high yielding varieties, the improper sowing time, and poor management practices, among other factors. It is essential that immediate attention should be given to increasing domestic production. Increased mustard production can result from both increased farmed area and increased productivity, or from both. However, the area under mustard is declining due to late harvesting of high yielding T. *aman* rice and increased cultivation of boro rice, which has resulted in a loss of 104 thousand hectares and a production of 68 thousand tons of mustard and rapeseed during the last ten years (Anon, 2006). As a result, increasing mustard yield by the use of HYV seed and good management practices, particularly optimum sowing time, could be a viable way to address these challenges. Proper agronomic manipulation could bring mustard yields closer to the level of variety potentiality.

At different sowing times, the days to flowering and maturity varied. The date of sowing had a significant influence on plant height, siliquae $plant^{-1}$, seeds $siliqua^{-1}$, seed yield, and seed oil content. Plant height, number of siliquae $plant^{-1}$, number of seeds $siliqua^{-1}$, seed yield, and stover yield all were significantly influenced by the interaction effect of variety and sowing date (Alam *et al.*, 2014). Sowing date is one of the critical components affecting mustard crop productivity. It is one of the most essential agronomic factors and non-monetary inputs that lead the way for better time management and play an important part in fully exploiting a variety's genetic potentiality by providing optimum growth circumstances such as temperature, light, humidity, and rainfall. Sowing time is also significant in determining crop environmental conditions, as well as the timing and rate of organ appearance, while predicting phenology is critical in crop growth analysis. The crop is grown mainly during the winter season (October-March). If the mustard is sown late, duration is reduced due to the high temperature during the reproductive phase with concomitant reduction in yield (Kumari *et al*., 2012). Some researchers demonstrated that the yield of mustard crop sown in second fortnight of September was significantly higher than that sown in first fortnight of October (Iraddi, 2008). In general, it was observed that the mustard crop sown after October 30th resulted in lower yields (Panwar *et al*., 2000; Singh *et al*., 2002; Sonani *et al*, 2002; Panda *et al*., 2004). Understanding the physiological and phenological factors of yield decline in relation to the date of sowing can aid the development of seed yield improvement strategies. It will also help to support the assertion that production is constrained by development pattern and process physiology in response to environment.

However, in oilseed rape and mustard row spacing or plant density may vary considerably worldwide; depending on the environment, production system and cultivar. Previous studies have shown that plant geometry is an important factor that affects rapeseed-mustard yield. Population density, as a result of planting geometry also influences growth, yield and yield contributing characters in rapeseed production (Johnson *et al.*, 2003). Planting geometry refers to row to row and plant to plant distances both of which are important in the production of rapeseed and mustard. Suboptimal planting geometry, wider rows and plant spacing result in a low population which fails to compensate for the yield obtained in an optimal plant stand whereas narrower row and plant spacing increase inter and intra-plant competitions which are resulting in poor growth and development, dry matter accumulation, and yield (Sonani *et al*, 2002). Lakra *et al.* (2018) suggested closer row spacing of 30 cm for better yields. Therefore, a uniform distribution of plants per unit area is a prerequisite for yield stability that securing good yield of a crop (Diepenbrock, 2000).

Therefore the study has been undertaken to identify the effect of sowing time and planting geometry on the growth and productivity of mustard with following objectives:

i. To determine the suitable sowing time for yield maximization of mustard.
ii. To evaluate the effect of planting geometry on growth and productivity of mustard.
iii. To find out the combined effect of sowing time and planting geometry on the growth and yield of mustard.

CHAPTER II

REVIEW OF LITERATURE

CHAPTER II

REVIEW OF LITERATURE

An attempt was made in this section to collect and study relevant information available in the country and abroad regarding the effect of planting geometry and sowing time on growth and productivity of mustard to gather knowledge helpful in conducting the present research work.

2.1 Effect of sowing time

Gawariya *et al.* (2015) conducted a field experiment was to study the effect of date of sowing and crop geometry on seed yield and quality of forage mustard (*var.* Chinese cabbage). The soil texture of the experimental site was clay loam with available nitrogen, phosphorus, potassium were 212, 20 and 256 kg ha^{-1}, respectively. There were 24 treatment combinations consisting of four dates of sowing (1^{st} October, 16^{th} October, 31^{st} October and 15^{th} November) and six crop geometry (60 × 15, 45 × 15, 45 × 20, 45 × 25, 30 × 20 and 30 × 25 cm) and the experiment was laid out in split plot design with four replications. From the result, sowing during 1^{st} October recorded significantly higher crop yield attributing characters *viz.* no. of primary, secondary and tertiary branches, number and weight of siliquae $plant^{-1}$ and ultimately seed yield (2013 kg ha^{-1}) with better growth and higher dry matter accumulation in yield components compared to 31^{st} October and 15^{th} November.

Lakra *et al.* (2018) conducted a field experiment during the winter (rabi) seasons of 2015-16 to study the response of Indian mustard (*Brassica juncea* L.) var. NRCHB-101 to sowing dates and crop geometry. Sowing on 27^{th} October was recorded significantly higher number of branches, seeds per siliquae, siliquae per plant, 1000 seed weight, and seed yield than that on 07^{th} November, 17^{th} November and 27^{th} November. Seed yield decreased progressively with delay in planting. Pronay *et al.* (2011) carried out an experiment on Improved Tori-7 and BARI Sarisha-10 with seven sowing date viz. Nov-8, Nov-15, Nov-22, Nov-29, Dec-6 and Dec-13. From the result it was observed that among the sowing dates 8 November sowing was the best for mustard and BARI Sarisha-10 was better than that of improved Tori-7. Sharma *et al*. (2006) reported that the significantly greater plant height was observed at 75 DAS with 29^{th} October sowing (160.6 cm) as compared to 22^{nd} October (158.5 cm), 12^{th}

October (145.7cm) and 6th October (140.4 cm) sowings. Sultana (2007) studied on rapeseed in Sher-e-Bangla Agriculture university farm to evaluate the effect of irrigation and variety on growth and yield. She revealed that seed yield highest (1827.0 kg ha^{-1}) at three irrigation (20, 35, 50 DAS). Bhuiyan *et al.* (2008) reported significantly higher plant height under 10th November sowing (115 cm) as compared to 30th October (105 cm), 20th November (104 cm), 20th October (100 cm), 30th November sowings. Shah and Rahman (2009) observed significantly higher plant height with 15th September (212.5 cm) sowing as compared to 25th September (203.8 cm), 5th October (183.2 cm), 15th October (188.3 cm), 25th October (181.1 cm), 5th November (155.6 cm), and 15th November (126.1 cm) sowings.

Lallu *et al*. (2010) conducted an experiment and revealed that November sowing caused the significant reduction in plant height (100.5 cm) as compared to October sowing (152.8 cm). Afroz *et al.* (2011) carried out an experiment at Mymensingh (Bangladesh) and observed that significantly higher plant height was found under 10th November sowing (99.4 cm) as compared to 20th November (93.0 cm) and 30th November (78.0 cm) sowings. Aziz *et al.* (2011) also reported that 15th November sown mustard crop produced the maximum plant height (162 cm) as compared to 25th November, 5th December and 15th December. Mondal *et al.* (2011) reported that plant height was significantly higher with 20th November sowing (104.2 cm) 20th October (102.9 cm) as compared to 10th November (100.7 cm), 1st November (100.1 cm) and 30th November (98.3 cm) sowings. Kumari *et al.* (2012) observed that 10th October sowing resulted into significantly higher plant height (217 cm) over 20th October sowing (208 cm) and 30th October sowing (187 cm).

Patel *et al.* (2017) conducted an experiment and revealed that plant height increased successively till 90 DAS under different dates of sowing. Different dates of sowing had no significant influence on plant height at 30 DAS which might be due to similar growth pattern at initial growth period. On the other hand at 60 DAS, 90 DAS and at harvest, plant height was found to be highest with crop shown on 14th November which was at par with 30th October and significantly higher over 15th October and 29th November. The varieties had no significant influence on plant height at 30 DAS which might be due to similar growth pattern at initial growth period whereas at 60, 90 DAS. Kumar *et al.* (2008) reported that the number of branches plant^{-1} were significantly greater in mustard were with 30th September (22.2 plant^{-1}) sowing as compared to 15th October (19.7 plant^{-1}), 30th October (16.6 plant^{-1}) and 14th November (14.3 plant^{-1}) sowings.

Mondal *et al.* (2011) conducted an experiment and revealed that number of siliquae (plant^{-1}) were significantly higher with 1st November (97) sowing as compared to 20th October (86), 10th November (71.0), 20th November (57.3) and 30th November (69.7) sowings. Kumari *et al.* (2012) suggested that 10th October sowing recorded significantly higher number of siliquae plant^{-1} (323) over 20th October sowing (302 plant^{-1}) and 30th October sowing (238 plant^{-1}). Shah and Rahman (2009) conducted a field experiment and revealed that the seed yield was found remarkably higher with 25th September (3.6 t ha^{-1}) sowing as compared to 5th October (2.8 t ha^{-1}), 15th October (2.3 t ha^{-1}), 15th September (1.7 t ha^{-1}), 25th October (1.3 t ha^{-1}) , 5th November (1.06 t ha^{-1}) and 15th November (0.5 t ha^{-1}) sowings. Biswas *et al.* (2011) conducted an experiment and revealed that the seed yield was found remarkably higher with 10th October sowing (2.28 t ha^{-1}) as compared to 17th October (2.20 t ha^{-1}), 24th October (1.81 t ha^{-1}), 1st November (1.69 t ha^{-1}), 8th November (1.37 t ha^{-1}) and 15th November (1.07 t ha^{-1}) sowings.

Sattar *et al.* (2013) conducted a study to investigate the response of seed yield, protein and oil content of canola varieties to different sowing times. Experiment was comprised of three varieties of canola viz; Bulbul-98, Zafar-2000 and Rainbow were sown at three different sowing dates, early (15th October), late (30th October) and very late (15th November). Results indicate that from all these three varieties, seed yield, protein and oil contents of all cultivars were decreased due to delayed sowing. The decline of grain yield with delay in sowing date could be largely explained by the decline in biomass at maturity while for protein and oil contents it could be related positively to harvest index and seed size, and negatively to temperature conditions at post-anthesis stage. Cultivar Zafar-2000 produced the maximum seed yield, protein and oil contents when planted earlier (15th October). It can be concluded that cultivar Zafar-2000 should be sown 15th October for attaining the maximum seed yield and oil contents under the sub-tropical climate of Pakistan.

Devi and Sharma (2017) carried out a study to determine the effect of sowing date on flowering and seed set of mustard (*Brassica juncea* L.). The studies were conducted in the mustard crop by inducing the plant to flower early or late through different sowing dates. The crop was sown during October- November in three different dates at an interval of fifteen days. Delay in sowing caused a significant reduction in the length of flowering period. The crop sown on D_1 had the longest flowering duration (45 days) followed by the crop sown on D_2 (41 days) and D3 (35 days). In the present investigations, crop sown on D_1 took significantly more days from sowing to the flowering stage as compared to D_2 and D_3. Delayed sowing of mustard resulted into reduction in the seed set due to short flowering duration. Delaying sowing time resulted in significant reduction in the seed set. Seed set percentage, 1000 seed weight and seed siliqua^{-1} did not vary significantly among different dates of sowing.

Ranabhat *et al.* (2021) conducted a field experiment to determine the response of different sowing dates on different rapeseed varieties in their final yield under the rain fed condition in Phulbari, Dang. Two rapeseed varieties Unnati and Surkhet Local on three dates of sowing October 4, October 24 and November 14 were tested under two factorial RCBD design in the year 2018. Data consisted growth attributes like plant height, branch per plant, no. of siliqua per plant, aborted siliqua and siliqua abortion percentage and yield attributes such as biological yield, biomass yield, seed yield, harvest index and test weight. Statistically no difference was found between varieties whereas differences were found on different sowing dates. Result showed that among the varieties, the highest yield (8.59 q ha^{-1}) was obtained in Surkhet Local than in Unnati (8.54 q ha^{-1}). In case of sowing dates, higher seed yield was obtained in October 4 sown crop (15.93 q ha^{-1}) followed by October 24 (7.47 q ha^{-1}) and November 14 (2.29 q ha^{-1}).The higher seed yield obtained in early sowing is due to shorter vegetative and longer reproductive phase. The comparison of mean values of the seed yield for interaction between variety and sowing date showed that variety Surkhet Local sown in October 4 plant had the highest seed yield (16.33 q ha^{-1}) followed by variety Unnati on same sowing date (15.54 q ha^{-1}). Based on the result obtained, Surkhet Local sowing on October 4 performed better in Dang condition.

Bikshapathi *et al.* (2021) conducted a field experiment during *rabi* season of 2019 at Crop Research Farm of Department of Agronomy at Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj with the objective to study the effect of sowing dates on growth and yield attributes of Indian mustard (*Brassica juncea* L.) varieties under late sown conditions. Experiment comprises of 9 treatments replicated thrice. With 3 different dates of sowing *viz.* 5th December, 10th December and 15th December; 3 varieties i.e., Varuna, Mahyco Bold, Pioneer. Maximum plant height (185.23 cm), No. of branches (9.41), No. of siliqua per plant (241.3), was recorded with the treatment no.1 Varuna + 5th December sowing. Highest no. of seeds per siliqua (15.5) was recorded with treatment no.1 Varuna + 5th December sowing and maximum test weight was recorded with treatment no. 5 Mahyco Bold+ 10th December.

Singh *et al.* (2017) conducted a field experiment at Agronomy Research Farm, N.D. University of Agriculture and Technology, Kumarganj, Faizabad during the Rabi season of 2011-12 to access the effect of sowing dates and varieties for higher productivity of Indian mustard (*Brassica juncea* L.). Treatments consisted of four dates of sowing viz. D_1 (25th September), D_2 (5th October), D_3 (15th October) and D_4 (25th October) was kept as main plot and five varieties viz.V_1 (Rohini), V_2 (Maya), V_3 (Coral-437), V_4 (Kranti) and V_5 (PBR-357) was kept as sub plot replicated three under split plot design. Results revealed that all the growth, yield attributes and quality were increased significantly under 25th October sowing. The agronomical parameters like initial plant stand per running meter, plant height (cm), days taken to 50 % flowering, leaf area index, dry matter accumulation (g $plant^{-1}$) and yield and yield attributes like number of siliquae $plant^{-1}$, number of seed $siliqua^{-1}$, length of siliqua (cm) and seed, stover yields (q ha^{-1}) of mustard crop were significantly higher with variety Coral-437. The highest seed yield oil content % was computed under 25th October sowing with Coral-437 variety. 25th October sowing with Coral-437 variety proved the most remunerative and economically feasible for cultivation of Indian mustard under the agro climatic conditions of eastern U.P.

Sharif *et al.* (2016) conducted an experiment at the field laboratory of the Patuakhali Science and Technology University, Patuakhali, Bangladesh during the period from November, 2011 to March 2012 under the tidal Floodplain region to find out optimum sowing time for the selected three cultivars (BARI Sharisha-15, BINA Sharisha-5 and BARI Sharisha-9). There were four sowing dates viz. 30 November, 15 December, 30 December and 15 January. Significant variations due to different sowing dates were observed in plant height, total dry matter, leaf area index, number of siliqua $plant^{-1}$, seeds $siliqua^{-1}$, 1000-grain weight, grain yield and HI. Results showed that the highest grain yield (1.73 t ha^{-1}) was obtained from the first sowing (30 November) with BINA Sharisha-5 and it was significantly different from the yields of all other combination.

Alam *et al.* (2014) carried out a field experiment at the Central Research Station of BARI, Gazipur for two consecutive years 2010-11 and 2011-12 with 30 varieties/genotypes of rapeseed-mustard under three dates of sowing viz., 25 November, 5 December, and 15 December to determine changes in crop phenology, growth and yield of mustard genotypes under late sown condition when the crop faced high temperature. Days to flowering and maturity were different at different planting times. Date of sowing significantly influenced plant height, siliquae plant^{-1}, seeds siliqua^{-1}, seed yield and oil content of seed in both the years. The highest seed yield (1310 and 1535 kg ha^{-1}) was obtained from the first planting (25 November) in both the years, which was significantly different from two other dates of sowing. Yield and yield attributes of different varieties varied significantly. Among the varieties, BARI Sarisha-16 of *Brassica juncea* gave significantly the highest seed yield (1495 and 1415 kg ha^{-1}), which was statistically identical to BJDH-11, BJDH-12, BJDH-05, BJDH-20, and BARI Sarisha-6 and significantly different from all other varieties. Interaction effect of variety and sowing date significantly influenced plant height, number of siliquae per plant, number of seeds per siliqua, seed yield, and strover yield. The highest seed yield (1758 and 1825 kg ha^{-1}) was recorded from BJDH-11 and BARI Sarisha-16 of *Brassica juncea* at 25 November planting and BJDH-11 produced the highest yield at 15 December in both the years. The maximum stover yield (3758 and 3825 kg ha^{-1}) was obtained from BJDH-11 and BARI Sarisha-16 of *Brassica juncea* at 25 November planting during 2010-11 and 2011-12. The highest oil content of seeds (44.4 % and 45.9 %) was obtained from the seed of BARI Sarisha-6 and BARI Sarisha-14 at 25 November planting in both the years.

Alam *et al.* (2015) conducted an experiment at Shibganj upazila under Bogra district during October, 2014 to January, 2015 to observe the effect of planting dates on the yield of mustard seed. There were five planting dates *viz.* 25 October, 30 October, 05 November, 10 November and 15 November. Significant variations due to different planting dates were observed in plant height, number of leaves plant^{-1}, number of siliqua plant^{-1}, number of seeds siliqua^{-1}, 1000 grain weight plot^{-1}, yield plot^{-1} and yield ha^{-1}of mustard. Results showed that the highest seed yield was 1.50 t ha^{-1} obtained from 30 October. The lowest seed yield was 1.0 t ha^{-1} from 15 November.

From the results, the best planting date of mustard is on 30 October in the northern parts of Bangladesh. Parminder and Sidhu (2006) conducted an experiment and found that the oil and protein content significantly decreased as sowing was delayed from 15 October to 15 December.

Kumar *et al.* (2018) conducted an experiment with 6 genotypes of Indian mustard (*Brassica juncea* L.) *viz.* RH-0116, RH-725, RH-923, RH-1019, RH-1077, RH-1301 for three dates of sowing i.e. 23 September, 16 October and 21 November in the field in randomized block design during rabi season of 2015-16 at Oil Seed Section, Chaudhary Charan Singh Haryana Agricultural University, Hisar to observe the effect of sowing dates on yield and yield attributes of Indian mustard genotypes. The values of yield and all yield attributes were highest on 16 October sowing while 21 November sowing dates showed lowest values of yield and yield attributing traits. Results showed that among sowing dates, 16 October sowing was the best for Indian mustard and genotypes RH-0116 performed better in terms of yield and yield attributes.

Tripathi *et al.* (2021) conducted a field experiments to study effect of sowing dates on growth and yields of Indian mustard (*Brassica juncea* L.). Keeping in this view experiment was conducted in Split Plot Design (SPD) with three replications having two factors. First factor comprised of three dates of sowing (15 October, 10 November and 05 December) whereas, second factor consisted of three Indian mustard varieties *viz*; Varuna, Narendra rai-1 and Kranti. Results showed that both dates and varieties (10 November and Varuna) was superior compared to rest of treatment. However, highest growth attributes (plant height, dry matter accumulation, days taken to 50% flowering, number of tillers, LAI and yield and yield attributes (No. of siliqua per plant, length of siliqua (cm), test weight, seed yield (q ha^{-1}) grain yield, stover yield, biological yield, and harvest index) was recorded under 10 November and Varuna, and oil character. Lowest yield recorded under dates and varieties at 15 October followed by 05 December and Narendra rai-1 and Kranti. Among treatment, dates and varieties (10 November and Varuna) showed effectively increasing the growth and yield and enhanced the nitrogen content efficiency and oil content and oil yield.

Keerthi *et al.* (2017) conducted a field experiment during *rabi* seasons of 2013-15 at Hisar to find out the response of Indian mustard to four dates of sowing (15^{th} October, 25^{th} October, 5^{th} November and 15^{th} November) and five nitrogen levels (0, 40, 60, 80 and 100 kg N ha^{-1}). Among the times of sowing, 15^{th} October being at par with 25^{th} October gave significantly higher seed yield, stover yield and nitrogen uptake probably due to higher growth and yield attributes. Application of 100 kg N ha^{-1} significantly improved the seed yield, stover yield and nitrogen uptake. Agronomic efficiency, apparent recovery and nutrient use efficiency were maximum at 15^{th} October sown crop and among the nitrogen doses agronomic and nutrient use efficiency was highest with 40 kg N ha^{-1} whereas apparent recovery was highest with 60 kg N ha^{-1}. Optimum economic dose of nitrogen for 15^{th} October, 25^{th} October, 5^{th} November and 15^{th} November were 119.8, 116.8, 110.6 and 101.8 kg ha^{-1} respectively.

