YIELD PERFORMANCE OF RAPESEED FOLLOWING THE APPLICATION OF GA_3

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JUNE, 2017

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BY

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REGISTRATION NO. 11-04357

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

MASTER OF SCIENCE

IN

AGRONOMY

SEMESTER: JANUARY- JUNE, 2017

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CERTIFICATE

*This is to certify that the thesis entitled "**YIELD PERFORMANCE OF RAPESEED FOLLOWING THE APPLICATION OF GA_3**" 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 IN AGRONOMY**, embodies the result of a piece of bona fide research work carried out by **MUBASSHIR AHMED**, Registration No. **11-04357** under my supervision and guidance. No part of this thesis has been submitted for any other degree or diploma.*

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

Dated:

Dhaka, Bangladesh

Professor Dr. Md. Jafar Ullah

Supervisor

DEDICATED TO MY BELOVED PARENTS

ACKNOWLEDGEMENTS

All praises goes to Almighty Allah, the Supreme Ruler of the universe who enabled the Author to complete the present piece of work.

The Author would like to express his heartiest gratitude, sincere appreciation and immense indebtedness to his supervisor ***Professor Dr. Md. Jafar Ullah,*** *Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh, for his scholastic guidance, careful planning, valuable suggestions, continuous encouragements and all kinds of support and help throughout the period of research work and preparation of this manuscript.*

Heartiest gratitude is due to the respectable ***Professor Dr. Parimal Kanti Biswas,*** *Co-supervisor, Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh, for his valuable suggestions, kind co-operation and dynamic guidance throughout the study and research works.*

The Author expresses his sincere respect to ***Professor Dr. Md. Shahidul Islam,*** *Chairman, Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh for his valuable advice, encouragement, proper assistance and support during the period of research works.*

*The Author wishes to record deep appreciation to his other course teachers-****Prof. Dr. Fazlul Karim, Prof. A. K. M. Ruhul Amin, Prof. Dr. H. M. M. Tariq Hossain, Prof. Dr. Tuhin Suvro Roy, Prof. Dr. Abdullahil Baque and Prof. Dr. Mirza Hasanuzzaman,*** *Department of Agronomy for their co-operations and constant encouragement.*

*Heartiest thanks and gratitude are due to the officials of Sher-e-Bangla Agricultural University Research System (****SAURES****), especially* ***Dr. Md. Akkas Ali,*** *Senior Scientific Officer of Sher-e-Bangla Agricultural University for his support to conduct the research.*

*The author acknowledges Bangladesh Agricultural Research Institute (****BARI****) for providing his planting material (BARI Sarisha-14 seed) to conduct the study.*

The author is especially grateful to ***Prof. Noor Md. Rahmatullah,*** *Department of Agricultural Statistics, Sher-e-Bangla Agricultural University, Dhaka, for his advice and sincere co-operation in the completion of the study.*

The Author also wishes to acknowledge his indebtedness to the Farm Division of SAU, especially two laborers ***Md. Jahidul Islam and Md. Rejaul Karim*** *and other staff of the Department of Agronomy for their co-operation in the implementation of research works.*

Author deeply owes his whole hearted thanks to all the relatives, friends, well wishers specially ***Jannatul Ferdous Tanni and Pallab Kumar Bagchi*** *for their constant support and criticism to improve the manuscript.*

The Author is also thankful to ***Md. Arif Hossain, Md. Minhaj uddin Sarkar, Md. Nozibullah Akondo*** *for their constant encouragement.*

At last but not the least, the Author feels indebtedness to his beloved parents whose sacrifice, inspiration, encouragement and continuous blessing, paved the way to his higher education. The Author is also grateful to his brothers and sisters and other members of the family for their forbearance, inspirations, sacrifices and blessings.