2.2 Effect of planting geometry

Gawariya *et al.* (2015) conducted a field experiment during *rabi* 2011-2012 at Forage Management and Research Centre, National Dairy Research Institute, Karnal to study the "Effect of date of sowing and crop geometry on seed yield and quality of forage mustard (var. Chinese cabbage)". The soil texture of the experimental site was clay loam with available nitrogen, phosphorus, potassium which was 212, 20 and 256 kg ha^{-1}, respectively. There were 24 treatment combinations consisting of four dates of sowing (1^{st} October, 16^{th} October, 31^{st} October and 15^{th} November) and six crop geometry (60 × 15, 45 × 15, 45 × 20, 45 × 25, 30 × 20 and 30 × 25 cm) and the experiment was laid out in split plot design with four replications. From the result, sowing during 1^{st} October recorded significantly higher crop yield attributing characters *viz.* no. of primary, secondary and tertiary branches, number and weight of siliquae $plant^{-1}$ and ultimately seed yield (2.03 t ha^{-1}) with better growth and higher dry matter accumulation in yield components compared to 31^{st} October and 15^{th} November. Crop geometry of 30 × 20 cm recorded significantly higher seed yield (1.8 t ha^{-1}) with better utilization of space, nutrients, water and sunshine resulting in higher dry matter translocation to yield components as compared to 60 × 15, 45 × 15, 45 × 20, 45 × 25 and 30 × 25 cm crop geometry.

Lakra *et al.* (2018) conducted a field experiment during the winter (rabi) seasons of 2015-16 to study the response of Indian mustard (*Brassica juncea* L.) var. NRCHB-101 to sowing dates and crop geometry. Sowing on 27th October was recorded significantly showing higher number of branches, seeds per siliquae, siliquae per plant,1000 seed weight, and seed yield than that on 07th November, 17th November and 27th November. Seed yield decreased progressively with delay in planting. However seed yield was significantly influenced by different crop geometry. Higher seed yield ha^{-1} was recorded with 30 cm row to row and 10 cm plant to plant spacing (30 × 10 cm) crop geometry. A planting geometry of 30 × 10 cm was found to be suitable for the Indian mustard var. sown on 27th October. Khanlou and Sharghi (2015) conducted an experiment to determine the effects of row spacing on yield components of three cultivars of winter canola and planting them in the test treatments and variety, in which the planting distance in 3 levels: 30, 40 and 50 cm in 3 levels and three varieties, including Opera, Zarfam and Modena. The results showed that effect of variety was significant on height of plant, diameter of stem. The effect of planting distance has a significant effect on the plant height ($P<0.01$).

Aziz (2014) conducted a field experiment to evaluate the growth and yield performance of mustard and rapeseed varieties as influenced by different sowing techniques at the Agronomy field of Sher-e-Bangla Agricultural University, Dhaka during the Rabi period in 2013-14. The variety treatments were BARI Sarisha-11, BARI Sarisha-13, BARI Sarisha-15 and SAU Sarisha-2. Sowing technique treatments were Broadcasting, Line Sowing, Raised Bed and System of Mustard Intensification (SMI). Result showed that plant height was significantly varied among the sowing techniques. Hossain *et al*. (2013) carried out an experiment at Agronomy field laboratory, Department of Agronomy and Agricultural Extension, University of Rajshahi to study the effect of irrigation and sowing method on yield and yield attributes of mustard. Sowing method had significant effect on plant height. Line sowing produced the tallest plant (96.51 cm) and the shortest one (94.26 cm) was found at broadcast method. Sam-Daliri *et al*. (2011) carried out a study on factorial experiment in randomized complete block design in three replicates in which the planting distance in 3 levels: 30, 40 and 50 cm in 3 levels and three varieties, including new lines (crossed two varieties of H19, oliath), Zarfam and Pahnab-e-joybar (Local varieties). The results showed that simple varieties has significant on the number of branches in plants ($P<0.05$). Oad *et al*. (2001) conducted an experiment in Pakistan to evaluate the effect of row spacing on growth and yield of rapeseed (*B. napus*). The homogeneous seeds of rape cv. P 53 were sown at 3 row spacing (30, 45 and 60 cm). They observed that branches plant^{-1} was affected significantly by row spacing and among them 60 cm row spacing proved the best.

Hasanuzzaman (2008) carried out a field experiment at Sher-e-Bangla Agricultural University (SAU) Farm, Dhaka-1207, Bangladesh. Accumulation of dry matter in siliqua, number of siliquae plant^{-1}, length of siliqua and seeds per siliqua of rapeseed (*Brassica campestris* L.) plants were studied under three irrigation levels (no irrigation, one irrigation at 30 DAS and two irrigations at 30 and 60 DAS) and three row spacing (20 cm, 30 cm and 40 cm). Number of siliquae plant^{-1} was affected by different irrigation levels and row spacing and the highest number of siliquae was produced by two irrigations (at 30 DAS and 60 DAS) with 40 cm row spacing. Atlassi *et al*. (2008) conducted an experiment in order to evaluate the effect of planting pattern on morphology, yield and yield components of canola. The experiment was laid on split-plot design. The treatments included four planting patterns (15, 30 and 50 cm row spacing and 60 cm wide ridges with a cultivated row in each side) as main plots and three cultivars (Pf 7045/91, Hyola 401 and RGS 003) as sub-plots. The effect of planting pattern on 1000 seeds weight was more significant.

Mottalebipour and Bahrani (2006) carried out a field experiment and revealed that increasing row spacing significantly increased the values of almost all yield attributes but it had no significant effect on number of branches plant^{-1}, seeds siliqua^{-1}, seed yield and oil yield. The highest oil content (35.3 %) was recorded for the crop sown in 15 October. A row spacing of 60 cm recorded a higher protein content and lower oil content than a row spacing of 45 or 30 cm. Faraji (2004) conducted an experiment and observed that a decrease in row spacing resulted in the increase in number of siliqua plant^{-1}, number of seed siliqua^{-1} and seed yield. Row spacing at 12 cm and the sowing rate of 6 kg seed ha^{-1} produced the highest seed yield of 5044 kg ha^{-1}. Bilgili *et al*. (2003) carried out a field study and observed that a significant response between yield contributing characters and seed yield of *B. rapa* L. It is observed that higher seed yield 14090 kg ha^{-1} was obtained from seeding rate 200 m^{-2} at 35 cm row spacing. Singh *et al.* (2003) conducted an experiment at C. S. Azad University of Agriculture and Technology, Kanpur and revealed that a row spacing of 45 cm resulted in the higher seed yield (2064 kg ha^{-1}). It is suggested that closer row spacing of 20 cm produces the lower seed yield of 1343 kg ha^{-1} (Kumar and Singh, 1994). A field experiment was conducted by Yadav *et al.* (2018) during *rabi season* of 2014 on the topic entitled "Effect of planting geometry on growth and yield of mustard (*Brassica juncea* L.) varieties" in sandy loam soil of N.D. University of Agriculture and Technology, Kumarganj, Faizabad (U.P.). The experimental comprised of three planting geometry *viz*., 40 × 15 cm, 40 × 20 cm, 40 × 25 cm and three varieties *viz*., Varuna, Vardan and NDR-8501. Results revealed that planting geometry of 40 × 15 cm produced significantly higher growth yield.

Venkaraddi (2008) carried out an experiment to observe the response of mustard varieties on date of sowing and row spacing at Main Agricultural Research Station, University of Agricultural Sciences, Dharwad. The experiment comprises of 12 treatment combinations consisting of three varieties (Pusa Agram, Pusa Mahak and EJ-15), two sowing dates (II fortnight of September and I fortnight of October) and two row spacing (30 cm and 45 cm). The performance of mustard with respect to growth and yield parameters was significantly superior with variety Pusa Agram, II fortnight of September sowing and 30 cm row spacing. Significantly higher net returns and B:C ratio were recorded with variety Pusa Agram (16081 Rs. ha^{-1} and 2.14), early sowing during II fortnight of September (13079 Rs. ha^{-1} and 1.78) and 30 cm row spacing (12600 Rs. ha^{-1} and 1.68). It is summarized that mustard seed yield (1326 kg ha^{-1}), oil yield (570.03 kg ha^{-1}), net returns (23107 Rs. ha^{-1}) and B:C ratio (3.12) were higher with variety Pusa Agram sown during II fortnight of September at 30 cm row spacing.

Biswas *et al.* (2019) conducted an experiment at Sher-e-Bangla Agricultural University farm to evaluate the performance of five rapeseed and mustard varieties under two different planting techniques. The planting techniques were as conventional sowing and sowing seeds in puddle soil that assigned to the main plot and five varieties viz. Improved Tori-7, BARI Sarisha-13, BARI Sarisha-15, BARI Sarisha-16 and SAU SR-3 in the sub-plots. Almost all the studied parameters were found statistically similar under two planting techniques except siliqua length that was higher (5.51 cm) in conventional method compared to that of sowing in puddled soil (5.14 cm). The highest number of siliquae $plant^{-1}$ (143.67) was obtained from BARI Sarisha-16 that was similar to SAU SR-03 (134.15) and Improved Tori-7 (116.90).

The maximum1000-seed weight (4.35 g) was obtained from BARI Sarisha-16 under conventional planting method that was similar to BARI Sarisha-13 irrespective of planting methods. The maximum number of siliqua plant^{-1} (145.20) was found in BARI Sarisha-16 under conventional planting method that was similar to the same variety in puddle soil (142.13), SAU SR-03 in both the planting method and Improved Tori-7 in conventional method (131.20). The Improved Tori-7 variety gave the maximum seed yield (2.24 t ha^{-1}) followed by BARI Sarisha-16 (1.96 t ha^{-1}). The highest seed yield was given by the variety BARI Sarisha-16 in conventional planting method (2.39 t ha^{-1}) that was similar to Improved Tori-7 variety irrespective of planting techniques.

Ahamed *et al.* (2019) carried out an experiment at Sher-e-Bangla Agricultural University Farm, Dhaka- 1207, Bangladesh during Rabi season, November 2017 to February 2018 to find out the effect of different sowing methods and varieties on the yield of (*Brassica campestris*). The experiment comprised of two factors- the treatment consisted of four sowing methods *viz.* S_0= Broadcast method, S_1= Line to line space 20 cm, S_2= Line to line space 25 cm and S_3= Line to line space 30 cm and three different varieties *viz.* V_1= BARI Sarisha-14, V_2= BARI Sarisha-15 and V_3= BARI Sarisha-17. The experiment was laid out in two factors Randomized Complete Block Design (RCBD) with three replications. The collected data were statistically analyzed and a significant variation among the treatments was found in respect of majority of the observed parameters. The highest plant population was recorded from Broadcast method of sowing. The tallest plant was recorded from the plot of broadcast method. The maximum number of leaves plant^{-1}, branches plant^{-1}, dry matter weight plant^{-1}, siliqua plant^{-1} and seed silliqua^{-1} were recorded from the treatment line to line space 30 cm. The maximum thousand seed weight (2.97 g) was recorded from the broadcast method. The maximum yield of seed ha^{-1} (1.11 t) was obtained from broadcast method. The highest plant population (77.25) was observed in case of BARI Sarisha-14. The tallest plant of mustard was found in case of with BARI Sarisha-15. The maximum branches plant^{-1}, dry matter weight plant^{-1}, siliqua plant^{-1}, number of seed silliqua^{-1} and length of silliqua were obtained from BARI Sarisha-15. The highest yield of seed (0.95 t ha^{-1}) was obtained from BARI Sarisha-15. The combinations of different sowing methods and different varieties had significant effect on almost all the parameters. The highest biological yield (5.08 t ha^{-1}) was obtained from broadcast method with BARI Sarisha-15 treatment combination.

Raghuvansi *et al.* (2019) conducted a field experiment at Research Farm of Jawaharlal Nehru Krishi Vishwa Vidyalaya, College of Agriculture, Tikamgarh (Madhya Pradesh), India during rabi season of 2015-16 to study the effect of sowing dates and planting geometry on growth, yield attributes and yield of Indian mustard var. RGN-73. The experiment was carried out in split plot design with 3 sowing dates viz., 20 October, 2015, 30 October, 2015 and 09 November, 2015, and 5 planting geometry viz., 45 cm × 30 cm, 45cm × 15 cm, 30 cm × 30 cm, 30 cm × 20 cm and 30 cm × 10 cm as main plot and sub-plot treatments, respectively. Among different sowing dates, crop sown on October 20 resulted into significantly greater plant height (cm), more number of branches $plant^{-1}$, higher leaf area index and higher total plant dry biomass $plant^{-1}$ (g) followed October 30 and November 09 sown crops. Similarly number of siliquae $plant^{-1}$, 1000-seed weight (g), seed yield (kg ha^{-1}), stover yield (kg ha^{-1}), biological yield (kg ha^{-1}) and harvest index were also significantly higher under October 20 followed by October 30 and November 09 sown crops. Consecutive 10 days deley in sowing from October 20 to October 30 and November 09 caused a loss in seed yield by 27.8 % and 40.7 %., respectively. Among different planting geometries, 45 cm × 30 cm showed significantly more number of branches $plant^{-1}$, higher leaf area index and more total dry biomass $plant^{-1}$ (g) and the lowest with 30 cm × 10 cm. However, significantly greater plant height (cm) was recorded with planting geometry of 30 cm × 10 cm. Similarly number of siliquae $plant^{-1}$, number of seeds $siliqua^{-1}$ and 1000–seed weight (g) was also observed higher with 45 cm × 30 cm. However, seed yield (kg ha^{-1}), biological yield (kg ha^{-1}) and harvest index were recorded significantly higher with 30 cm × 10 cm as compared to other planting geometries.

Pandey *et al.* (2015) conducted a field experiment was at Agronomy Research Farm of Narendra Deva University of Agriculture and Technology, Kumarganj, Faizabad, UP during Rabi season of 2011-12. The experiment was carried out in a randomized block design (RBD) with 12 treatment combinations comprising of three varieties NRC-HB 101, Rohini and Narendra Rye-8501 and four spacings *viz.* 30 × 10, 45 × 10, 45 × 15 and 60 × 10 cm. All the treatment combinations were replicated three times. The maximum plant height was recorded in Narendra Rye-8501 that was significantly superior over Rohini and NRC-HB 101 with plant geometry 45 × 15 cm at 30, 60 and 90 days after sowing and at harvest stage of crop growth which was significantly higher over 30 × 10 cm, 45 × 10 cm and 60 × 10 cm plant spacing at all the stages of crop growth except at 30 DAS and other growth attributes *viz.* primary branches, secondary branches and total branches plant^{-1} were also significantly superior in Narendra Rye-8501 under plant geometry of 45 × 15 cm at all growth stages. Number of seeds siliqua^{-1} was significantly increased in Narendra Rye-8501 under plant geometry 45 × 15 cm which led to significantly maximum seed yield of mustard superior to other treatments.

From the above review of literature it is evident that planting geometry and sowing time has a significant influence on yield and yield components of mustard. The literature suggests that early or delay sowing other than optimum time reduces the seed yield of mustard which is directly related with the temperature of the growing period of the crop. As well as planting geometry influenced the yield and yield contributing components of mustard. The literature revealed that without accurate knowledge of the sowing time of any particular variety with proper planting geometry at a particular area it is critical to achieve a higher seed yield of mustard.

CHAPTER III

MATERIALS AND METHODS

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted at the Agronomy field of Sher-e-Bangla Agricultural University, Dhaka to study the effect of planting geometry and sowing time on growth and productivity of mustard. Materials used and methodologies followed in the present investigation have been described in this chapter.

3.1 Description of the experimental site

3.1.1 Site and soil

Geographically the experimental field was located at 23° 77' N latitude and 90° 33' E longitudes at an altitude of 8.6 m above the mean sea level. The soil belonged to the Agro-Ecological Zone "Modhupur Tract" (AEZ-28). The land topography was medium high and soil texture was silty clay with pH 5.6. The morphological, physical and chemical characteristics of the experimental soil have been presented in Appendix- II.

3.1.2 Climate and weather

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 prevailing weather conditions during the study period have been presented in Appendix- I.

3.2 Plant materials

BARI Sharisha-16 was used as planting material. BARI Sharisha-16 was developed through microspore embryogenesis for Rajat and released by BARI in 2009. The cultivar is late planting potential. The cultivar is drought and salt tolerant. Plant height of the cultivar ranges from 175-195 cm. Leaf with light green color and smooth. It produces 180-200 siliquae plant^{-1} with two chambers. Each siliqua contains 9-11 seeds. Seed color is pink. 1000 seed weight is 4.70-4.90 g. Crop duration 105-115 days. Average yield is 2.00-2.50 t ha^{-1}.

3.3 Treatments under investigation

There were two factors in the experiment namely sowing time and planting geometry as mentioned below:

A. Factor-1: Sowing time (3):

a) S_1= Sowing on 25th October
b) S_2= Sowing on 10th November
c) S_3= Sowing on 30th November

B. Factor-2: Planting geometry (4): (created by varying row to row and constant plant to plant distance)

The line to line distances were maintained with 25 cm, 30 cm and 35 cm. The constant distance for plant to plant within the lines was maintained with 5 cm by thinning of plants after germination. However, the planting geometries were designated as follows:

a) G_1= Random geometry (by broadcasting of seeds)
b) G_2= 25 cm × 5 cm
c) G_3= 30 cm × 5 cm
d) G_4= 35 cm × 5 cm

3.4 Experimental design and layout

The experiment was laid out in Randomized Completely Block Design (RCBD) design having 3 replications. There were 12 treatment combinations and 36 unit plots. The unit plot size was 3.88 m^2 (2.5 m × 1.55 m). The blocks and unit plots were separated by 1.0 m and 0.50 m spacing, respectively.

3.5 Land preparation

The experimental land was opened with a power tiller on 15th October, 2019. Ploughing and cross ploughing were done with this tiller followed by laddering. Land preparation was completed on 22nd October, 2019 and was made ready for sowing seeds as of treatments designed.

3.6 Fertilizer application

The Urea, TSP, MoP, Gypsum, $ZnSO_4$ and Boric acid were applied @ 250 kg ha^{-1}, 170 kg ha^{-1}, 85 kg ha^{-1}, 150 kg ha^{-1}, 5 kg ha^{-1} and 5 kg ha^{-1}, respectively. All the fertilizers were applied during final land preparation except urea. A half portion of urea was applied during final land preparation and the rest half was applied at 20 DAS in all plots. All fertilizers (basal dose) were applied by broadcasting and covered with soil by laddering.

3.7 Sowing of seeds

Seeds were sown at the rate of 12 kg ha^{-1} in the furrow and broadcasting as of treatment and the furrows were covered with the soils soon after seeding. The rows were made as par treatment and the seeds were sown in row by hand. After germination the seedling was thinned out at 35 DAS maintaining the plant to plant (approximately 5 cm) distance as par treatment.

3.8 Intercultural operations

3.8.1 Weed control

The crop was infested with some weeds during the early stage of crop establishment. Two hand weddings were done; first weeding was done at 10 days after sowing followed by second weeding at 15 days after first weeding.

3.8.2 Application of irrigation water

Irrigation water was added to each plot, first irrigation was done as pre sowing and second was done at 25 DAS and the third one was done at 55 DAS.

3.8.3 Plant protection measures

The crop was infested by common cutworm. Siphanon 57 EC containing active ingredient malathion was applied two times at an interval of 1 week to control insect, 1^{st} one was at 20 DAS. There was no disease infestation during the experimentation period, so no fungicide was applied.

3.9 Harvesting and sampling

The crop was harvested plot wise when about 80% of the pods became yellowish in color. Harvesting was done in the morning to avoid shattering. Before harvesting the whole plot, five plants were sampled randomly from each plot, bundled separately, tagged and brought to a clean cemented threshing floor for collecting data on different yield attributes. One square meter area from the center of each plot was harvested for recording yield data. The sampled plants were uprooted prior to harvest and plants were tied into bundles and carried to the threshing floor. The crop was sun dried properly by spreading them over floor. Seeds were separated from the siliquae by beating the bundles with bamboo sticks. The seeds thus collected were dried in the sun for reducing the moisture in the seed to about 9% level. The stovers were further dried in the sun. Seed and stover yield were recorded separately. By summing of the seed yield and stover yield, the biological yield was calculated.

3.10 Threshing

Seeds were separated from the plants by beating the bundles with bamboo sticks. The seeds were separated, cleaned and dried in the sun for 3 to 5 days for achieving safe moisture of seed.

3.11 Drying, cleaning and weighing

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

3.12 Recording of data

The data were recorded on the following parameters

i. Plant height (cm)
ii. Leaves plant^{-1} (no.)
iii. Branches plant^{-1} (no.)
iv. Dry matter weight plant^{-1} (g)
v. Siliquae plant^{-1} (no.)
vi. Length of siliqua (cm)
vii. Seeds siliqua^{-1} (no.)

viii. 1000 seed weight (g)
ix. Seed yield (t ha^{-1})
x. Stover yield (t ha^{-1})
xi. Biological yield (t ha^{-1})
xii. Harvest index (%)

3.13 Procedure of recording data

i. Plant height (cm)

The heights of the five selected plants were measured from the ground level to the tip of the plant at 30, 45, 60, 75 DAS and harvest.

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

The leaves $plant^{-1}$ was counted from five randomly sampled plants 30, 45, 60, 75 DAS and harvest. It was done by counting total number of leaves of all sampled plants then the average data were recorded.

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

The primary and secondary branches $plant^{-1}$ was counted from five randomly sampled plants at 30, 45, 60, 75 DAS and harvest. It was done by counting total number of primary and secondary branches of all sampled plants then the average data were recorded.

iv. Dry matter content $plant^{-1}$(g)

Five plants were collected randomly from each plot at 30, 45, 60, 75 DAS and harvest. The sample plants were oven dried for 72 hours at 70°C and then dry matter content $plant^{-1}$ was determined.

v. Siliquae $plant^{-1}$ (no.)

Siliquae $plant^{-1}$ was counted from the 10 selected plant sample and then the average siliqua number was calculated.

vi. Length of siliqua (cm)

Length of siliqua was measured by meter scale from 10 siliquae of plants and then the average length was calculated.

vii. Seeds siliqua^{-1} (no.)

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

viii. Weight of 1000 seeds (g)

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

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

Seed yield was recorded on the basis of total harvested seeds plot^{-1} avoiding the boarder plants and was calculated in t ha^{-1}.

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

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

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

The summation of seed yield and above ground stover yield was the biological yield. Biological yield (t ha^{-1}) = Seed yield (t ha^{-1}) + Stover yield (t ha^{-1}).

xii. Harvest index (%)

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

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

Here, Biological yield (t ha^{-1}) = Seed yield (t ha^{-1}) + Stover yield (t ha^{-1})

3.14 Data analysis technique

The collected data were compiled and analyzed statistically using the analysis of variance (ANOVA) technique with the help of a computer package program MSTAT-

C and the mean differences were adjusted by Least Significance Difference (LSD) test at 5% level of probability (Gomez and Gomez, 1984).

CHAPTER IV

RESULTS AND DISCUSSION

CHAPTER IV

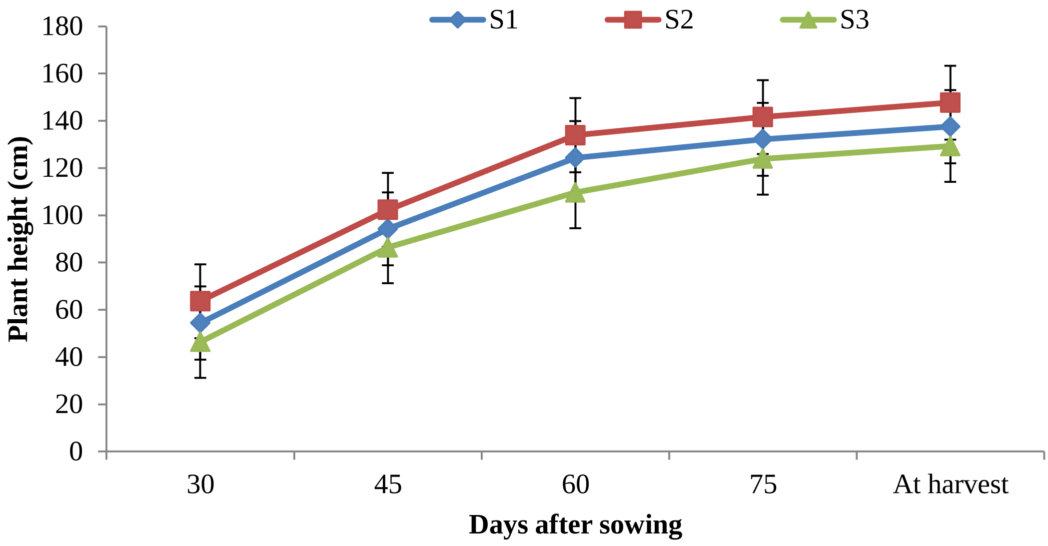
RESULTS AND DISCUSSION

Present study was undertaken to investigate the effect sowing time and planting geometry on growth and productivity of mustard. Data on different yield contributing characters and yield were recorded to determine the effect of sowing time and planting geometry on growth and productivity of mustard. The results of the experiment have been presented and discussed in this chapter.

4.1 Plant height (cm)

4.1.1 Effect of sowing time

Plant height of mustard was gradually increased up to 60 DAS thereafter a slower rate of increase was recorded up to harvest. Significant variation was observed on the plant height of mustard at 30, 45, 60, 75 DAS and at harvest due to varied sowing time (Figure 1). Result from the experiment observed that the tallest plant (63.62, 102.27, 133.92, 141.63 and 147.69 cm at 30, 45, 60, 75 DAS and at harvest, respectively) was achieved from the treatment S_2. On the other hand the shortest plant (46.36, 86.40, 109.67, 123.96 and 129.30 cm at 30, 45, 60, 75 DAS and at harvest, respectively) was observed from the treatment S_3. The result of our investigation also coincided with the findings of Bhuiyan *et al.* (2008) who reported that significantly higher plant height under 10^{th} November sowing (115 cm) as compared to 30^{th} October (105 cm), 20^{th} November (104 cm), 20^{th} October (100 cm), 30^{th} November sowings. Afroz *et al.* (2011) observed the similar trends and stated that significantly higher plant height was found under 10^{th} November sowing (99.4 cm) as compared to 20^{th} November (93.0 cm) and 30^{th} November (78.0 cm) sowings.

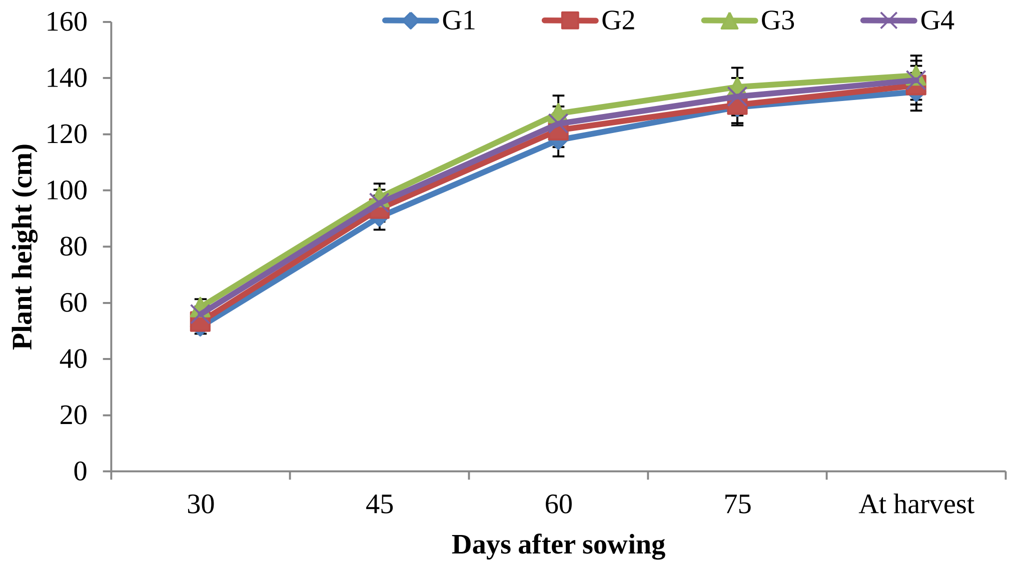


S_1= Sowing on 25th October, S_2= Sowing on 10th November and S_3= Sowing on 30th November

Figure 1. Effect of sowing time on the plant height of mustard at different days after sowing ($LSD_{0.05}$= 2.83, 4.17, 4.94, 5.36 and 4.11 at 30, 45, 60, 75 DAS and harvest, respectively)

4.1.2 Effect of planting geometry

Plant height was gradually increased up to harvest. Statistically significant variation was observed on the plant height of mustard due to varied planting geometry throughout the growing period (Figure 2). Among the different planting geometry, G_3 (30 cm × 5 cm) produced the tallest plant (58.43, 97.56, 127.42, 136.82 and 140.91 cm at 30, 45, 60, 75 DAS and harvest, respectively) which were statistically similar with G_4 at 30, 60 and 75 DAS; with G_4 and G_2 at 45 DAS and at harvest. Again the shortest plant (51.55, 90.61, 117.98, 129.71 and 135.12 cm at 30, 45, 60, 75 DAS and harvest, respectively) were produced by planting geometry G_1 (Random geometry) which was statistically similar with G_2 at 30, 60 and 75 DAS. Raghuvansi *et al.* (2019) reported that significantly greater plant height (cm) was recorded with planting geometry of 30 cm × 10 cm. The results agreed with the findings of Lakra *et al.* (2018) and Gawariya *et al.* (2015).



G_1= Random geometry, G_2= 25 cm × 5 cm, G_3= 30 cm × 5 cm and G_4= 35 cm × 5 cm

Figure 2. Effect of planting geometry on the plant height of mustard at different days after sowing ($LSD_{0.05}$= 3.27, 4.81, 5.71, 6.19 and 4.75 at 30, 45, 60, 75 DAS and harvest, respectively)

4.1.3 Interaction effect of sowing time and planting geometry

Interaction of sowing time and planting geometry had significant effect on the plant height of mustard throughout the growth period (Table 1 and Appendix IV). The tallest plant (67.58, 106.27, 138.31, 147.58 and 150.44 cm at 30, 45, 60, 75 DAS and harvest, respectively) was produced by treatment combination of S_2G_3 which was statistically similar with treatment combinations S_2G_4 at 30 DAS; with S_2G_4, S_2G_2 and S_2G_1 at 45, 60, 75 DAS and at harvest. The shortest plant (43.61, 81.67, 103.33, 121.83 and 125.38 cm at 30, 45, 60, 75 DAS and harvest, respectively) was produced by treatment combination S_3G_1 which was statistically similar with the treatment combinations S_3G_2, S_3G_3 and S_3G_4 at 30, 75 DAS and at harvest; with S_3G_2 and S_3G_4 at 45 and 60 DAS.

Table 1. Combined effect of sowing time and planting geometry on plant height at different days after sowing of mustard

Treatment combinations	Plant height (cm) at different days after sowing				
	30	45	60	75	At harvest
S_1G_1	50.92 e-g	91.54 d-f	120.83 de	128.67 c-f	135.11 d-f
S_1G_2	52.63 ef	93.76 c-f	123.11 c-e	130.27 c-f	136.29 d-f
S_1G_3	58.43 cd	96.29 b-e	127.53 b-d	136.31 b-d	140.06 b-d
S_1G_4	55.64 de	95.41 b-e	126.03 b-e	133.55 b-e	138.64 c-e
S_2G_1	60.11 b-d	98.62 a-d	129.77 a-d	137.21 a-d	144.87 a-c
S_2G_2	61.46 bc	101.33 a-c	132.97 a-c	139.30 a-c	147.18 ab
S_2G_3	67.58 a	106.27 a	138.31 a	147.58 a	150.44 a
S_2G_4	65.33 ab	102.87 ab	134.61 ab	142.43 ab	148.27 ab
S_3G_1	43.61 h	81.67 g	103.33 g	121.83 f	125.38 g
S_3G_2	45.76 gh	85.50 fg	108.27 fg	123.25 ef	128.92 fg
S_3G_3	49.27 f-h	90.13 ef	116.43 ef	126.57 d-f	132.22 d-g
S_3G_4	46.80 gh	88.31 e-g	110.65 fg	124.19 ef	130.67 e-g
$LSD_{0.05}$	**5.67**	**8.34**	**9.89**	**10.72**	**8.22**
CV%	**6.11**	**5.22**	**4.76**	**4.77**	**3.52**

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

Notes *viz:*

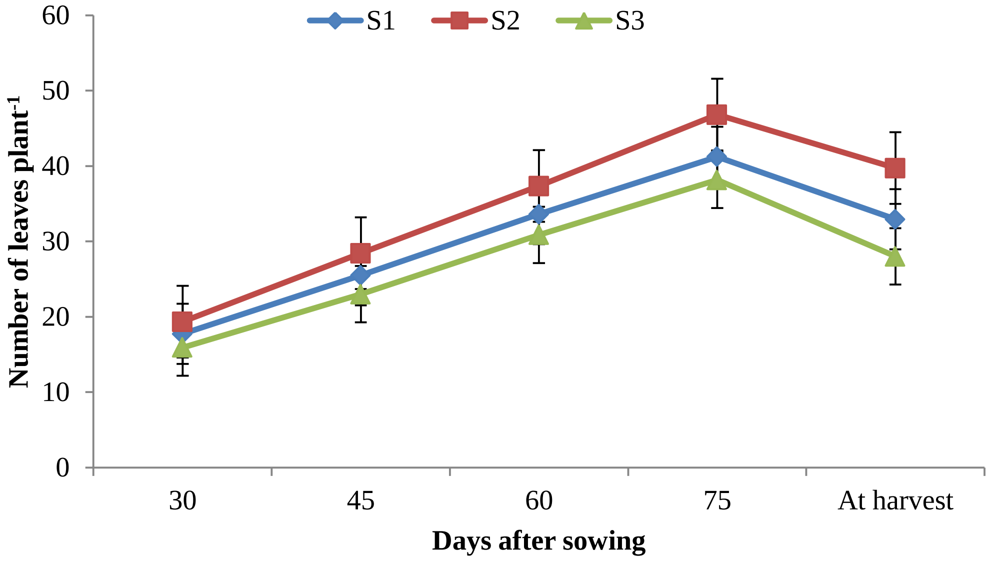
S_1= Sowing on 25th October
S_2= Sowing on 10th November
S_3= Sowing on 30th November

G_1= Random Geometry
G_2= 25 cm × 5 cm
G_3= 30 cm × 5 cm
G_4= 35 cm × 5 cm

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

4.2.1 Effect of sowing time

There was a gradual increase of leaves plant^{-1} of mustard observe up to 75 DAS and finally a little decrease occurred at harvesting time. Sowing time showed significant variation on leaves plant^{-1} in the whole growing period (Figure 3). The highest leaves plant^{-1} (19.34, 28.43, 37.35, 46.82 and 39.73 at 30, 45, 60, 75 DAS and harvest, respectively) was recorded from the treatment S_2 and the lower leaves plant^{-1} (15.92, 22.99, 30.87, 38.15 and 28.01 at 30, 45, 60, 75 DAS and harvest, respectively) was recorded from the treatment S_3. The result of the experiment coincided with the findings of Alam *et al.* (2015) who reported that number of leaves plant^{-1} showed significant influence due to different sowing times.

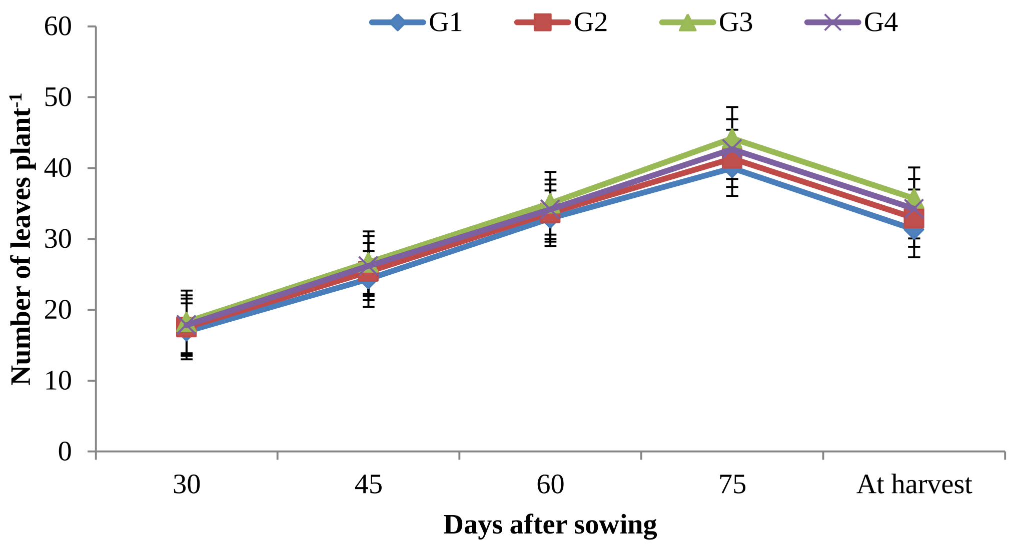


S_1= Sowing on 25th October, S_2= Sowing on 10th November and S_3= Sowing on 30th November

Figure 3. Effect of sowing time on the leaves plant^{-1} of mustard at different days after sowing ($LSD_{0.05}$= 0.82, 1.49, 1.38, 1.43 and 1.25 at 30, 45, 60, 75 DAS and harvest, respectively)

4.2.2 Effect of planting geometry

Similar trend of increasing leaves plant^{-1} of mustard was observed due to variation in planting geometry. Planting geometry showed significant variation on leaves plant^{-1} of mustard in the whole growing period (Figure 4). The highest leaves plant^{-1} (18.29, 26.68, 35.03, 44.19 and 35.70 at 30, 45, 60, 75 DAS and harvest, respectively) was recorded from planting geometry G_3 which was statistically at par with G_4 and G_2 at 30, 45 and 60 DAS; with G_4 at 75 DAS. Planting geometry G_1 consistently produced lowest leaves plant^{-1} (16.96, 24.32, 32.91, 40.00 and 31.32 at 30, 45, 60, 75 DAS and harvest, respectively) which was statistically at par with G_2 at 75 DAS. Ahamed *et al.* (2019) revealed that the maximum number of leaves plant^{-1}, branches plant^{-1}, dry matter weight plant^{-1}, siliqua plant^{-1} and seed silliqua^{-1} were recorded from the treatment line to line space 30 cm.



G_1= Random geometry, G_2= 25 cm × 5 cm, G_3= 30 cm × 5 cm and G_4= 35 cm × 5 cm

Figure 4. Effect of planting geometry on the leaves plant^{-1} of mustard at different days after sowing ($LSD_{0.05}$= 0.95, 1.73, 1.60, 1.65 and 1.44 at 30, 45, 60, 75 DAS and harvest, respectively)

4.2.3 Interaction effect of sowing time and planting geometry

Similar trend of increasing leaves plant^{-1} of mustard was observed due variation in sowing time and planting geometry. Interaction of sowing time and planting geometry showed significant variation on leaves plant^{-1} of mustard in the whole growing period (Table 2 and Appendix V). The highest leaves plant^{-1} (20.07, 29.67, 39.20, 50.93 and 42.32 at 30, 45, 60, 75 DAS and harvest, respectively) were recorded from treatment combinations S_2G_3 which was statistically at par with S_2G_4, S_2G_2 and S_2G_1 at 30 DAS; with S_2G_4 and S_2G_2 at 45 and 60 DAS. Treatment combination S_3G_1 consistently produced lowest leaves palnt^{-1} (15.21, 21.52, 30.05, 36.74 and 26.33 at 30, 45, 60, 75 DAS and harvest, respectively) which was statistically at par with S_3G_2, S_3G_3 and S_3G_4 at 30, 45, 60 and 75 DAS; with S_3G_2 and S_3G_4 at harvest.

Table 2. Combined effect of sowing time and planting geometry on number of leaves plant^{-1} at different days after sowing of mustard

Treatment combinations	Number of leaves plant^{-1} at different days after sowing				
	30	**45**	**60**	**75**	**At harvest**
S_1G_1	16.92 d-g	24.77 de	32.95 ef	39.71 e-h	30.83 fg
S_1G_2	17.65 c-f	25.19 de	33.37 d-f	40.87 d-g	32.43 ef
S_1G_3	18.33 b-d	26.25 b-d	34.21 c-e	42.48 c-e	34.87 de
S_1G_4	17.97 b-e	25.81 cd	33.88 de	41.83 d-f	33.55 e
S_2G_1	18.75 a-c	26.67 b-d	35.73 b-d	43.57 cd	36.81 cd
S_2G_2	19.13 a-c	28.41 a-c	36.85 a-c	45.24 bc	39.11 bc
S_2G_3	20.07 a	29.67 a	39.20 a	50.93 a	42.32 a
S_2G_4	19.40 ab	28.95 ab	37.61 ab	47.55 b	40.67 ab
S_3G_1	15.21 h	21.52 f	30.05 g	36.74 i	26.33 h
S_3G_2	15.83 gh	22.58 ef	30.77 fg	38.00 hi	27.27 h
S_3G_3	16.48 e-h	24.11 d-f	31.67 e-g	39.18 f-i	29.91 g
S_3G_4	16.17 f-h	23.75 d-f	31.00 fg	38.67 g-i	28.53 gh
$LSD_{0.05}$	**1.65**	**2.99**	**2.76**	**2.85**	**2.50**
CV%	**5.51**	**6.89**	**4.81**	**4.01**	**4.40**

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

Notes *viz:*

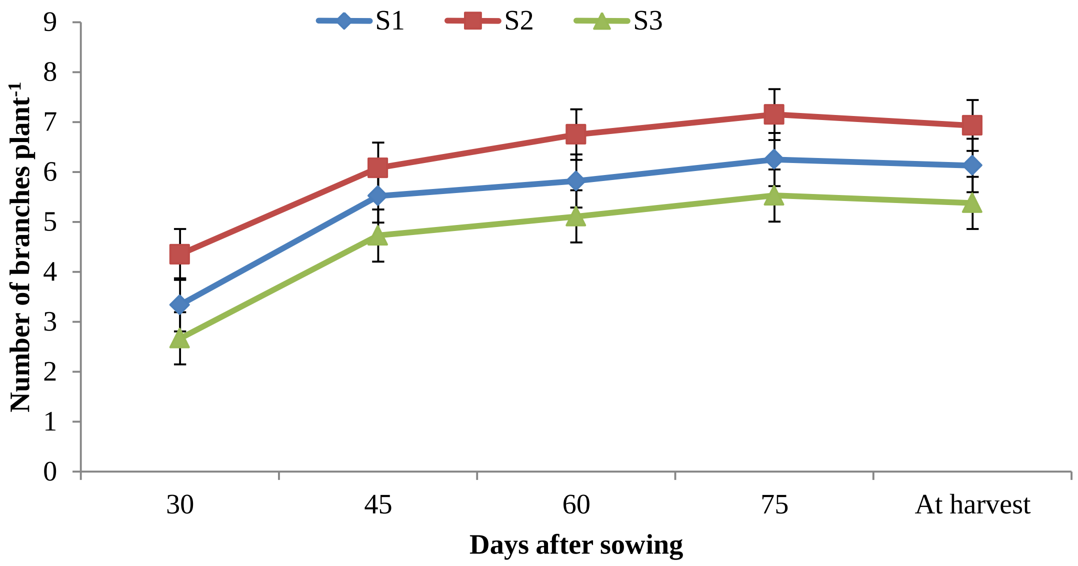
S_1= Sowing on 25th October
S_2= Sowing on 10th November
S_3= Sowing on 30th November

G_1= Random Geometry
G_2= 25 cm × 5 cm
G_3= 30 cm × 5 cm
G_4= 35 cm × 5 cm

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

4.3.1 Effect of sowing time

Primary and secondary branches plant^{-1} of mustard was gradually increased up to harvest. Sowing time had significant effect on total number of branches plant^{-1} in the whole growth period (Figure 5). The results of the experiment revealed that, the maximum number of branches plant^{-1} (4.35, 6.08, 6.75, 7.15 and 6.93 at 30, 45, 60, 75 DAS and harvest, respectively) was observed in sowing time S_2 and the minimum ones (2.67, 4.73, 5.11, 5.53 and 5.38 at 30, 45, 60, 75 DAS and harvest, respectively) was observed in sowing time S_3. The findings of the experiment was similar with the findings of Lakra *et al.* (2018) who reported that sowing on 27th October was recorded significantly higher number of branches, seeds per siliquae, siliquae per plant, 1000 seed weight, and seed yield than that on 07th November, 17th November and 27th November.