YIELD PERFORMANCE OF RAPESEED FOLLOWING THE APPLICATION OF GA_3

ABSTRACT

The experiment was conducted at the experimental field of Sher-e-Bangla Agricultural University, Dhaka during the rabi season from November 2016 to February 2017 to investigate the yield performance of mustard following the application of GA_3. The treatment consisted of two factors, application time of GA_3 *viz*. S_1 = vegetative stage and S_2 = flowering stage; and six different levels of GA_3 *viz*. G_0 = 0 ppm, G_{20}= 20 ppm, G_{40} =40 ppm, G_{60} =60 ppm, G_{80} =80 ppm, and G_{100} =100 ppm. The experiment was laid out in Randomized Complete Block Design (factorial) with three replications. Results showed a significant variation among the treatments in respect of most of the parameters studied. The maximum length of silique (over 5 cm), number siliquae per plant (over 55), number of seeds per siliquae (over 31) and 1000 seed weight (over 3 g) were shown by 60-80 ppm GA_3 application of GA_3. Accordingly, the maximum yield of seeds per hectare (0.69-0.90 t) was obtained from 60-80 ppm application of GA_3 at both the stages. The lowest seed yield per hectare (0.44 tones) was obtained from the fields wherein no GA_3 was applied.

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LIST OF ABBREVIATION AND ACRONYMS

AEZ	=	Agro-Ecological Zone
B	=	Boron
BARI	=	Bangladesh Agricultural Research Institute
BBS	=	Bangladesh Bureau of Statistics
cm	=	Centimeter
CV%	=	Percentage of Coefficient of Variance
^{0}C	=	Degree Celsius
DAS	=	Days after sowing
et al.	=	And others
FAO	=	Food and Agricultural Organization
g	=	gram (s)
GA_3	=	Gibberellic acid
ha^{-1}	=	Per hectare
kg	=	Kilogram
LSD	=	Least Significant Difference
Max	=	Maximum
Min	=	Minimum
MoP	=	Muirate of Potash
N	=	Nitrogen
no.	=	Number
NPK	=	Nitrogen, Phosphorus and Potassium
NS	=	Not significant
RCBD	=	Randomized Complete Block Design
SAU	=	Sher-e-Bangla Agricultural University
SRDI	=	Soil Resources and Development Institute
tha^{-1}	=	Ton per hectre
TSP	=	Triple Super Phosphate
wt	=	Weight
Zn	=	Zinc
%	=	Percent

CHAPTER I

INTRODUCTION

Mustard (*Brassica campestris* L.) is a bright yellow flowering member of the family Brassicaceae, originated from Asia minor and is known as an oil yielding crop in Canada, Australia, China, India and other countries in the world including Bangladesh. It has been grown by humans for around thousands of years and is of the few edible oilseeds capable of being grown in cool temperate climates. Cabbage, broccoli, Brussels sprouts, cauliflower etc. is also close to both mustard in view of morphology and physiology. It well known that mustard is a popular crop in crop rotations, since it enhances yields of wheat and barley, and breaks disease cycles in cereal grains.

In Bangladesh, 2.75% oil seed was cultivated of total area of crop production during the year 201-2015 and mustard was cultivated in 803 acres of land and production was 447 $kgac^{-1}$(BBS, 2015).

Again the production of mustard seed was 1.13 tha^{-1} in 2010, 0 .45 tha^{-1} in 2015 and 1.51 tha^{-1} in 2016 in Bangladesh (FAO, 2016).

Mustard oil is one of the most important edible oils contain 40-45% oil from them 33% oil may be extracted using ghani and 20-25% protein and plays a vital role in human diet (Mondal and Wahhab, 2001). Its nutritive value is excellent due to the abundant unsaturated fatty acids. It is not only rich source of energy (about 9 kcal/g) but also rich in soluble vitamins A, D, E and K. Mustards or mustard seeds are an excellent source of essential B-complex vitamins such as folates, niacin, thiamin, riboflavin, pyridoxine (vitaminB-6), pantothenic acid. The B-complex groups of vitamins help in enzyme synthesis, nervous system function and regulating body metabolism. These vitamins are essential in the sense that body requires them from external sources to replenish. The National Nutrition Council (NNC) of Bangladesh reported that the recommended dietary allowance (RDA) per capita per day should be 6 g of oil for a diet with 2700 K cal. On RDA basis, the edible oil need for 150 millions peoples are 0.39 million tons of oil equivalent to 0.82 million tons of oilseed (NNC, 1984). Mustard contains more phenolic compounds, sinapic acid and its derivatives, most notable sinapine compared to any other oilseed plant (Nowak *et al*., 1992) which has potential value in the regulation of low density lipoprotein (LDL), cholesterol oxidation as a biomarker for cardiovascular diseases (DiSilvestro, 2001; Halliwell, 1995) and suggesting that phenolics are functional food element that intended for health benefit. The aroma and pungent flavor of mustard comes from secondary metabolite, glucosinolate which is hydrolyzed by myrosinase to produce isothiocyanate that can inhibit weed seed germination during crop production. It has been also reported that 100 g of mustards provide 4.733 mg of niacin, vitamin B_3 which is a part of nicotinamide co-enzymes; helps regulate blood cholesterol and triglyceride levels in human body. Oil cake is a nutritious food item for cattle and fish and also used as a good organic fertilizer. Dry mustard plants may be used as fuel. This information is suggesting that mustard has diversified functions in a both agriculture and human physiology.