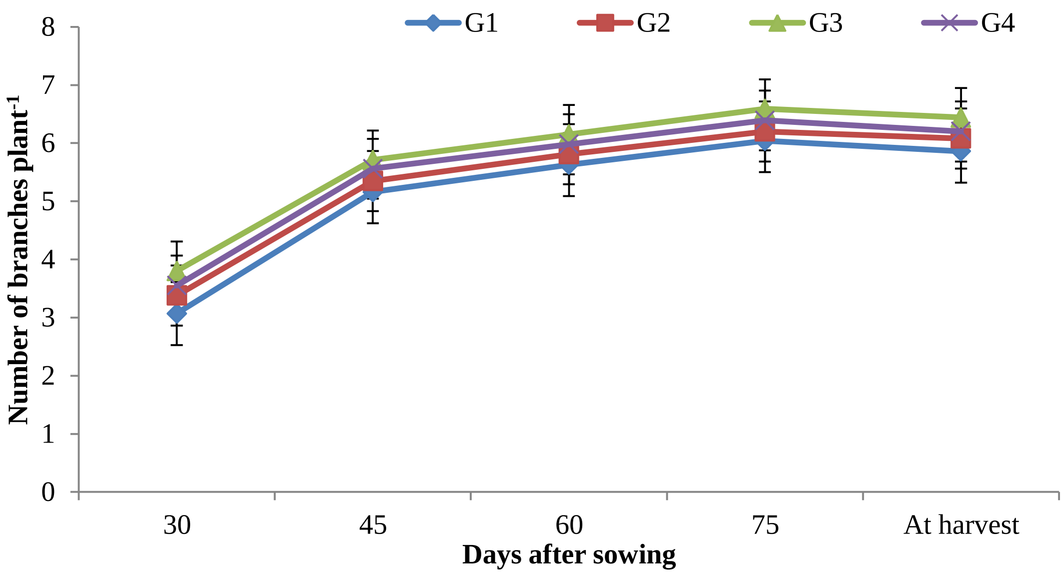


S_1= Sowing on 25th October, S_2= Sowing on 10th November and S_3= Sowing on 30th November

Figure 5. Effect of variety on the primary branches plant^{-1} of mustard at different days after sowing ($LSD_{0.05}$= 0.22, 0.27, 0.29, 0.23 and 0.19 at 30, 45, 60, 75 DAS and harvest, respectively)

4.3.2 Effect of planting geometry

Number of branches plant^{-1} of mustard was gradually increased up to 75 DAS and slightly decreased at harvest. Planting geometry had significant effect on number of branches plant^{-1} of mustard in the whole growth period (Figure 6). The results of the experiment revealed that, the maximum number of branches plant^{-1} (3.80, 5.71, 6.15, 6.59 and 6.44 at 30, 45, 60, 75 DAS and harvest, respectively) was observed in planting geometry G_3 which was statistically similar with G_4 at 30, 45, 60 and 75 DAS. On the other hand the minimum number of branches plant^{-1} (3.07, 5.16, 5.63, 6.04 and 5.86 at 30, 45, 60, 75 DAS and harvest, respectively) was observed in planting geometry G_1 which was statistically similar with G_2 at 45, 60, 75 DAS and at harvest except 30 DAS. Similar trends was observed by Lakra *et al.* (2018) who revealed that number of branches plant^{-1} significantly higher on the planting geometry 30 × 10 cm. Mottalebipour and Bahrani (2006) found the dissimilar result and they reported that increasing row spacing significantly increased the values of almost all yield attributes but it had no significant effect on number of branches plant^{-1}.



G_1= Random geometry, G_2= 25 cm × 5 cm, G_3= 30 cm × 5 cm and G_4= 35 cm × 5 cm

Figure 6. Effect of planting geometry on the number of branches plant^{-1} of mustard at different days after sowing ($LSD_{0.05}$= 0.25, 0.32, 0.33, 0.27 and 0.22 at 30, 45, 60, 75 DAS and harvest, respectively)

4.3.3 Interaction effect of sowing time and planting geometry

There was a gradual increase of primary branches plant^{-1} of mustard was observed up to 75 DAS and slightly decreased at harvest. Interaction of sowing time and planting geometry had significant effect on number of branches plant^{-1} of mustard in the whole growth period (Table 3 and Appendix VI). The results of the experiment revealed that, the maximum number of branches plant^{-1} (4.87, 6.40, 7.00, 7.43 and 7.23 at 30, 45, 60, 75 DAS and harvest, respectively) was observed in treatment combination S_2G_3 which was statistically similar with S_2G_4 at 30 DAS; with S_2G_4 and S_2G_2 at 45, 60, 75 DAS and at harvest. On the other hand the minimum number of branches plant^{-1} (2.40, 4.33, 4.81, 5.18 and 5.00 at 30, 45, 60, 75 DAS and harvest, respectively) was observed in treatment combination S_3G_1 which was statistically similar with S_3G_2 and S_3G_4 at 30, 45 and 60 DAS; with S_3G_2 at 75 DAS and finally at harvest.

Table 3. Combined effect of sowing time and planting geometry on number of branches plant^{-1} at different days after sowing of mustard

Treatment combinations	Number of branches plant^{-1} at different days after sowing				
	30	**45**	**60**	**75**	**At harvest**
S_1G_1	3.00 f-h	5.33 de	5.67 d-f	6.00 ef	5.87 e-g
S_1G_2	3.27 e-g	5.41 c-e	5.73 d-f	6.13 d-f	6.03 ef
S_1G_3	3.65 de	5.72 b-d	6.03 cd	6.52 cd	6.43 cd
S_1G_4	3.43 d-f	5.63 b-d	5.84 c-e	6.33 de	6.19 de
S_2G_1	3.81 cd	5.81 b-d	6.41 bc	6.93 bc	6.72 bc
S_2G_2	4.20 bc	5.93 a-c	6.67 ab	7.05 ab	6.87 ab
S_2G_3	4.87 a	6.40 a	7.00 a	7.43 a	7.23 a
S_2G_4	4.50 ab	6.17 ab	6.93 ab	7.19 ab	6.90 ab
S_3G_1	2.40 i	4.33 g	4.81 h	5.18 h	5.00 i
S_3G_2	2.67 hi	4.71 fg	5.03 gh	5.43 gh	5.33 hi
S_3G_3	2.87 gh	5.00 ef	5.41 e-g	5.83 fg	5.67 f-h
S_3G_4	2.73 hi	4.87 e-g	5.19 f-h	5.67 fg	5.50 gh
$LSD_{0.05}$	**0.44**	**0.55**	**0.58**	**0.47**	**0.37**
CV%	**7.55**	**5.95**	**5.77**	**4.36**	**3.59**

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

Notes *viz:*

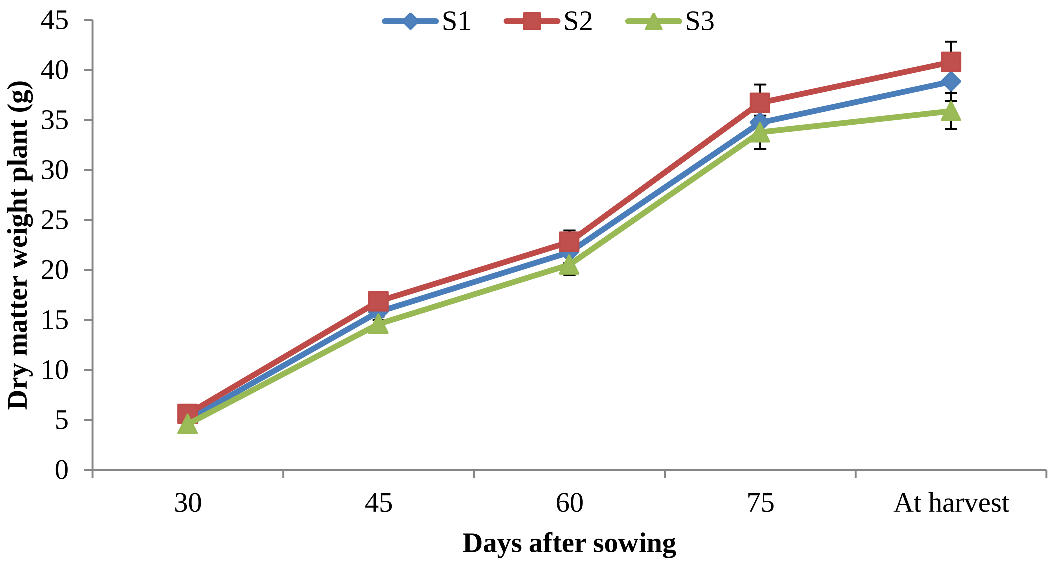
S_1= Sowing on 25th October
S_2= Sowing on 10th November
S_3= Sowing on 30th November

G_1= Random Geometry
G_2= 25 cm × 5 cm
G_3= 30 cm × 5 cm
G_4 = 35 cm × 5 cm

4.4 Dry matter weight plant^{-1} (g)

4.4.1 Effect of sowing time

There was a gradual increase of dry mater weight plant^{-1} was observed from 30 DAS up to harvest. Dry matter weight plant^{-1} of mustard significantly varied due to varied sowing time (Figure 7). Data revealed that, the maximum dry matter weight pant^{-1} (5.59, 16.87, 22.80, 36.71 and 40.79 g at 30, 45, 60, 75 DAS and harvest, respectively) was scored by S_2 and the minimum one (4.59, 14.60, 20.53, 33.77 and 35.90 g at 30, 45, 60, 75 DAS and harvest, respectively) was scored by S_3. Similar results was observed by Singh *et al.* (2016) who reported that dry matter accumulation (g plant^{-1}) increased significantly under 25th October sowing. Sharif *et al.* (2016) revealed that the maximum total dry matter, leaf area index was obtained from the first sowing (30 November) with BINA Sharisha-5. Tripathi *et al.* (2021) revealed the similar trends of result. They revealed that varieties (10 November and Varuna) superior compare to rest of treatment. However, highest growth attributes (plant height, dry matter accumulation, Days taken to 50% flowering, number of tillers, LAI and yield and yield attributes (No. of siliqua per plant, length of siliqua (cm), test weight, seed yield (q ha^{-1}) grain yield, stover yield, biological yield, and harvest index) was recorded under 10 November and Varuna variety.

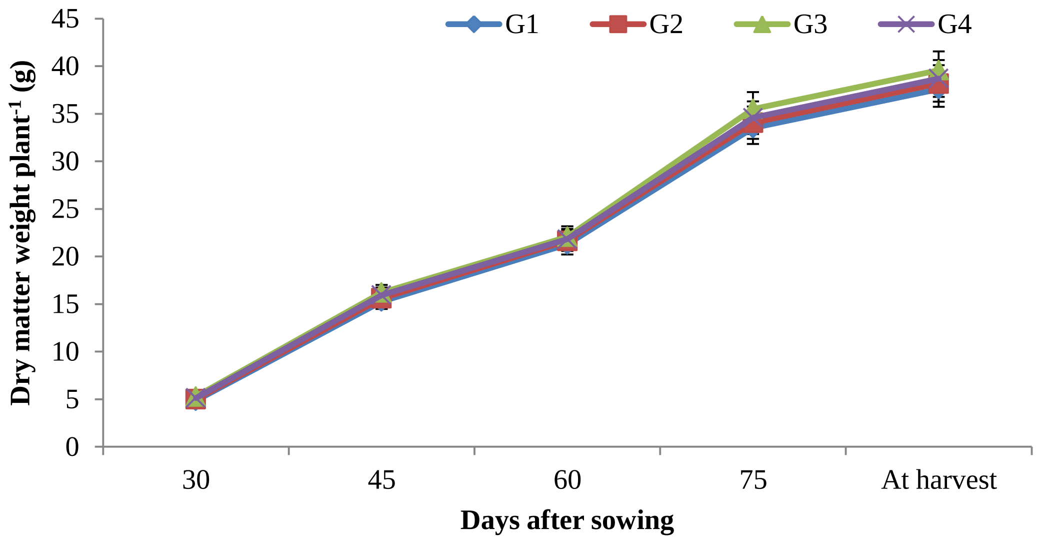


S_1= Sowing on 25th October, S_2= Sowing on 10th November and S_3= Sowing on 30th November

Figure 7. Effect of sowing time on the dry matter weight plant^{-1} of mustard at different days after sowing ($LSD_{0.05}$= 0.17, 0.40, 0.52, 0.98 and 1.26 at 30, 45, 60, 75 DAS and harvest, respectively)

4.4.2 Effect of planting geometry

Dry matter is the constant dry weight of a plant. It is one of the important parameter which determines the partitioning of the photosynthates of a plant during grain filling stage. There was a gradual increase of dry mater weight plant^{-1} which was observed from 30 DAS up to harvest in case of planting geometry. Dry matter weight plant^{-1} of mustard significantly varied due to planting geometry through the whole growing period (Figure 8). Data revealed that, the maximum dry matter weight pant^{-1} (5.29, 16.21, 22.06, 35.50 and 39.57 g at 30, 45, 60, 75 DAS and harvest, respectively) was scored by G_3 which was statistically similar with G_4 at 30, 45 and 75 DAS; with G_4 and G_2 at 60 DAS and harvest. On the other hand the minimum ones (4.85, 15.26, 21.28, 33.49 and 37.59 g at 30, 45, 60, 75 DAS and harvest, respectively) was scored by G_1 which was statistically similar with G_2 at 30, 45 and 75 DAS. The result of the investigation was in coincidence with the findings of Gawariya *et al.* (2015) who reported that crop geometry of 30 × 20 cm recorded significantly higher seed yield with better utilization of space, nutrients, water and sunshine resulting in higher dry matter translocation to yield components as compared to 60 × 15, 45 × 15, 45 × 20, 45 × 25 and 30 × 25 cm crop geometry.



G_1= Random geometry, G_2= 25 cm × 5 cm, G_3= 30 cm × 5 cm and G_4= 35 cm × 5 cm

Figure 8. Effect of planting geometry on the dry matter weight plant^{-1} of mustard at different days after sowing (LSD$_{0.05}$= 0.20, 0.47, 0.59, 1.14 and 1.46 at 30, 45, 60, 75 DAS and harvest, respectively)

4.4.3 Interaction effect of sowing time and planting geometry

There was a gradual increase of dry mater weight plant^{-1} was observed from 30 DAS up to harvest in case of sowing time and planting geometry. Dry matter weight plant^{-1} of mustard significantly varied due to interaction of sowing time and planting geometry through the whole growing period (Table 4 and Appendix VII). Data revealed that, the maximum dry matter weight pant^{-1} (5.86, 17.45, 23.09, 37.62 and 42.29 g at 30, 45, 60, 75 DAS and harvest, respectively) was scored by treatment combination S_2G_3 which was statistically similar with S_2G_4 at 30 DAS; with S_2G_4 and S_2G_2 at 45 DAS; with S_2G_4, S_2G_2 and S_2G_1 at 60, 75 DAS and at harvest. On the other hand the minimum ones (4.42, 14.11, 19.87, 30.85 and 34.93 g at 30, 45, 60, 75 DAS and harvest, respectively) was scored by treatment combination S_3G_1 which was statistically similar with S_3G_2 and S_3G_4 at 30, 45, 60 and 75 DAS; with S_3G_2, S_3G_3, and S_3G_4 at harvest.

Table 4. Combined effect of sowing time and planting geometry on dry matter weight plant^{-1} at different days after sowing of mustard

Treatment combinations	Dry matter weight plant^{-1} (g) at different days after sowing				
	30	**45**	**60**	**75**	**At harvest**
S_1G_1	4.81 e-g	15.33 e-g	21.43 d-g	33.64 d-f	38.00 c-f
S_1G_2	4.97 d-f	15.72 d-f	21.67 c-f	34.45 c-e	38.70 b-e
S_1G_3	5.23 cd	16.19 cd	22.07 a-d	35.72 a-c	39.62 bc
S_1G_4	5.06 de	15.97 c-e	21.91 b-e	35.13 b-d	39.06 b-d
S_2G_1	5.31 cd	16.33 b-d	22.53 a-c	36.00 a-c	39.85 a-c
S_2G_2	5.50 bc	16.67 a-c	22.77 ab	36.43 ab	40.17 a-c
S_2G_3	5.86 a	17.45 a	23.09 a	37.62 a	42.29 a
S_2G_4	5.67 ab	17.03 ab	22.81 ab	36.79 ab	40.83 ab
S_3G_1	4.42 h	14.11 i	19.87 h	30.85 h	34.93 g
S_3G_2	4.53 gh	14.44 hi	20.51 gh	31.27 gh	35.67 fg
S_3G_3	4.77 e-g	15.00 f-h	21.03 e-g	33.15 e-g	36.81 d-g
S_3G_4	4.65 f-h	14.83 g-i	20.72 f-h	31.81 f-h	36.19 e-g
$LSD_{0.05}$	**0.35**	**0.80**	**1.03**	**1.97**	**2.52**
CV%	**4.05**	**3.04**	**2.81**	**3.38**	**3.87**

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

Notes *viz:*

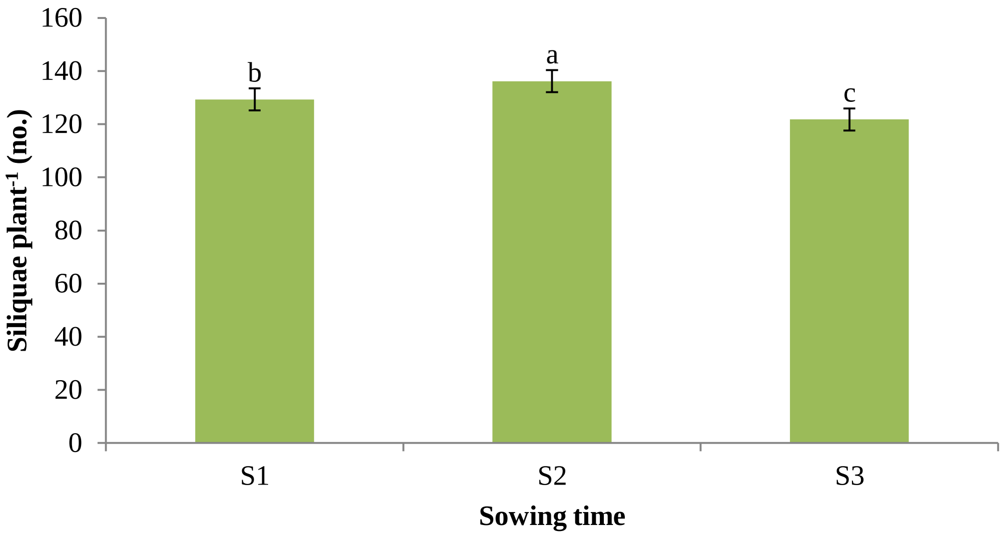
S_1= Sowing on 25th October
S_2= Sowing on 10th November
S_3= Sowing on 30th November

G_1= Random Geometry
G_2= 25 cm × 5 cm
G_3= 30 cm × 5 cm
G_4= 35 cm × 5 cm

4.5 Siliquae plant^{-1} (no.)

4.5.1 Effect of sowing time

There was marked difference in siliquae plant^{-1} of mustard due to varied sowing time (Figure 9). Result of the experiment showed that, the maximum and minimum siliquae plant^{-1} (136.17 and 121.78) was produced by S_2 and S_3, respectively. Similar results were observed by Mondal *et al.* (2011), Kumari *et al.* (2012) and Singh *et al.* (2016). They reported that number of siliquae plant^{-1} were significantly higher with 1st November (97) as compared to 20th October (86), 10th November (71.0), 20th November (57.3) and 30th November (69.7) sowings. Alam *et al.* (2014) observed that interaction effect of variety and sowing date significantly influenced the number of siliquae per plant was recorded from BJDH-11 and BARI Sarisha-16 of *Brassica juncea* at 25 November planting.

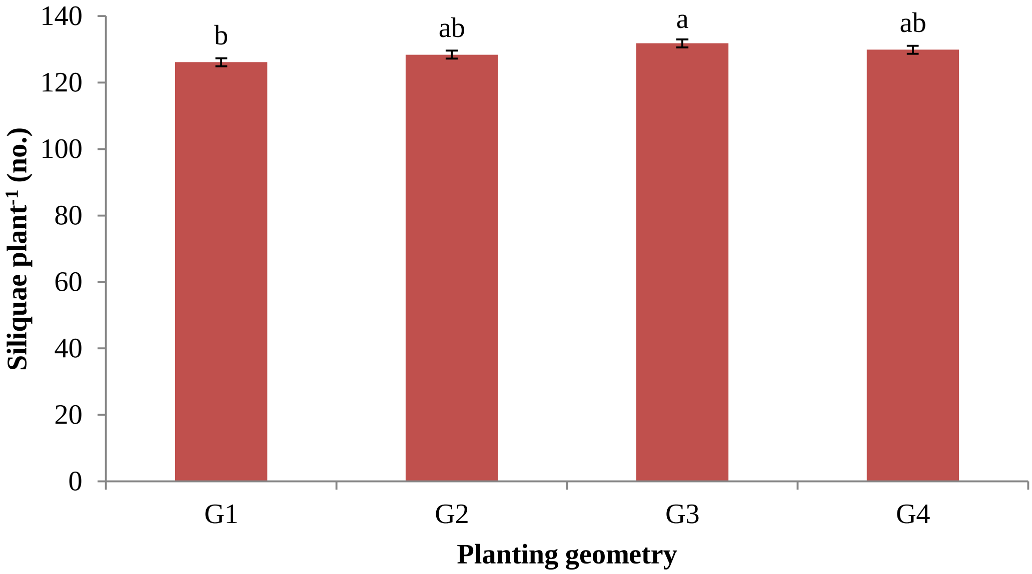


S_1= Sowing on 25th October, S_2= Sowing on 10th November and S_3= Sowing on 30th November

Figure 9. Effect of sowing time on the siliquae plant^{-1} of mustard ($LSD_{0.05}$= 4.48)

4.5.2 Effect of planting geometry

There was marked difference in siliquae plant^{-1} of mustard due to variation in planting geometry (Figure 10). Result of the experiment showed that, the maximum siliquae plant^{-1} (131.84) was produced by G_3 treatment which was statistically similar with G_4 and G_2. The minimum siliquae plant^{-1} (126.15) was produced by G_1 treatment which was statistically dissimilar with other treatments. Hasanuzzaman (2008) observed the similar trends of result that number of siliquae plant^{-1} was higher on row spacing geometry with two irrigations at 30 and 60 DAS.



G_1= Random geometry, G_2= 25 cm × 5 cm, G_3= 30 cm × 5 cm and G_4= 35 cm × 5 cm

Figure 10. Effect of planting geometry on the siliquae plant^{-1} of mustard ($LSD_{0.05}$= 5.17)

4.5.3 Interaction effect of sowing time and planting geometry

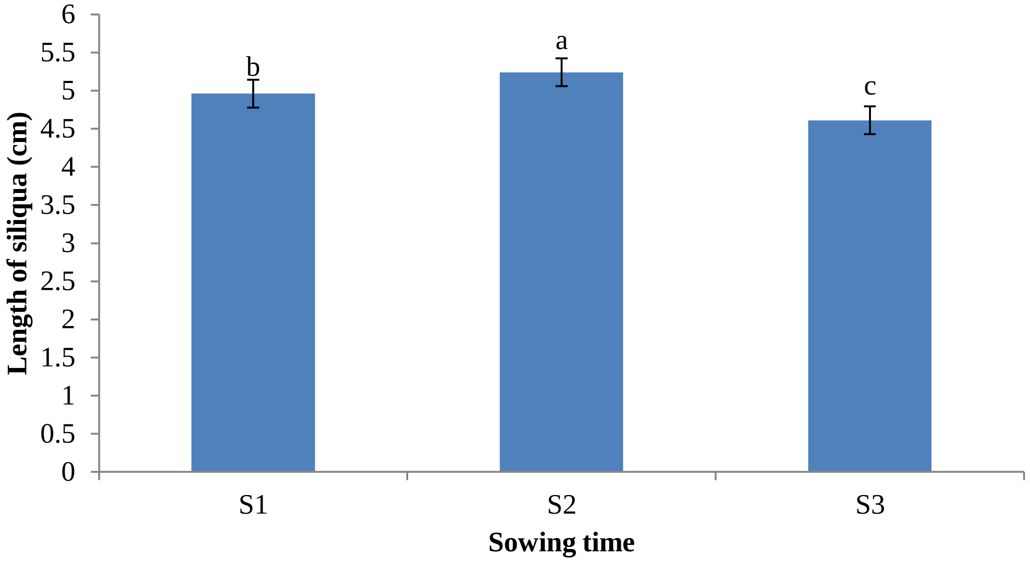
There was marked difference in siliquae plant^{-1} of mustard due to variation in the interaction of sowing time and planting geometry (Table 5 and Appendix VIII). Result of the experiment showed that, the maximum siliquae plant^{-1} (139.80) was produced by S_2G_3 treatment combination which was statistically similar with S_2G_4, S_2G_2, S_2G_1, S_1G_4, and S_1G_3. The minimum siliquae plant^{-1} (118.27) was produced by S_3G_1 treatment which was statistically similar with S_3G_2, S_3G_3, S_3G_4, and S_1G_1.

4.6 Length of siliqua (cm)

4.6.1 Effect of sowing time

Length of siliqua was significantly influenced by varied sowing time (Figure 11). From the results of the experiment, higher and lower length of siliqua (5.24 and 4.61 cm) was recorded from S_2 and S_3. The result of the investigation was in conformity to the findings of Singh *et al.* (2016) who reported that length of siliqua (cm) was significantly higher on 25th October sowing with variety Coral-437. 25th October sowing with Coral-437 variety proved the most remunerative and economically feasible for cultivation of Indian mustard under the agro climatic conditions of eastern

U.P. Tripathi *et al.* (2021) observed that length of siliqua (cm) was recorded maximum was recorded under 10 November sowing with Varuna variety.

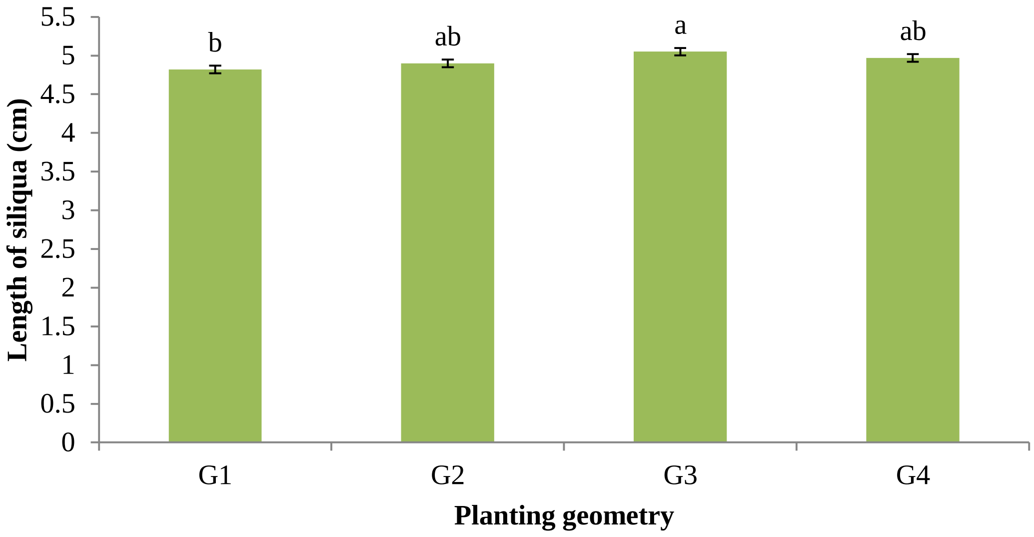


S_1= Sowing on 25th October, S_2= Sowing on 10th November and S_3= Sowing on 30th November

Figure 11. Effect of sowing time on length of siliqua of mustard ($LSD_{0.05}$= 0.19)

4.6.2 Effect of planting geometry

Length of siliqua of mustard was significantly influenced by varied planting geometry (Figure 12). The result of the experiment revealed that the highest length of siliqua (5.05 cm) was recorded from G_3 treatment which was statistically similar with rest of the planting geometry except G_1 and the lowest length of siliqua (4.82 cm) was recorded from G_1 treatment. Hasanuzzaman (2008) revealed that length of siliqua was affected significantly by row spacing planting (30 cm) along with two irrigations at 30 and 60 DAS. Dissimilar result was observed by Biswas *et al.* (2019) who reported that almost all the studied parameters were found statistically similar under two planting techniques (conventional sowing and sowing seeds in puddle soil) except siliqua length that was higher (5.51 cm) in conventional method compared to that of sowing in puddled soil (5.14 cm).



G_1= Random geometry, G_2= 25 cm × 5 cm, G_3= 30 cm × 5 cm and G_4= 35 cm × 5 cm

Figure 12. Effect of planting geometry on the length of siliqua of mustard ($LSD_{0.05}$= 0.21)

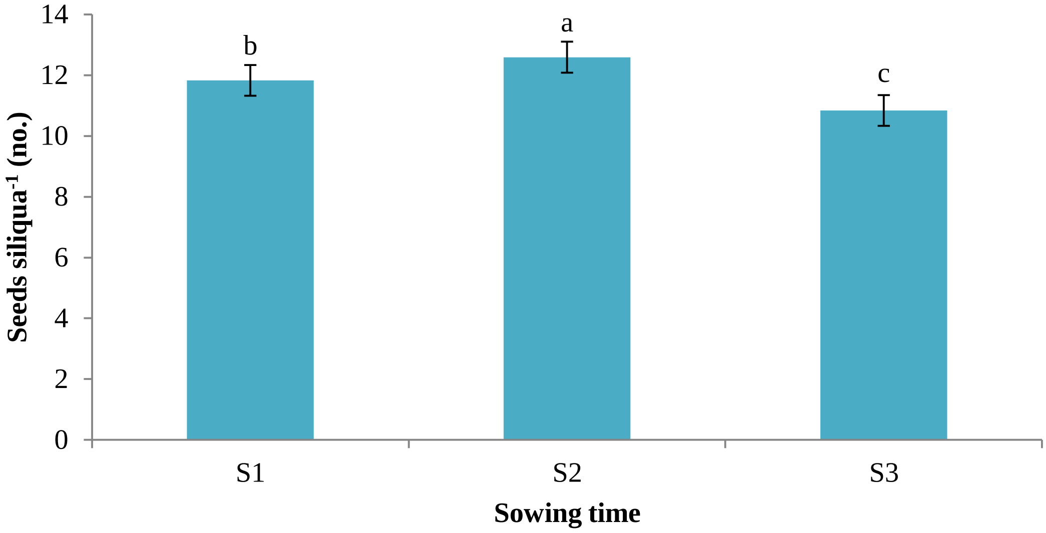
4.6.3 Interaction effect of sowing time and planting geometry

There was marked difference in length of siliqua of mustard due to variation in the interaction of sowing time and planting geometry (Table 5 and Appendix VIII). Result of the experiment showed that, the highest length of siliqua (5.31 cm) was produced by S_2G_3 treatment combination which was statistically similar with S_2G_4, S_2G_2, S_2G_1, S_1G_4, and S_1G_3. The lowest length of siliqua (4.47 cm) was produced by S_3G_1 treatment which was statistically similar with S_3G_2, S_3G_3, S_3G_4, and S_1G_1.

4.7 Seeds siliqua^{-1} (no.)

4.7.1 Effect of sowing time

There was marked difference in seeds siliqua^{-1} of mustard due to varied sowing time (Figure 13). Result of the experiment showed that, the maximum and minimum seeds siliqua^{-1} (12.59 and 10.84) was produced by S_2 and S_3, respectively. Similar trends was also found by Lakra *et al.* (2018) who reported that Sowing on 27th October was recorded with significantly higher number of branches, seeds per siliquae, siliquae per plant, 1000 seed weight, and seed yield than that on 07th November, 17th November and 27th November. Bikshapathi *et al.* (2021) observed that highest no. of seeds per siliqua (15.5) was recorded with treatment no.1 Varuna + 5th December sowing and maximum test weight was recorded with treatment no. 5 Mahyco Bold+ 10th December.

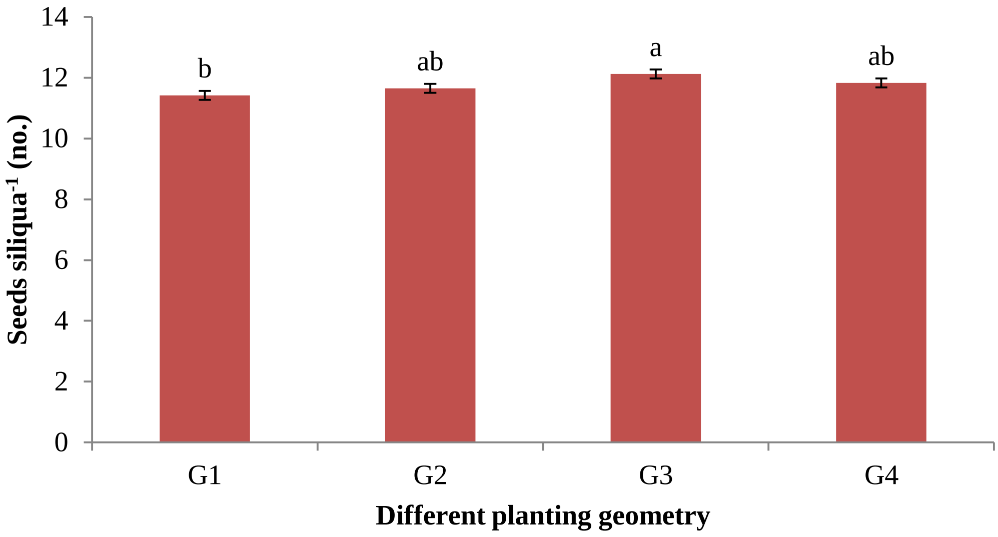


S_1= Sowing on 25th October, S_2= Sowing on 10th November and S_3= Sowing on 30th November

Figure 13. Effect of sowing time on the seeds siliqua^{-1} of mustard ($LSD_{0.05}$= 0.41)

4.7.2 Effect of planting geometry

There was marked difference in seeds siliqua^{-1} of mustard due to variation in planting geometry (Figure 14). Result of the experiment showed that, the maximum seeds siliqua^{-1} (12.12) was produced by G_3 treatment which was statistically similar with G_4 and G_2. The minimum seeds siliqua^{-1} (11.42) was produced by G_1 treatment which was statistically dissimilar with other treatments. The findings of the investigation was in coincided with the findings of Lakra *et al.* (2018) who revealed that seeds per siliquae was higher on planting geometry of 30 × 10 cm which was found to be suitable for the Indian mustard var. sown on 27th October. Hasanuzzaman (2008) also revealed that seeds per siliqua of rapeseed were produced higher on 30 cm row spacing.



G_1= Random geometry, G_2= 25 cm × 5 cm, G_3= 30 cm × 5 cm and G_4= 35 cm × 5 cm

Figure 14. Effect of planting geometry on the seeds siliqua^{-1} of mustard ($LSD_{0.05}$= 0.47)

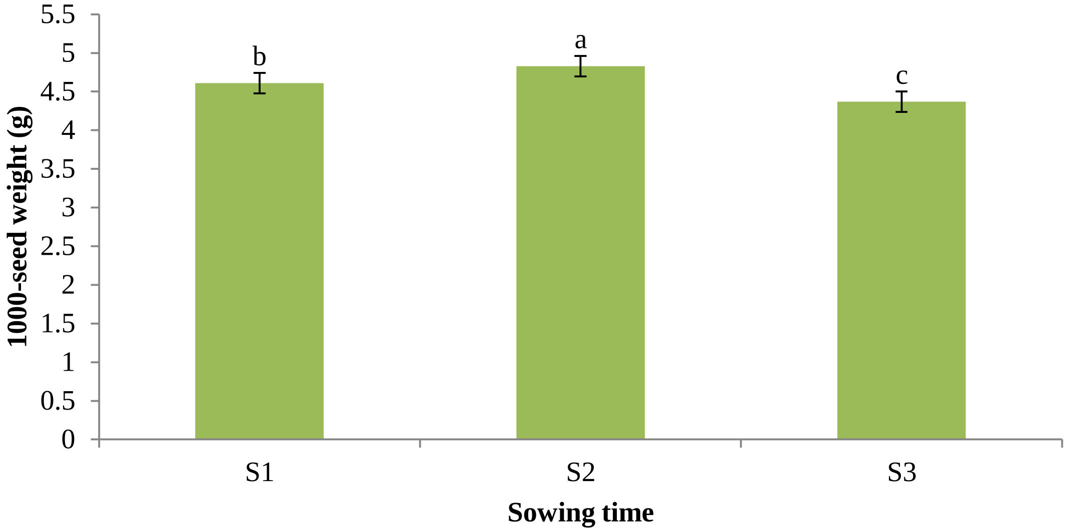
4.7.3 Interaction effect of sowing time and planting geometry

There was marked difference in seeds siliqua^{-1} of mustard due to variation in the interaction of sowing time and planting geometry (Table 5 and Appendix VIII). Result of the experiment showed that, the maximum seeds siliqua^{-1} (12.95) was produced by S_2G_3 treatment combination which was statistically similar with S_2G_4, S_2G_2, S_2G_1, S_1G_4, and S_1G_3. The minimum seeds siliqua^{-1} (10.42) was produced by S_3G_1 treatment which was statistically similar with S_3G_2, S_3G_3 and S_3G_4.

4.8 1000 seed weight (g)

4.8.1 Effect of sowing time

Considerable variation on 1000 seed weight was found due to different sowing time (Figure 15). The maximum 1000 seed weight (4.83 g) was found from S_2 and the minimum one (4.37 g) was from S_3. Lakra *et al.* (2018) found that sowing on 27th October was recorded significantly higher number of seeds per siliquae, siliquae per plant, 1000 seed weight, and seed yield than that on 07th November, 17th November and 27th November. Devi and Sharma (2017) revealed that 1000 seed weight and seed siliqua^{-1} did not vary significantly among different dates of sowing. Sharif *et al.* (2016) observed the similar trends of result and they stated that 1000-grain weight was highest from the first sowing (30 November) with BINA Sharisha-5 and it was significantly different from the yields of all other combination.

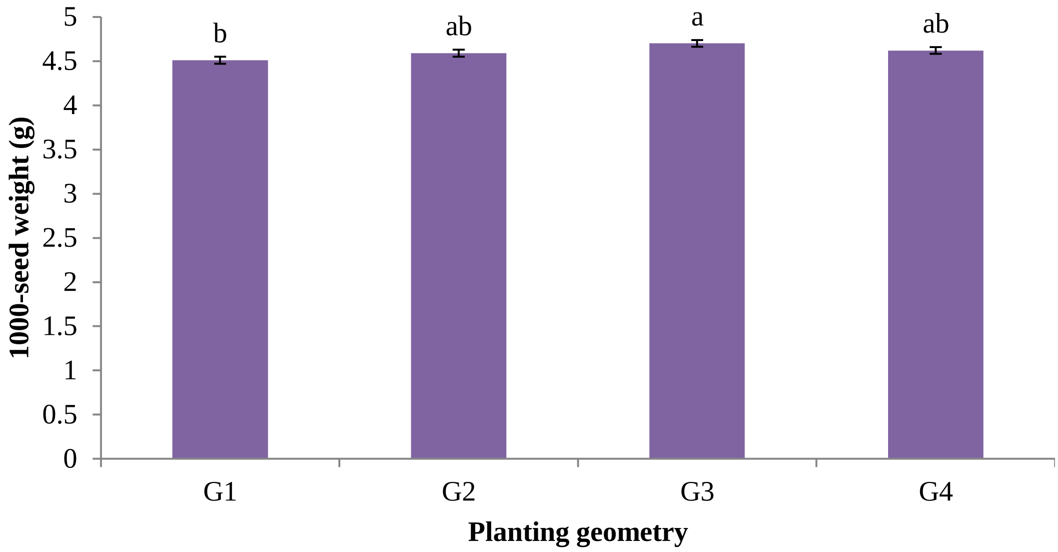


S_1= Sowing on 25th October, S_2= Sowing on 10th November and S_3= Sowing on 30th November

Figure 15. Effect of sowing time on the 1000 seed weight of mustard ($LSD_{0.05}$= 0.15)

4.8.2 Effect of planting geometry

There was marked difference in 1000 seed weight of mustard due to variation in planting geometry (Figure 16). Result of the experiment showed that, the maximum 1000 seed weight (4.70 g) was produced by G_3 treatment which was statistically similar with G_4 and G_2. The minimum 1000 seed weight (4.51 g) was produced by G_1 treatment which was statistically dissimilar with other treatments. Lakra *et al.* (2018) found that the similar trends of result. They revealed that 1000 seed weight was maximum with 30 cm row to row and 10 cm plant to plant spacing (30 × 10 cm) crop geometry. A planting geometry of 30 × 10 cm was found to be suitable for the Indian mustard. Hasanuzzaman (2008) revealed that the effect of planting pattern on 1000 seeds weight was more significant.