It is well known that mustard is one the major oilseed crop in Bangladesh and covering about 70% of the total production. The area and production of mustard in this country was about 0.481 million hectares and 0.536 million tons, respectively with an average yield of 1.11 tha^{-1} during 2010-2011 (AIS, 2012). The present domestic edible oilseed production is 267 thousand tons, which meets only one third of national oil demand. So, Bangladesh had to import a large quantity of edible oil every year at the cost of huge amount of foreign exchange worth BDT 11000 million during 2005-2006 fiscal years (BBS, 2006).

The plant growth regulators (PGR) have a significant role in directing plant developments, enhancing seed yield and quality traits. It has long been ascertained that plant hormones including auxins, gibberellic acid, cytokinin, abscisic acid and ethylene are involved in controlling developmental events such as cell division, cell elongation and protein synthesis. PGRs have been implicated in efficient utilization of nutrients and translocation of photo-assimilates. Canola seedlings relative with water content and photosynthetic activity in seedling for maximum level of germination, which is an important factor (Faizanullah *et al.*, 2014).

The plant breeders play an important role in the breeding of canola cultivars (Rahman, 2013). Several factors either endogenous or environmental conditions contribute to sink strength, but the sink activity can mainly be enhanced gibberellins17. In comparison to the large number of studies on the foliar application of PGRs, much less effort has been applied to understanding, how this exogenous application of GA_3 may elicit change in the allocation pattern with the leaf age. Mobin *et al.* (2007) reported that foliar application of GA_3 enhance the flower number and create a balance between source and sink. The impact of GA_3 was most conspicuous and resulted in a higher growth, efficient translocation and utilization of nutrients. GA_3 increased partitioning of biomass to the leaves and stem. Gibberellic acid (GA_3) is a growth regulator that is needed in small quantities at low concentration to accelerate plant growth and development. GA_3 enhances growth activities of a plant, stimulates stem elongation, and increases the seed yield (Deotale *et al.*, 1998, Lee, 1990 and Maske *et al.*, 1998). Like other photoperiodic or low temperature requiring plants, exogenous application of GA_3 promotes flowering in certain brassica varieties Ashraf *et al*. (1989); Ashraf *et al*, (1987); Friend (1985) and Hermandez (1997). GA_3 is found to increase stem length and accelerate the bud development and flower per plant (Kabar, 1990 and Lee *et al.*, 1999). Overall plant growth regulators have a positive impact in enhancing qualitative characters in plants. Based on this background a study was initiated to yield performance of mustard following the application of GA_3.

In view of above points a field experiment containing the treatments of GA_3 was conducted with the following objectives:

1. To find out the effects of various concentrations of GA_3 on the growth and yield of rapeseed.
2. To find out the appropriate application time of GA_3 for obtaining higher seed yields.
3. To estimate the effective dose of GA_3 for receiving better growth and yield of rapeseed.

CHAPTER II

REVIEW OF LITERATURE

Mustard is one of the most popular oil crop of the world as well as Bangladesh. The crop received much attention to the researcher of different countries including Bangladesh. But a few investigations have been taken on the effect of plant growth regulators on mustard production. There is a little or no combined research work to the yield performance of mustard following the application of GA_3. The literature and research results related to the present study are reviewed in this chapter.

2.1 Effect of GA_3 on the growth and yield of mustard

Saini *et al*. (2017) conducted an experiment during rabi season, 2016-2017 at the Main Experiment Station (MES) Farm of Narendra Deva University of Agriculture and Technology, Kumarganj, Faizabad-224 229 (U.P.) in randomized block design with eight treatments, three replications and variety Narendra rai (NDR-8501). Various concentrations of GA_3 (15ppm, 30ppm, 45ppm, 60ppm, 75ppm, 90ppm, 125ppm) were taken along with untreated control. Sprayed was done at 30 DAS. Yield contributing traits were taken as number of siliquae plant^{-1}, length of silique plant^{-1}, number of seeds silique^{-1}, seed yield plant^{-1}, yield quintal ha^{-1} after harvest. Foliar sprayed of different concentrations of GA_3 increased yield and quality characters of mustard crop. Yield and quality contributing traits were maximum recorded with foliar sprayed of GA_3 125ppm followed by foliar sprayed with GA_3 90 ppm over rest of the treatments including control, during the investigation.

Mazid and Naz (2017) carried out an experiment with an aim to enhance the performance of chickpea by the spray of a small quantity of phosphorus (P) and/or sulphur (S) with or without the soaking of GA treatment (10^{-6} M GA for 8h) and/ or the GA spray treatment (10^{-6} M GA at 60-70 DAS). P and S each at 2 kg/ha were sprayed in two equal splits i.e. half at 60 and the remaining half at the 70 DAS alone or in combination with the GA treatment. Prior to sowing, total seeds of chickpea were grouped into two; one group of seeds was soaked in 0M GA (control) and the other group were soaked in 10^{-6} M GA aqueous solution, each for 8 hours. There were total sixteen treatments with ten combinations of P and/or S with GA are possible viz., FPS, SGA + FP, SGA + FS, SGA + FPS, FGAP, FGAS, FGAPS, SGA + FGAP, SGA + FGAS and SGA+FGAPS. The combined application of P and S with GA showed better responses and further improvement in carbonic anhydrase (CA) activity, stomatal conductance (*gs*), net photosynthetic rate (*PN*), nitrate reductase activity (NR), and leghemoglobin content (Lb) at two sampling stages (90 and 100 DAS). This treatment also increased pod number per plant, seed yield per plant and harvest index (HI), seed protein and carbohydrate content at harvest. This combination augmented the protein content (21%), carbohydrate content (11%), seed yield (86%) and HI (91.78%).

Siddiqui *et al*. (2016) conducted a research to evaluate the effect of foliar application of nitrogen, phosphorus; gibberellic acid and indole-3-acetic acid with two canola mutants R00-125/14, W97-75/16 with their respective parents Rainbow and Westar were used in this experiment. The application of N, P fertilizers increased 67% seed yield in brassica. The early days to maturity was recorded under treatment of and maximum number of branches plant^{-1}, siliqua plant^{-1}, 1000 seed weight and seed yield kg ha^{-1} was recorded under the treatment of 90N-45P-1 0GA_3-10 IAA while minimum number of branches plant-1, sliqua plant^{-1} and 1000 seed weight were recorded under the treatment of 90N-45P-15GA_3-15 IAA. It is recommended that brassica should be sown under the treatment of 90N-45P-10GA_3-10 IAA to achieve best performance to produce more seed yield and quality trait in brassica.

Sardoei (2014) conducted an experiment to this study was performed in three factorial test based on completely randomized design and 4 repeats with 9 treatments. The aim of this work is to study the effect of foliar application with gibberellic acid (GA_3) at 0, 100 and 200 mg.L^{-1}and and benzyladenine (BA) at

0, 100 and 200 mg.L-1 levels. The results showed, The highest rate of Plant Height with 76.5, 52.5 and 36.25 cm belonged to 200 mg l^{-1} GA_3+200 mg l^{-1} BA, respectively between three indoor plants *Ficus benjamina*, *Schefflera arboricola* and *Dizigotheeca elegantissima*. The lowest rate of Plant Height with 57.5, 31 and 27 cm belonged to control treatment, respectively in three indoor plants *Ficus benjamina*, *Schefflera arboricola* and *Dizigotheeca elegantissima.* According to results, the highest rate of Plant Height in three indoor plants *Ficus benjamina*, *Schefflera arboricola* and *Dizigotheeca elegantissima* was related to *Ficus benjamina* plant that had higher Plant Height compared to two other plants. The highest rate of Number of leaves/plant with 133.25, 22.75 and 41.5 belonged to 200 mg l^{-1} GA_3+100 mg l^{-1} BA and 200 mg l^{-1} GA_3+200 mg l^{-1} BA for plants *Ficus benjamina, Schefflera arboricola* and *Dizigotheeca elegantissima*. The highest value of *Ficus benjamina, Schefflera arboricola* and *Dizigotheeca elegantissima* of sum pigments in level of 100 mg l^{-1} GA_3+200 mg l^{-1} BA and 200 mg l^{-1} GA_3+200 mg l^{-1} BA with average of 19.59, 21.65 and 21.88 mg.ml^{-1}.