G_1= Random geometry, G_2= 25 cm × 5 cm, G_3= 30 cm × 5 cm and G_4= 35 cm × 5 cm

Figure 16. Effect of planting geometry on the 1000 seed weight of mustard ($LSD_{0.05}$= 0.17)

4.8.3 Interaction effect of sowing time and planting geometry

There was marked difference in 1000 seed weight of mustard due to variation in the interaction of sowing time and planting geometry (Table 5 and Appendix VIII). Result of the experiment showed that, the maximum 1000 seed weight (4.95 g) was produced by S_2G_3 treatment combination which was statistically similar with S_2G_4, S_2G_2, S_2G_1 and S_1G_3. The minimum 1000 seed weight (4.31 g) was produced by S_3G_1 treatment which was statistically similar with S_3G_2, S_3G_3, S_3G_4, S_1G_2 and S_1G_1.

Table 5. Combined effect of sowing time and planting geometry on number of siliquae plant^{-1}, length of siliqua, seeds siliqua^{-1} and weight of 1000-seed of mustard

Treatment combinations	Siliquae plant^{-1} (no.)	Length of siliqua (cm)	Seeds siliqua^{-1} (no.)	weight of 1000-seed (g)
S_1G_1	126.67 c-f	4.81 c-f	11.51 d-g	4.50 c-e
S_1G_2	128.17 b-e	4.89 b-e	11.75 c-f	4.59 b-e
S_1G_3	131.42 a-d	5.09 a-d	12.17 a-d	4.70 a-c
S_1G_4	130.91 a-d	5.03 a-d	11.87 b-e	4.63 b-d
S_2G_1	133.51 a-c	5.18 a-c	12.33 a-c	4.73 a-c
S_2G_2	135.23 a-c	5.22 ab	12.42 a-c	4.81 ab
S_2G_3	139.80 a	5.31 a	12.95 a	4.95 a
S_2G_4	136.14 ab	5.25 ab	12.67 ab	4.84 ab
S_3G_1	118.27 f	4.47 f	10.42 h	4.31 e
S_3G_2	121.83 ef	4.59 ef	10.77 gh	4.36 de
S_3G_3	124.31 d-f	4.74 d-f	11.23 e-h	4.44 c-e
S_3G_4	122.71 d-f	4.62 ef	10.95 f-h	4.39 de
$LSD_{0.05}$	**8.95**	**0.37**	**0.82**	**0.29**
CV%	**4.10**	**4.45**	**4.11**	**3.77**

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

Notes *viz:*

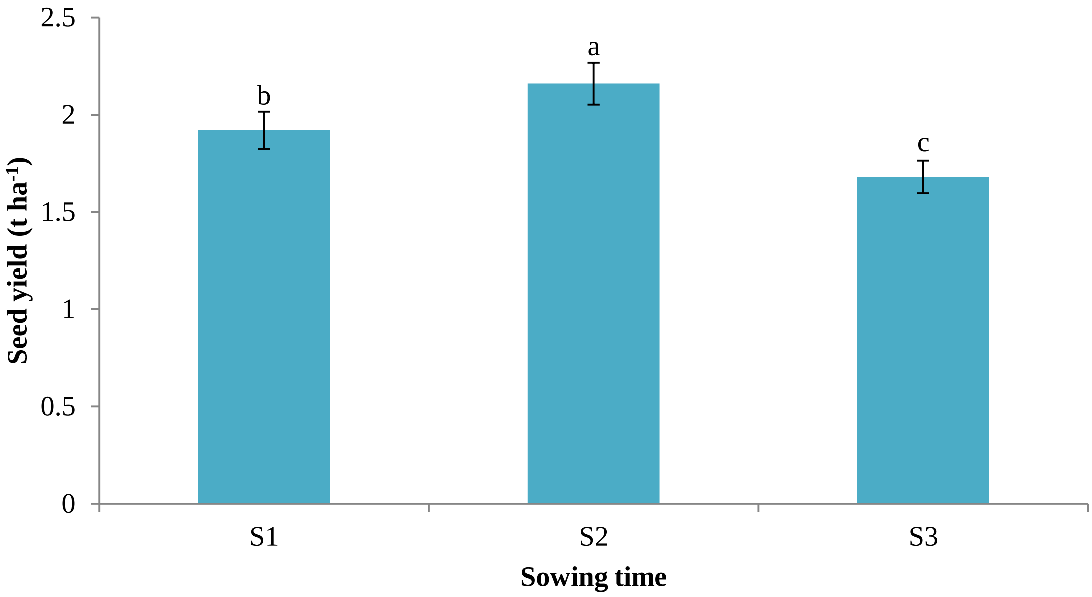
S_1= Sowing on 25th October
S_2= Sowing on 10th November
S_3= Sowing on 30th November

G_1= Random Geometry
G_2= 25 cm × 5 cm
G_3= 30 cm × 5 cm
G_4= 35 cm × 5 cm

4.9 Seed yield (t ha^{-1})

4.9.1 Effect of sowing time

Sowing time exerted significant variation on the seed yield (Figure 17). The result of the investigation expressed that the higher seed yield (2.16 t ha^{-1}) was recorded from S_2 whereas the lower one (1.68 t ha^{-1}) was from S_3. Similar result was also observed by Lakra *et al.* (2018) who reported that seed yield decreased progressively with delay in planting. Sowing on 27th October was recorded significantly higher number of branches, seeds per siliquae, siliquae per plant, 1000 seed weight, and seed yield than that on 07th November, 17th November and 27th November. Shah and Rahman (2009) revealed that the seed yield was found remarkably higher with 25th September (3.6 t ha^{-1}) sowing as compared to 5th October (2.8 t ha^{-1}), 15th October (2.3 t ha^{-1}), 15th September (1.7 t ha^{-1}), 25th October (1.3 t ha^{-1}) , 5th November (1.06 t ha^{-1}) and 15th November (0.5 t ha^{-1}) sowings. Sattar *et al.* (2013) also revealed that seed yield, protein and oil contents of all cultivars were decreased due to delayed sowing. Cultivar Zafar-2000 produced the maximum seed yield, protein and oil contents when planted earlier (15th October). It can be concluded that cultivar Zafar-2000 should be sown 15th October for attaining the maximum seed yield and oil contents under the sub-tropical climate of Pakistan. Ranabhat *et al.* (2021) also found the similar trends of result. They observed that in case of sowing dates, higher seed yield was obtained in October 4 sown crop (15.93 q ha^{-1}) followed by October 24 (7.47 q ha^{-1}) and November 14 (2.29 q ha^{-1}).The higher seed yield obtained in early sowing is due to shorter vegetative and longer reproductive phase. The comparison of mean values of the seed yield for interaction between variety and sowing date showed that variety Surkhet Local sown in October 4 plant had the highest seed yield (16.33 q ha^{-1}) followed by variety Unnati on same sowing date (15.54 q ha^{-1}).

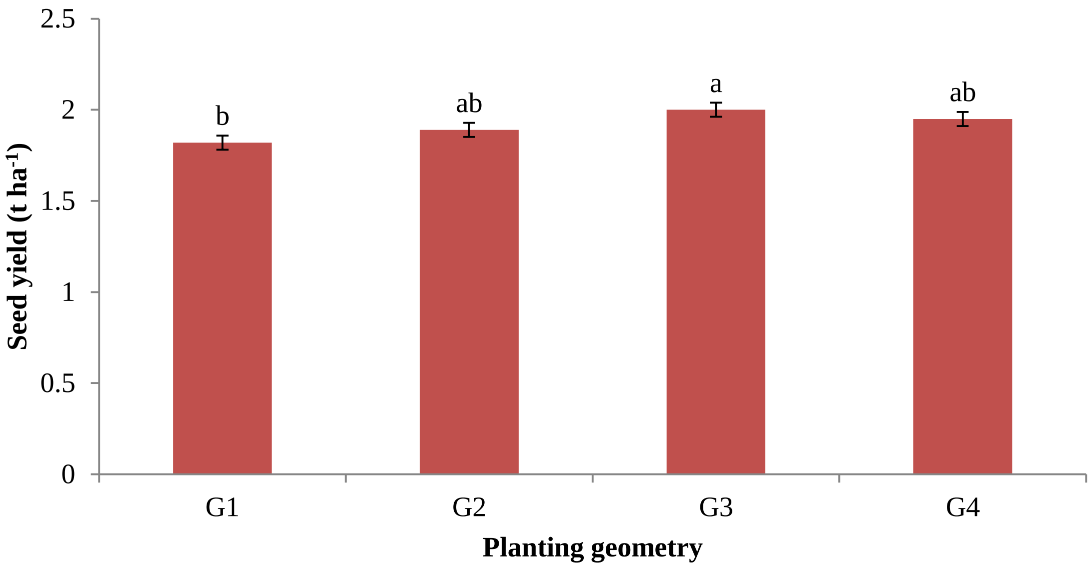


S_1= Sowing on 25th October, S_2= Sowing on 10th November and S_3= Sowing on 30th November

Figure 17. Effect of sowing time on the seed yield of mustard ($LSD_{0.05}$= 0.13)

4.9.2 Effect of planting geometry

Planting geometry exerted significant variation on the seed yield of mustard (Figure 18). The result of the investigation expressed that the highest seed yield (2.00 t ha^{-1}) was recorded from G_3 followed by G_4 (1.95 t ha^{-1}) and G_2 (1.89 t ha^{-1}) whereas the lowest one (1.82 t ha^{-1}) was from G_1. Similar trends of the finding was also observed by Gawariya *et al.* (2015) who reported that crop geometry of 30 × 20 cm recorded significantly higher seed yield (1.8 t ha^{-1}) with better utilization of space, nutrients, water and sunshine resulting in higher dry matter translocation to yield components as compared to 60 × 15, 45 × 15, 45 × 20, 45 × 25 and 30 × 25 cm crop geometry. Lakra *et al.* (2018) revealed that planting geometry of 30 × 10 cm was found to be suitable for the Indian mustard production. Faraji (2004) observed that a decrease in row spacing resulted in the increase in number of siliqua $plant^{-1}$, number of seed $siliqua^{-1}$ and seed yield. Row spacing at 12 cm and the sowing rate of 6 kg seed ha^{-1} produced the highest seed yield of 5044 kg ha^{-1}. Venkaraddi (2008) found the similar results and he reported that mustard seed yield (1326 kg ha^{-1}), oil yield (570.03 kg ha^{-1}), net returns (23107 Rs. ha^{-1}) and B:C ratio (3.12) were higher with variety Pusa Agram sown during II fortnight of September at 30 cm row spacing.



G_1= Random geometry, G_2= 25 cm × 5 cm, G_3= 30 cm × 5 cm and G_4= 35 cm × 5 cm

Figure 18. Effect of planting geometry on the seed yield of mustard ($LSD_{0.05}$= 0.15)

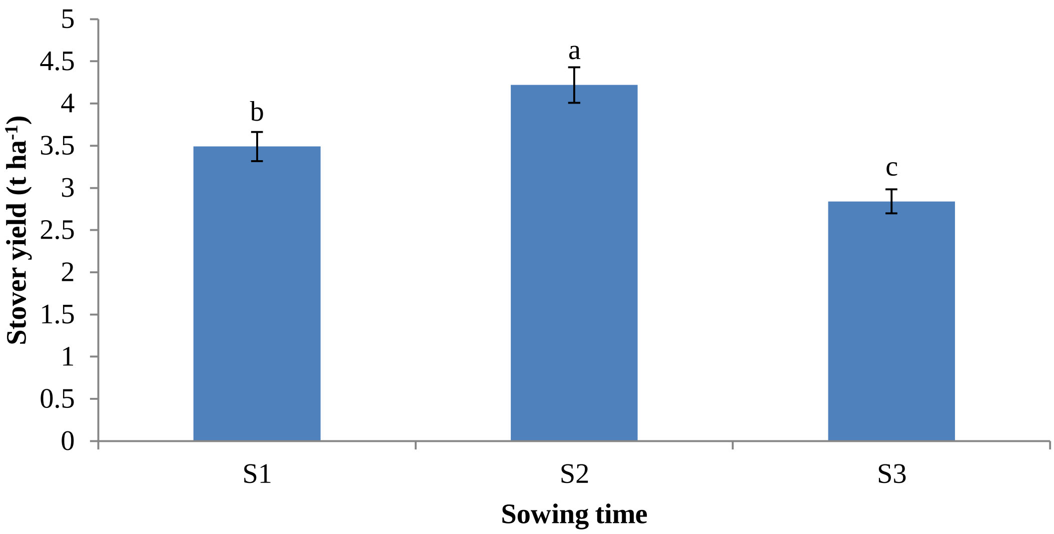
4.9.3 Interaction effect of sowing time and planting geometry

There was marked difference in seed yield of mustard due to variation in the interaction of sowing time and planting geometry (Table 6 and Appendix IX). Result of the experiment showed that, the maximum seed yield (2.24 t ha^{-1}) was produced by S_2G_3 treatment combination which was statistically similar with S_2G_4, S_2G_2, S_2G_1 and S_1G_3. The minimum seed yield (1.58 t ha^{-1}) was produced by S_3G_1 treatment which was statistically similar with S_3G_2, S_3G_3, S_3G_4, S_1G_2 and S_1G_1.

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

4.10.1 Effect of sowing time

Sowing time exerted significant variation on the stover yield (Figure 19). The result of the investigation expressed that the higher stover yield (4.22 t ha^{-1}) was recorded from S_2 whereas the lower one (2.84 t ha^{-1}) was from S_3. Similar result was found by Singh *et al.* (2016) who suggested that stover yields of mustard crop were significantly higher with variety Coral-437 sowing on 25th October. 25th October sowing with Coral-437 variety proved the most remunerative and economically feasible for cultivation of Indian mustard under the agro climatic conditions of eastern U.P. Alam *et al.* (2014) revealed the dissimilar result. They stated that the maximum stover yield (3758 and 3825 kg ha^{-1}) was obtained from BJDH-11 and BARI Sarisha-16 of *Brassica juncea* at 25th November planting.

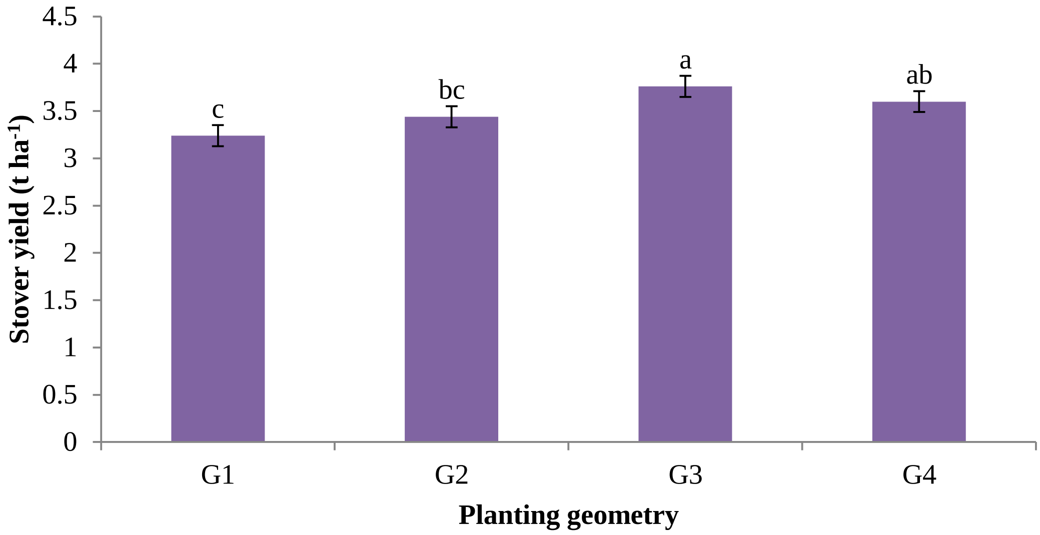


S_1= Sowing on 25th October, S_2= Sowing on 10th November and S_3= Sowing on 30th November

Figure 19. Effect of sowing time on the stover yield of mustard ($LSD_{0.05}$= 0.26)

4.10.2 Effect of planting geometry

Planting geometry exerted significant variation on the stover yield of mustard (Figure 20). The result of the investigation expressed that the highest stover yield (3.76 t ha^{-1}) was recorded from G_3 followed by G_4 (3.60 t ha^{-1}) whereas the lowest one (3.24 t ha^{-1}) was from G_1 which was statistically similar with G_2 (3.44 t ha^{-1}). Similar result was also observed by Raghuvansi *et al.* (2019) who reported that seed yield, biological yield and harvest index were recorded significantly higher with 30 cm × 10 cm as compared to other planting geometries.



G_1= Random geometry, G_2= 25 cm × 5 cm, G_3= 30 cm × 5 cm and G_4= 35 cm × 5 cm

Figure 20. Effect of planting geometry on the stover yield of mustard ($LSD_{0.05}$= 0.30)

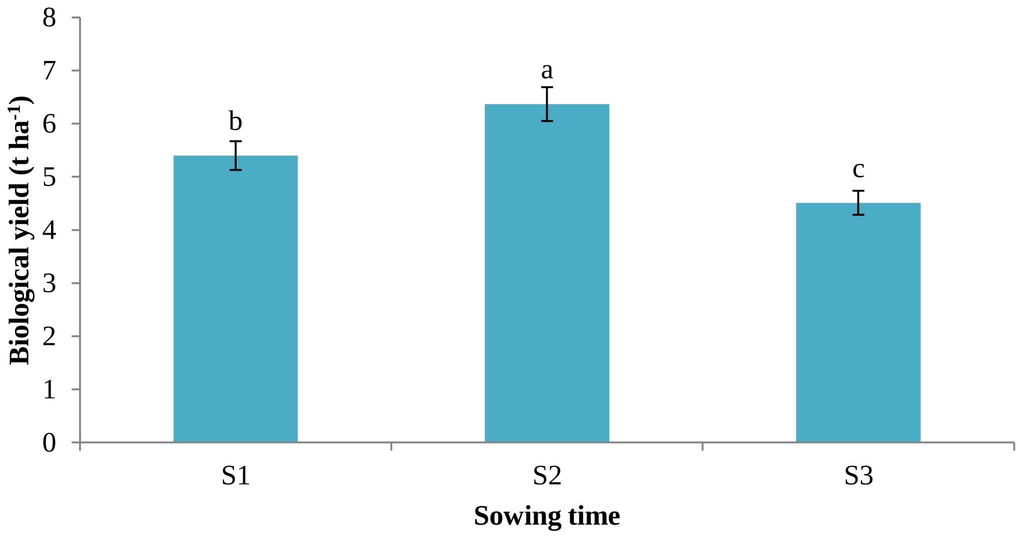
4.10.3 Interaction effect of sowing time and planting geometry

There was marked difference in stover yield of mustard due to variation in the interaction of sowing time and planting geometry (Table 6 and Appendix IX). Result of the experiment showed that, the maximum stover yield (4.54 t ha^{-1}) was produced by S_2G_3 treatment combination which was statistically similar with S_2G_4 and S_2G_2. The minimum stover yield (2.63 t ha^{-1}) was produced by S_3G_1 treatment which was statistically similar with S_3G_2, S_3G_3 and S_3G_4.

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

4.11.1 Effect of sowing time

Sowing time exerted significant variation on the biological yield of mustard (Figure 21). The result of the investigation expressed that the highest biological yield (6.37 t ha^{-1}) was recorded from S_2 whereas the lower one (4.51 t ha^{-1}) was from S_3. The results of the experiment was in coincidence with the findings of Ranabhat *et al.* (2021) who reported that biological yield was higher on early sowing. The higher seed yield, stover yield and biological yield obtained in early sowing are due to shorter vegetative and longer reproductive phase. Tripathi *et al.* (2021) also revealed the similar result and stated that 10 November and Varuna variety superior compare to rest of treatment. However, highest growth attributes (plant height, dry matter accumulation, Days taken to 50% flowering, number of tillers, LAI and yield and yield attributes (No. of siliqua per plant, length of siliqua (cm), test weight, seed yield (q ha^{-1}) grain yield, stover yield, biological yield, and harvest index) was recorded under 10 November and Varuna variety, and oil character.



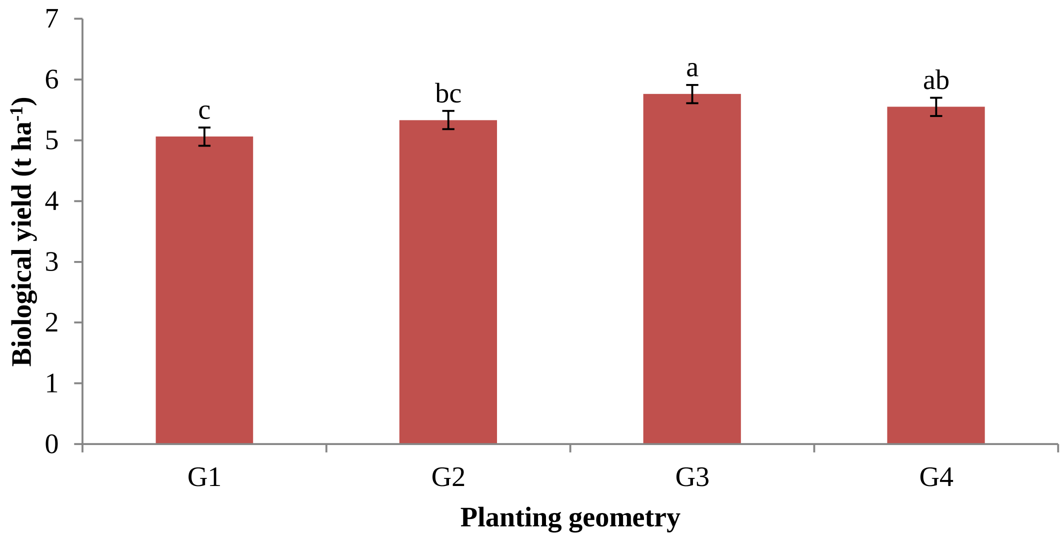
S_1= Sowing on 25th October, S_2= Sowing on 10th November and S_3= Sowing on 30th November

Figure 21. Effect of sowing time on the biological yield of mustard ($LSD_{0.05}$= 0.36)

4.11.2 Effect of planting geometry

Planting geometry exerted significant variation on the biological yield of mustard (Figure 22). The result of the investigation expressed that the highest biological yield

(5.76 t ha^{-1}) was recorded from G_3 followed by G_4 (5.55 t ha^{-1}) whereas the lowest one (5.06 t ha^{-1}) was from G_1 which was statistically similar with G_2 (5.33 t ha^{-1}). Similar result was also observed by Lakra *et al.* (2018). Dissimilar result was observed by Ahamed *et al.* (2019) who reported that the highest biological yield per hectare (5.08 t ha^{-1}) was obtained from broadcast method with BARI Sarisha-15 treatment combination. Raghuvansi *et al.* (2019) stated that biological yield (kg ha^{-1}) and harvest index were recorded significantly higher with 30 cm × 10 cm as compared to other planting geometries.



G_1= Random geometry, G_2= 25 cm × 5 cm, G_3= 30 cm × 5 cm and G_4= 35 cm × 5 cm

Figure 22. Effect of planting geometry on the biological yield of mustard ($LSD_{0.05}$= 0.42)

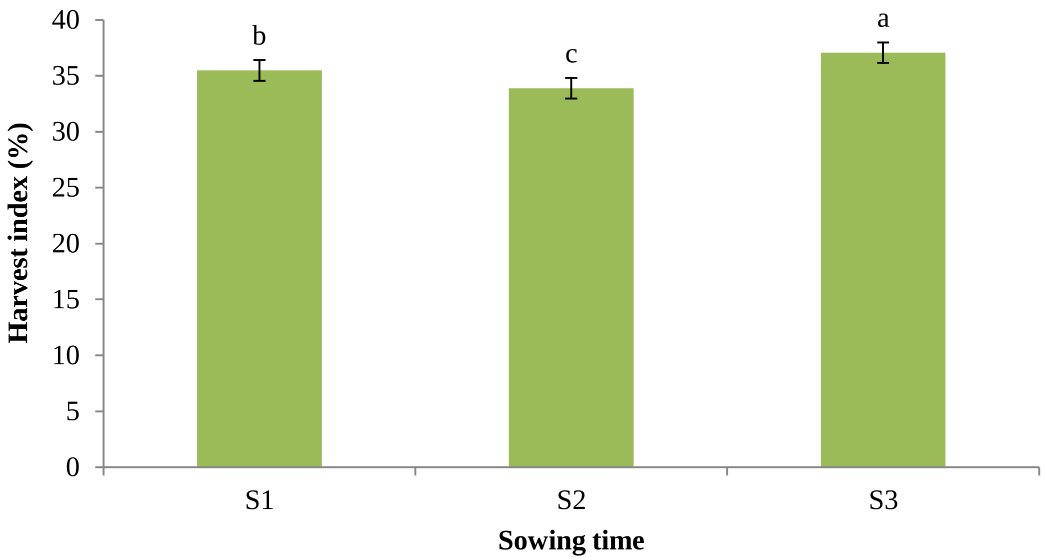
4.11.3 Interaction effect of sowing time and planting geometry

There was marked difference in biological yield of mustard due to variation in the interaction of sowing time and planting geometry (Table 6 and Appendix IX). Result of the experiment showed that, the maximum biological yield (6.78 t ha^{-1}) was produced by S_2G_3 treatment combination which was statistically similar with S_2G_4 and S_2G_2. The minimum biological yield (4.21 t ha^{-1}) was produced by S_3G_1 treatment which was statistically similar with S_3G_2, S_3G_3 and S_3G_4.

4.12 Harvest Index (%)

4.12.1 Effect of sowing time

Harvest index was significantly affected by sowing time (Figure 23). The maximum and minimum harvest index (37.07 and 33.89 %) was recorded from S_3 and S_2, respectively. The result of the experiment was in coincided with the findings of Sattar *et al.* (2013) who reported that the decline of grain yield with delay in sowing date could be largely explained by the decline in biomass at maturity while for protein and oil contents it could be related positively to harvest index and seed size, and negatively to temperature conditions at post-anthesis stage. Ranabhat *et al.* (2021) stated that sowing date significantly impacted on harvest index of mustard. Tripathi *et al.* (2021) also observed the similar results and reported that harvest index was higher on 10th November sowing than 15th October and 5th December.

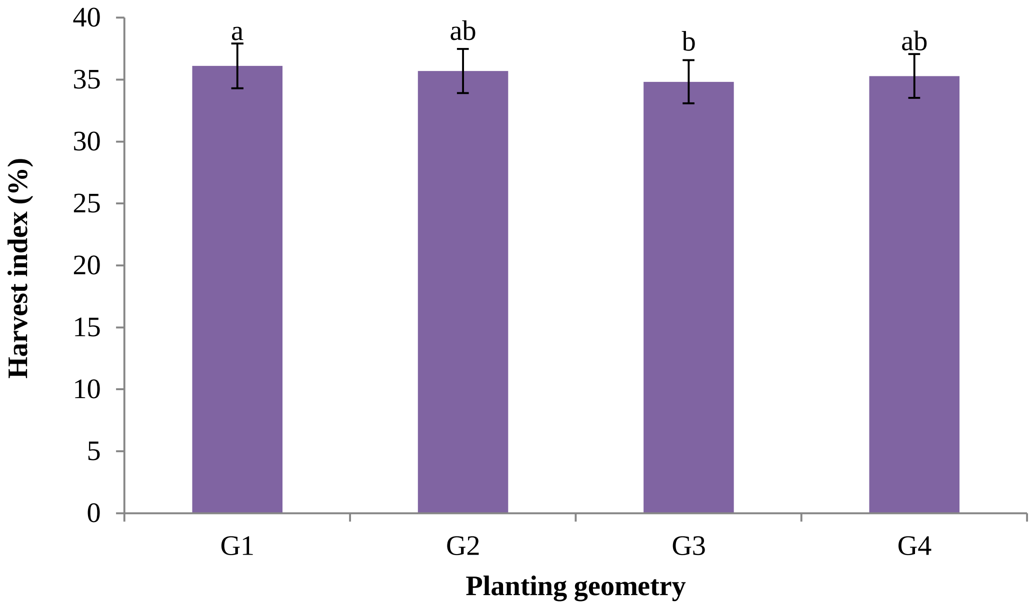


S_1= Sowing on 25th October, S_2= Sowing on 10th November and S_3= Sowing on 30th November

Figure 23. Effect of sowing time on the harvest index of mustard ($LSD_{0.05}$= 0.80)

4.12.1 Effect of planting geometry

Marked variation was observed on harvest index of mustard by planting geometry (Figure 24). The maximum and minimum harvest index (36.11 and 34.83 %) was recorded from G_1 and G_3, respectively. The result of the investigation was in conformity to the findings of Raghuvansi *et al.* (2019) who revealed that harvest index was recorded significantly higher with 30 cm × 10 cm as compared to other planting geometries.



G_1= Random geometry, G_2= 25 cm × 5 cm, G_3= 30 cm × 5 cm and G_4= 35 cm × 5 cm

Figure 24. Effect of planting geometry on the harvest index of mustard ($LSD_{0.05}$ = 0.92)

4.12.3 Interaction effect of sowing time and planting geometry

There was marked difference in harvest index of mustard due to variation in the interaction of sowing time and planting geometry (Table 6 and Appendix IX). Result of the experiment showed that, the maximum harvest index (37.50 %) was observed by S_3G_1 treatment combination which was statistically similar with S_2G_4, S_2G_3 and S_2G_2. The minimum harvest index (33.02 %) was observed by S_2G_3 treatment which was statistically similar with S_2G_4 and S_2G_2.

Table 6. Combined effect of sowing time and planting geometry on seed yield, stover yield, biological yield and harvest index of mustard

Treatment combinations	Seed yield ($t\ ha^{-1}$)	Stover yield ($t\ ha^{-1}$)	Biological yield ($t\ ha^{-1}$)	Harvest index (%)
S_1G_1	1.82 d-h	3.21 e-g	5.03 e-g	36.18 a-d
S_1G_2	1.89 c-g	3.41 d-f	5.30 d-f	35.67 b-e
S_1G_3	2.00 a-e	3.74 cd	5.74 c-e	34.86 d-f
S_1G_4	1.95 b-f	3.59 de	5.54 de	35.21 c-f
S_2G_1	2.06 a-d	3.89 b-d	5.95 b-d	34.65 d-f
S_2G_2	2.15 a-c	4.14 a-c	6.29 a-c	34.18 e-g
S_2G_3	2.24 a	4.54 a	6.78 a	33.02 g
S_2G_4	2.18 ab	4.29 ab	6.47 ab	33.70 fg
S_3G_1	1.58 h	2.63 h	4.21 h	37.50 a
S_3G_2	1.64 gh	2.77 gh	4.41 gh	37.22 ab
S_3G_3	1.76 e-h	3.01 f-h	4.77 f-h	36.60 a-c
S_3G_4	1.72 f-h	2.93 f-h	4.65 f-h	36.97 ab
$LSD_{0.05}$	**0.26**	**0.51**	**0.72**	**1.60**
CV%	**8.07**	**8.63**	**7.85**	**2.67**

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

Notes *viz:*

S_1= Sowing on 25th October
S_2= Sowing on 10th November
S_3= Sowing on 30th November

G_1= Random Geometry
G_2= 25 cm × 5 cm
G_3= 30 cm × 5 cm
G_4= 35 cm × 5 cm

CHAPTER V

SUMMARY AND CONCLUSION

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was carried out at the Agronomy field of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during October, 2019 to March, 2020 to study the effect of planting geometry and sowing time on growth and productivity of mustard. The experiment consisted of two factors. Factor A: Three sowing time *viz.*, S_1= Sowing on 25th October, S_2= Sowing on 10th November and S_3= Sowing on 30th November and Factor B: Four planting geometry *viz.*, G_1= Random geometry (broadcasting of seeds), G_2= 25 cm × 5 cm, G_3= 30 cm × 5 cm and G_4= 35 cm × 5 cm. There were 12 treatment combinations. The total numbers of unit plots were 36. The size of unit plot was 3.88 m^2 (2.5 m × 1.55 m). Data on different yield contributing characters and yield were recorded to find out the best sowing time and optimum planting geometry for the potential yield of mustard.

Different growth and yield contributing parameters were significantly influenced by different sowing time. The tallest plant (63.62, 102.27, 133.92, 141.63 and 147.69 cm at 30, 45, 60, 75 DAS and at harvest, respectively) was achieved from the treatment S_2 (sowing on 10th November), while the shortest plant (46.36, 86.40, 109.67, 123.96 and 129.30 cm at 30, 45, 60, 75 DAS and at harvest, respectively) was observed from the treatment S_3 (sowing on 30th November). The highest leaves plant^{-1} (19.34, 28.43, 37.35, 46.82 and 39.73 at 30, 45, 60, 75 DAS and harvest, respectively) was recorded from the treatment S_2 (sowing on 10th November) while the lower leaves plant^{-1} (15.92, 22.99, 30.87, 38.15 and 28.01 at 30, 45, 60, 75 DAS and harvest, respectively) was recorded from the treatment S_3 (sowing on 30th November). The maximum number of branches plant^{-1} (4.35, 6.08, 6.75, 7.15 and 6.93 at 30, 45, 60, 75 DAS and harvest, respectively) was observed in sowing time S_2 and the minimum ones (2.67, 4.73, 5.11, 5.53 and 5.38 at 30, 45, 60, 75 DAS and harvest, respectively) was observed in sowing time S_3. The maximum dry matter weight pant^{-1} (5.59, 16.87, 22.80, 36.71 and 40.79 g at 30, 45, 60, 75 DAS and harvest, respectively) was scored by S_2 and the minimum one (4.59, 14.60, 20.53, 33.77 and 35.90 g at 30, 45, 60, 75 DAS and harvest, respectively) was scored by S_3. The maximum siliquae plant^{-1} (136.17), length of siliqua (5.24 cm), seeds siliqua^{-1} (12.59), 1000 seed weight (4.83 g), seed yield (2.16 t ha^{-1}), stover yield (4.22 t ha^{-1}), biological yield (6.37 t ha^{-1}) were scored by S_2 (sowing on 10^{th} November). On the other hand, the minimum siliquae plant^{-1} (121.78), length of siliqua (4.61 cm), seeds siliqua^{-1} (10.84), 1000 seed weight (4.37 g), seed yield (1.68 t ha^{-1}), stover yield (2.84 t ha^{-1}), biological yield (4.51 t ha^{-1}) were obtained by S_3 (sowing on 30^{th} November). The maximum and minimum harvest index (37.07 and 33.89 %) was scored by S_3 and S_2.

Different growth and yield contributing parameters were significantly influenced by different planting geometry. The tallest plant (58.43, 97.56, 127.42, 136.82 and 140.91 cm at 30, 45, 60, 75 DAS and harvest, respectively) was achieved from the treatment G_3 (30 cm × 5 cm), while the shortest plant (51.55, 90.61, 117.98, 129.71 and 135.12 cm at 30, 45, 60, 75 DAS and harvest, respectively) were produced by planting geometry G_1 (Random geometry). The highest leaves plant^{-1} ((18.29, 26.68, 35.03, 44.19 and 35.70 at 30, 45, 60, 75 DAS and harvest, respectively) was recorded from the treatment G_3 (30 cm × 5 cm) while the lower leaves plant^{-1} (16.96, 24.32, 32.91, 40.00 and 31.32 at 30, 45, 60, 75 DAS and harvest, respectively) was recorded from the treatment G_1 (Random geometry). The maximum number of branches plant^{-1} (3.80, 5.71, 6.15, 6.59 and 6.44 at 30, 45, 60, 75 DAS and harvest, respectively) was observed in planting geometry G_3 and the minimum ones (3.07, 5.16, 5.63, 6.04 and 5.86 at 30, 45, 60, 75 DAS and harvest, respectively) was observed in G_1 (Random geometry). The maximum dry matter weight pant^{-1} (5.29, 16.21, 22.06, 35.50 and 39.57 g at 30, 45, 60, 75 DAS and harvest, respectively) was scored by G_3 and the minimum one (4.85, 15.26, 21.28, 33.49 and 37.59 g at 30, 45, 60, 75 DAS and harvest, respectively) was scored by G_1. The maximum siliquae plant^{-1} (131.84), length of siliqua (5.05 cm), seeds siliqua^{-1} (12.12), 1000 seed weight (4.70 g), seed yield (2.00 t ha^{-1}), stover yield (3.76 t ha^{-1}), biological yield (5.76 t ha^{-1}) were scored by G_3 (30 cm × 5 cm). On the other hand, the minimum siliquae plant^{-1} (126.15), length of siliqua (4.82 cm), seeds siliqua^{-1} (11.42), 1000 seed weight (4.51 g), seed yield (1.82 t ha^{-1}), stover yield (3.24 t ha^{-1}), biological yield (5.06 t ha^{-1}) were obtained by G_1 (Random geometry). The maximum and minimum harvest index (36.11 and 34.83 %) was scored by G_1 (Random geometry) and G_3 (35 cm × 5 cm).

Different growth and yield contributing parameters were significantly influenced by the interaction effect of different sowing time and planting geometry. The tallest plant The tallest plant (67.58, 106.27, 138.31, 147.58 and 150.44 cm at 30, 45, 60, 75 DAS and harvest, respectively) was produced by treatment combination of S_2G_3 while the shortest plant (43.61, 81.67, 103.33, 121.83 and 125.38 cm at 30, 45, 60, 75 DAS and harvest, respectively) was produced by treatment combination S_3G_1. The highest leaves plant^{-1} (20.07, 29.67, 39.20, 50.93 and 42.32 at 30, 45, 60, 75 DAS and harvest, respectively) were recorded from treatment combinations S_2G_3 while S_3G_1 consistently produced lowest leaves palnt^{-1} (15.21, 21.52, 30.05, 36.74 and 26.33 at 30, 45, 60, 75 DAS and harvest, respectively). The maximum number of branches plant^{-1} (4.87, 6.40, 7.00, 7.43 and 7.23 at 30, 45, 60, 75 DAS and harvest, respectively) was observed in treatment combination S_2G_3 and the minimum ones (2.40, 4.33, 4.81, 5.18 and 5.00 at 30, 45, 60, 75 DAS and harvest, respectively) was observed in treatment combination S_3G_1. The maximum dry matter weight pant^{-1} (5.86, 17.45, 23.09, 37.62 and 42.29 g at 30, 45, 60, 75 DAS and harvest, respectively) was scored by treatment combination S_2G_3 and the minimum one (4.42, 14.11, 19.87, 30.85 and 34.93 g at 30, 45, 60, 75 DAS and harvest, respectively) was scored by treatment combination S_3G_1. The maximum siliquae plant^{-1} (139.80), length of siliqua (5.31 cm), seeds siliqua^{-1} (12.95), 1000 seed weight (4.95 g), seed yield (2.24 t ha^{-1}), stover yield (4.54 t ha^{-1}), biological yield (6.78 t ha^{-1}) were scored by S_2G_3 treatment combination. On the other hand, the minimum siliquae plant^{-1} (118.27), length of siliqua (4.47 cm), seeds siliqua^{-1} (10.42), 1000 seed weight (4.31 g), seed yield (1.58 t ha^{-1}), stover yield (2.63 t ha^{-1}), biological yield (4.21 t ha^{-1}) were obtained by S_3G_1 treatment combination. The maximum and minimum harvest index (37.50 and 33.02 %) was scored by S_3G_1 and S_2G_3 treatment combination.

The results in this research indicated that the plants performed better in respect of seed yield in S_2G_3 (2.24 t ha^{-1}) treatment than the combination S_3G_1 (1.58 t ha^{-1}) which showed the least performance. It can be therefore, concluded from the above study that the treatment combination S_2G_3 (mustard sowing on 10th November with 30 cm × 5 cm planting geometry) was found to be most suitable combination for the potential yield of mustard in Bangladesh.

REFERENCES

REFERENCES

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

Ahamed, K. U., Rahman, A., Islam, N. M., Fatima, S., Monir, M. R., Kirtania, M. (2019). Effect of different sowing methods and varieties on the yield of mustard (*Brassica campestris L.). Intl. J. Adv. Agric. Sci*., **4**(10): 8-19.

Ahmed. (2008). Results of farm level socio-economic study on mustard production. *Bangladesh J. Agril. Res*., **13**(1): 20-23.

Alam, M. J., Ahmed, K. S., Mollah, M. R. A., Tareq, M. Z. and Alam J. (2015). Effect of planting dates on the yield of mustard seed. *Intl. J. App. Sci. Biotech.*, **3**(4):651-654.

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

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

Atlassi, P., Meskarbashee, M. and Mamghani, R. (2008). Effect of planting pattern on morphology, yield and yield components of three spring canola varieties in Ahvaz climatic conditions. *Res. Crops.*, **9**(1): 39-44.

Aziz, K. M. T. (2014). Growth and yield performance of mustard and rapeseed varieties as influenced by different sowing techniques. M. S. thesis, SAU, Dhaka, Bangladesh. P. 1-65.

Aziz, M. A., Remi Chakma, Ahmed, M., Rahman, A. K. M. M. and Roy, K. (2011). Effect of sowing dates on the growth, development and yield of mustard in the hilly areas. *J. Expt. Bio. Sci.*, **2**(1): 33-36.

BBS (Bangladesh Bureau of Statistics). (2020). Statistical year book of Bangladesh. *Bangladesh Bureau of Statistics*, Dhaka. P. 40.

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

Bhuiyan, M. S., Mondol, M. R. I., Rahaman, M. A., Alam, M. S. and Faisal, A. H. M. A. (2008). Yield and yield attributes of rapeseed as influenced by date of planting. *Intl. J. Sustain. Crop Prod.,* **3**(3): 25-29.

Bikshapathi, M., Singh, R. and Singh, E. (2021). Effect of sowing dates on growth and yield attributes of Indian mustard (*Brassica juncea* L.) varieties under late sown conditions. *Intl. J. Chem. Stud.,* **9**(2): 751-754.

Bilgili, U., Sincik, M., Uzun, A. and Acikgoz, E. (2003). The influence of row spacing and seedling rate on seed yield and yield components of forage turnip (*Brassica rapa* L.). *J. Agron. Crop Sci.,* **189**(4): 250.

Biswas, C., Singh, R. and Vijaya, P. K. (2011). Dynamics of white rust disease in mustard (*Brassica juncea*) in relation to date of sowing and weather parameters. *Indian J. Agric. Sci.,* **81**(12): 1187–90.

Biswas, P. K., Ferdous, L. J., Roy, T. S. and Masum, S. M. (2019). Performance of rapeseed and mustard with different planting techniques. *Bangladesh J. Agron.,* **22**(1): 79-88.

DAE. (2015). Department of Agricultural Extension Annual Report, Ministry of Agriculture, Dhaka, Bangladesh.

Devi, M. and Sharma, H. K. (2017). Effect of sowing date on flowering and seed set of mustard (*Brassica juncea* L.). *J. Entom. and Zool. Stud*., **5**(5): 1534-1537.

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

FAO (Food and Agriculture Organization). (2012). FAO production year Book. Food and Agricultural organization, Rome. Italy. pp. 54-59.

FAO (Food and Agriculture Organization). (2019). FAO Production Year Book. Food Agriculture Organization of United Nations, Rome, Italy. pp. 68-76.

Faraji, A. (2004). Effects of row spacing and seed rate on yield and yield components of rapeseed (Quantum cultivar) in Gonbad. *Seed Pl.*, **20**(3): 297-303.

Gawariya, S. C., Chopra, N. K., Chopra, N. and Harika, A. S. (2015). Effect of date of sowing and crop geometry on growth and yield parameters of forage mustard (var. *Chinese Cabbage*). *African J. Agril. Res.,* **10**(33): 3292-3295.

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

Hasanuzzaman, M. (2008). Siliqua and seed development in Rapeseed (*Brassica campestris* L.) as affected by different Irrigation levels and row spacing. Department of Agronomy, Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka- 1207, Bangladesh. *Agric. Conspectus Sci.,* **73(**4): 221-226.

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

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

Johnson, B. L., Zakaria, A. K. M. and Hanson, B. K. (2003). Row spacing interaction on spring canola performance in the North Great Plains. *Agron. J.,* **95**(3): 703-708.

Keerthi, P., Pannu, R. K., Dhaka, A. K. and Chaudhary, K. (2017). Effect of sowing time and nitrogen on growth, yield and nutrient uptake by Indian mustard (*Brassica Juncea* L.) under Western Haryana. *Chem. Sci. Rev. Lett.,* **6**(24): 2526-2532.

Khanlou, A. S. and Sharghi, Y. (2015). Effects of planting density on morphological traits canola. *Res. J. Fish. Hydrobiol.,* **10**(10): 290-293.

Kumar, A., Lal, M., Mohan, N., Kumar, M. and Kumar, N. (2018). Effect of different sowing dates on yield and yield attributes of Indian mustard (*Brassica juncea* L.) genotypes. *Intl. J. Pure App. Biosci.,* **6**(2): 848-853.

Kumar, R., Singh, R. P. and Yeshpal (2008). Yield and quality of *Brassica species* as influenced by different dates of sowing and varieties. *Pantnagar J. Res.,* **6** (1): 6-11.

Kumar, V. and Singh, D. (1994). Genetics of yields and its components of Indian mustard (*Brassica juncea* L. Czern and Cross). *Crops Res*., **7**(2): 243-246.

Kumari, A., Singh, R. P. and Yeshpal (2012). Productivity, nutrient uptake and economics of mustard hybrid (*Brassica juncea*) under different planting time and row spacing. *Indian J. Agron.*, **57** (1): 61-67.

Lakra, R. K., Alam, P. and Nayar, A. (2018). Effect of sowing time and crop geometry on productivity of mustard (*Brassica juncea* L.) under irrigated condition of Jharkhand. *Int. J. Curr. Microbiol. App. Sci.,* **7**: 777-781.

Lallu, R. S., Baghel, V. S. and Srivastava, S. B. L. (2010). Assessment of mustard genotypes for thermo tolerance at seed development stage. *Indian J. Pl. Physiol.,* **15**(10): 36-43.

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

MOA. (Ministry of Agriculture). (2006). Agriculture Statistics Database of the official website of the Ministry of Agriculture of the People’s Republic of Bangladesh.

Mondol, M. R. I., Begum, F. and Saiyed, I. M. (2011). Effect of planting dates on seed and oil yield of rapeseed (*Brassica campestries* L.) genotype BCYS- 03. *SAARC J. Agric.,* **9**(1): 85-93.

Mottabebipour, S. and Bahrani, M. J. (2006). Response of two irrigated rapeseed cultivars to plant population. *Crop Res. Hisar*., **32**(3): 320-324.

Oad, F. C., Solangi, B. K., Samo, M. A., Lakho, A. A. and Oad, N. L. (2001). Growth yield and relationship of rapeseed (*Brassica napus* L.) under different row spacing. *Intl. J. Agril. Biol*., **3**(4): 475-476.

Panda, B. B., Shivay, Y. S. and Bandyopadhyay, S. K. (2004). Growth and development of Indian mustard (*Brassica juncea* L.) under different levels of irrigation and dates of sowing. *Indian J. Pl. Physiol*., **9**(4): 419-425.

Pandey, N., Kumar, S. and Singh, G. (2015). Effect of planting geometry on growth and yield of mustard varieties. *Int. J. of Farm Sci.,* **5**(2): 47-52.

Panwar, K. S., Sharma, S. K. and Nanwal, R. K. (2000). Influence of sowing times on the yield of different mustard cultivars (Brassica spp.) under conserved soil moisture conditions. *Indian J. Agric. Sci.,* **70**(6): 398-399.

Parminder, K. and Sidhu, M. S. (2006). Effect of sowing date, nitrogen level and row spacing on oil quality of Ethiopian mustard. *Environ. Ecol.,* **24**(Special 4): 1112-1114.

Patel, A., Singh, A. K., Singh, S. V., Sharma, A., Raghuvanshi, N. and Singh, A. K. (2017). Effect of different sowing dates on growth, yield and quality of various Indian mustard (*Brassica juncea* L.) varieties. *Intl. J. Curr. Microbiol. App. Sci.,* **4**: 71-77

Pronay, B., Azad, A. K. and Hossain, M. F. (2011). Yield response of mustard to sowing date. *Libyan Agric. Res. Center J. Intl.,* **2**(3): 112-117.

Raghuvansi, G., Tyagi, P. K., Dubey, K. and Sahu, M. P. (2019). Effect of sowing dates and crop geometry on total plant dry matter, oil content and yield of Indian mustard. *Intl. J. Pure App. Biosci.,* **7**(2): 440-445.

Rahman, M. M. (2002). Status of oil seeds and future prospects on Bangladesh, Paper presented in Review workshop on the Impact of Technology transfer on Oil Crops, held at BARI on 29 April, 2002.

Ranabhat, G., Tiwari, P., Dhakal, A., Oli, P., Chapagain, A., and Neupane, S. (2021). Effect of sowing dates on different rapeseed varieties under rain fed condition. *J. of Agric. and Nat. Res.,* **4**(1): 176-190.

Rashid, M. M., Moniruzzaman, M., Masud, M. M., Biswas, P. K. and Hossain, M. A. (2010). Growth parameters of different mustard (*Brassica campestris* L) varieties as affected by different levels of fertilizers. *Bull. Inst. Trop. Agr., Kyushu Univ.,* **33**: 73-81.

Sam-Daliri, M., Mousavi, R. V., Morteza, S. J., and Bagheri, H. (2011). Study of planting density on some agronomic traits of rapeseed three cultivar (*Brassica napus* L.). *Australian J. Basic Appl. Sci.*, **5**(12): 2625-2627.

Sattar, A., Mumtaz, A., Cheema, Wahid, M. A., Saleem, F. M., Ghaffari, M. A., Hussain, S. and Arshad, M. S. (2013). Effect of sowing time on seed yield and oil contents of canola varieties. *J. Glob. Innov. Agric. Soc. Sci.*, **1**(1): 1-4.

Shah, S. A. and Rahman, K. (2009). Yield and growth response of rapeseed (*Brassica napus* L.) mutants to different seeding rates and sowing dates. *Pakistan J. Bot.,* **41**(6): 2711-16.

Sharif, M. A. R., Haque, M. Z., Howlader, M. H. K. and Hossain, M. J. (2016). Effect of sowing time on growth and yield attributes of three mustard cultivars grown in Tidal Floodplain of Bangladesh. *J. Bangladesh Agril. Univ.,* **14**(2): 155–160.

Sharma, S. K. Mendhe, S. N. Kolte, H. S. Rajput, G. R. and Yenpreddiwar, M. D. (2006). Effect of sowing and irrigation management on growth and yield of mustard (*Brassica juncea* L.). *J. Soils Crops*., **16**(2): 455-459.

Singh, A. K., Singh, H., Rai, O. P. Singh, G. and Singh, V. P. (2017). Effect of sowing dates and varieties for higher productivity of Indian mustard (*Brassica juncea* L.). *J. App. Nat. Sci.,* **9**(2): 883-887.

Singh, G. K., Kedar, P. and Prasad, K. (2003). Effect of row spacing and nitrogen doses on nutrient uptake and oil yield in mustard. *Crop Res. Hisar*., **259**(3): 431-435.

Singh, M., Swarankar, G. B., Prasad, L. and Rai, G. (2002). Genetic variability, heritability and genetic advance for quality traits in Indian mustard (*Brassica juncea* L. Czem and Cross). *Pl. Arch.,* **2**(1): 27-31.

Sonani, V. V., Patel, P. T. and Patel, G. G. (2002). Performance of mustard under different dates of sowing in Bhal and Coastal Agro-climatic zone of Gujarat. *J. Oilseeds Res.*, **19**(1): 122.

Stryer, L. (1980). Fatty acid metabolism in Biochemistry (2nd ed.) Stanford Univ. Freeman Co. New York, San Francisco. p. 385.

Sultana, S. (2007). Effect of irrigation and varieties on the growth and yield of rapeseed. M. S. thesis, Dept. of Agronomy, Sher-e-Bangla Agril. Univ. Dhaka. pp. 1-55.

Tripathi, K. B. M., Gaur, T., Pandey, L., Singh, A., Tiwari, A. and Prakash, V. (2021). Effect of Sowing Dates on Growth and Yield of Indian Mustard (*Brassica juncea* L.). *Intl. J. Curr. Microbiol. App. Sci.*, **10**(01): 3046-3057.

Ullah, A. (1989). Food consumption pattern of rice growing and rice mustard growing household of Pabna district in Bangladesh: A comparative study. M.S. Thesis. Inst. Human Nutr. Food. UPLB. Philippines. pp. 1-50.

Venkaraddi, S. (2008). Response of mustard [*Brassica juncea* (L.) Czernj and Cosson] varieties to date of sowing and row spacing in northern transition zone of Karnataka. MS thesis in Agronomy, Department of Agronomy, College Of Agriculture, Dharwad University of Agricultural Sciences, Dharwad-580005. pp. 1-69.

Verma, O. S. (1990). Plants stand geometry. Proc. Indo-Swedish Symposium on Research Rapeseed and Mustard, pp: 131–6. September 4-6, 1989.

Yadav, A., Singh, A. K., Chaudhari, R. and Mishra, S. R. (2018). Effect of planting geometry on growth and yield of mustard (*Brassica juncea* L.) varieties. *J. Pharmac. and Phytochem.*, **7**(3): 2624-2627.

APPENDICES

APPENDICES

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

Month and year	RH (%)	Air temperature (°C)			Rainfall
		Max.	*Min.*	*Mean*	(mm)
October, 2019	58.40	29.40	16.2	22.80	22.0
November, 2019	56.25	28.70	8.62	18.66	14.5
December, 2019	51.75	26.50	9.25	17.87	12.0
January, 2020	46.20	23.70	11.55	17.62	0.0
February, 2020	37.95	22.85	14.15	18.50	0.0
March, 2020	35.75	21.55	15.25	18.40	0.0

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

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

A. Morphological characteristics of the experimental field

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

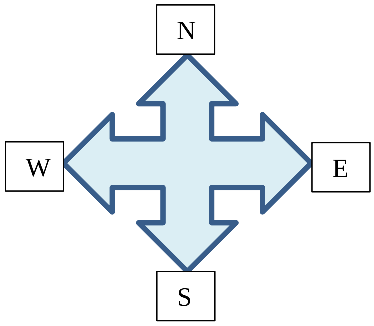
Source: Soil Resource Development Institute (SRDI)

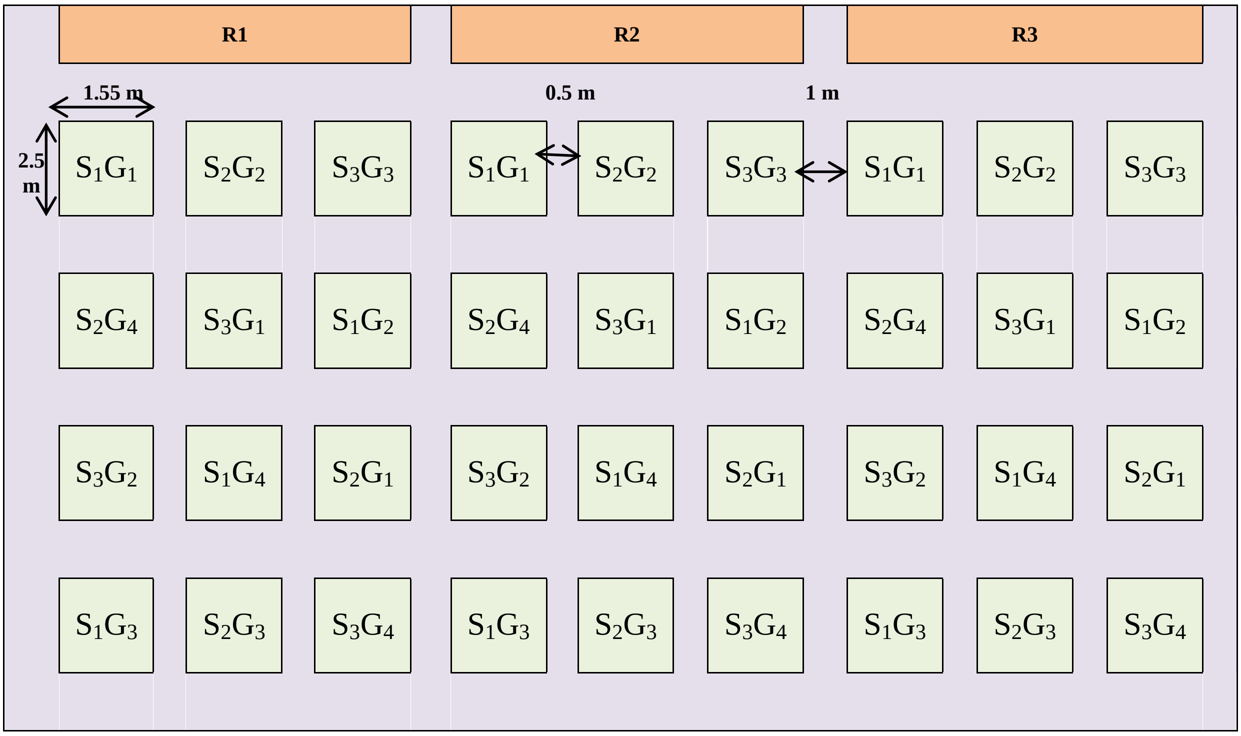
B. Physical and chemical properties of the initial soil

Characteristics	**Value**
Partical size analysis % Sand	27
%Silt	43
% Clay	30
Textural class	Silty Clay Loam
pH	6.2
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total N (%)	0.03
Available P (ppm)	20
Exchangeable K (me/100 g soil)	0.1
Available S (ppm)	45

Source: Soil Resource Development Institute (SRDI)

Appendix III: Layout of the experimental field





Length of plot: 2.5 m, **Width of plot:** 1.55 m

Replication to replication distance: 1 m

Plot to plot distance: 0.5 m,

Unit plot size: 2.5 m × 1.55 m (3.88 m^2)

Appendix IV. Mean square values of plant height at different days after sowing of mustard growing under the experiment

Sources of variation	Degrees of freedom	Mean square of plant height at				
		30 DAS	45 DAS	60 DAS	75 DAS	Harvest
Replication	2	417.70	2133.33	1875.00	1093.40	1250.40
Factor A	2	895.10**	755.60**	1790.14**	937.84**	1018.52**
Factor B	3	81.89**	79.11*	141.91*	93.97*	55.03*
A × B	6	1.65*	2.64*	5.82*	6.91*	1.02*
Error	22	11.21	24.24	34.09	40.06	23.59

* significant at 5% level of significance
** significant at 1% level of significance

Appendix V. Mean square values of number of leaves plant^{-1} at different days after sowing of mustard growing during experimentation

Sources of variation	Degrees of freedom	Mean square of number of leaves plant^{-1} at				
		30 DAS	45 DAS	60 DAS	75 DAS	Harvest
Replication	2	208.58	414.02	346.94	305.02	192.00
Factor A	2	35.02**	88.81**	126.81**	232.14**	415.50**
Factor B	3	2.82*	9.47*	7.10*	28.94**	31.34**
A × B	6	0.04*	0.44*	0.76*	4.63*	0.61*
Error	22	0.95	3.12	2.66	2.84	2.18

* significant at 5% level of significance
** significant at 1% level of significance

Appendix VI. Mean square values of number of branches plant^{-1} at different days after sowing of mustard growing during experimentation

Sources of variation	Degrees of freedom	Mean square of number of branches plant^{-1} at				
		30 DAS	45 DAS	60 DAS	75 DAS	Harvest
Replication	2	1.45	8.00	6.35	4.61	5.27
Factor A	2	8.56**	5.53**	8.14**	7.93**	7.26**
Factor B	3	0.84**	0.52**	0.45*	0.52**	0.53**
A × B	6	0.05*	0.02*	0.02*	0.01*	0.01*
Error	22	0.07	0.10	0.12	0.08	0.05

* significant at 5% level of significance
** significant at 1% level of significance

Appendix VII. Mean square values of dry matter plant^{-1} at different days after sowing of mustard growing during experimentation

Sources of variation	Degrees of freedom	Mean square of dry matter plant^{-1} at				
		30 DAS	45 DAS	60 DAS	75 DAS	Harvest
Replication	2	7.33	73.75	96.50	199.22	228.73
Factor A	2	2.98**	15.55**	15.47**	74.19**	72.60**
Factor B	3	0.31**	1.54**	0.98*	6.52**	6.34*
A × B	6	0.01*	0.02*	0.07*	0.16*	0.23*
Error	22	0.04	0.23	0.37	1.35	2.22

* significant at 5% level of significance
** significant at 1% level of significance

Appendix VIII. Mean square values of number of siliquae plant^{-1}, length of siliqua, number of seeds siliqua^{-1} and weight of 1000 seeds of mustard growing during experimentation

Sources of variation	Degrees of freedom	Mean square of			
		Number of siliquae plant^{-1}	Length of siliqua	Number of seeds siliqua^{-1}	Weight of 1000-seed
Replication	2	915.78	1.77	24.85	2.35
Factor A	2	621.76**	1.21**	9.23**	0.63**
Factor B	3	52.15*	0.08*	0.78*	0.05*
A × B	6	1.94*	0.01*	0.01*	0.001*
Error	22	27.96	0.05	0.23	0.03

* significant at 5% level of significance
** significant at 1% level of significance

Appendix IX. Mean square values of seed yield, stover yield, biological yield and harvest index of mustard growing under the experiment

Sources of variation	Degrees of freedom	Mean square of			
		Seed yield	Stover yield	Biological yield	Harvest index
Replication	2	0.5266	4.1067	12.2816	246.86
Factor A	2	0.6984**	5.7188**	10.4127**	30.43**
Factor B	3	0.0538*	0.4466**	0.8103**	2.71*
A × B	6	0.0003*	0.0095*	0.0099*	0.08*
Error	22	0.0239	0.0919	0.1815	0.89

* significant at 5% level of significance
** significant at 1% level of significance