Growth regulators are organic compounds other than nutrients; small amounts of which are capable of modifying growth (Leopold, 1963). Among the growth regulators, auxin causes enlargement of plant cell and gibberellins stimulates cell division, cell enlargement or both (Nickell, 1982). Gibberellic acid (GA_3) and Naphthalene acetic acid (NAA) exhibited beneficial effect in several crops (Thapa *et al*., 2013). Due to diversified use of productive land, it is necessary to increase the food production and growth regulators may a contributor in achieving the desired goal.

Roy and Nasiruddin (2011) conducted the research work to study the effect of GA_3 on growth and yield of cabbage. Single factor experiment consisted of four concentrations of GA_3, viz. 0, 25, 50 and 75 ppm. Significantly the minimum number of days to head formation (43.54 days) and maturity (69.95 days) was recorded with 50 ppm GA_3 and 50 ppm GA_3 gave the highest diameter (23.81 cm) of cabbage head while the lowest diameter (17.89 cm) of cabbage head was found in control condition (0 ppm GA_3) treatment. The application of different concentrations of GA_3 as influenced independently on the growth and yield of cabbage. Significantly the highest yield (104.66 t/ha) was found from 50 ppm GA_3.

Studies on influence of GA, NAA and CCC at three different concentrations on different growth parameters of cabbage (cv. PRIDE OF INDIA) were studied by Lendve *et al*. (2010) and found that application of GA_3 50 ppm was found significantly superior over most of the treatments in terms of number of the leaves, plant spread, and circumference of stem, left area, fresh and dry weight of the plant, shape index of head, length of root, fresh and dry weight of root. Except treatment GA 75 ppm, which gave better results for days required for head initiation and head maturity.

An experiment was conducted by Yu *et al*. (2010) with ‘8398’ cabbage (*Brassica oleracea var. captata* L.) plants with 7 true leaves and ‘Jingfeng No. 1’ cabbage plants with 9 true leaves were vernalized in incubator. Then, '8398' cabbage plants vernalized for 18 days and ‘Jingfeng No. 1’ cabbage plants vernalized for 21 days were treated by high temperature of 37^0C for 12 hours to explore the changes of endogenous hormone during devernalization in cabbage. The results showed that: GA_3 content had less changes, IAA content rose and ABA content decreased during devernalization. Compared with CK (vernalization period), GA_3 and ABA content decreased significantly, whereas IAA content rose significantly when devernalization ended. Lower GA_3 and ABA content, and higher IAA content can benefit the accomplishment of devernalization.

A study was conducted by Roy *et al*. (2010) at the Horticulture Farm of Bangladesh Agricultural University, Mymensingh to study the effect of starter solution and GA_3 on growth and yield of cabbage. The two factor experiment consisted of four levels of starter solution, viz. 0, 1.0, 1.5 and 2.0% of urea, and four concentrations of GA_3, viz. 0, 25, 50 and 75ppm. The application of starter solution and different concentrations of GA_3 influenced independently and also in combination on the growth and yield of cabbage. The highest yield (104.93 t/ha) was obtained from 1.5% starter solution which was significantly different from other solutions, and the lowest yield (66.86 t/ha) was recorded from the control. Significantly the highest yield (104.66 t/ha) was found from the treatment of 50 ppm GA_3, while the lowest yield (66.56 t/ha) was recorded from control. In case of combined effect, the highest yield of cabbage (121.33 t/ha) was obtained from the treatment combination of 1.5% starter solution + 50 ppm GA_3 followed by 1.5% starter solution + 75 ppm GA_3 (115.22 t/ha), while the lowest yield (57.11 t/ha) was produced by the control treatment. Economic analysis revealed that 1.5% starter solution + 50 ppm GA_3 treatment was the best treatment combination in respect of net return (Tk. 173775/ha) with a benefit cost ratio of 3.52.

Sarmah and Sarma (2009) experiment was designed to study the interaction between GA_3 and CCC (Chlorocholine chloride) on growth and yield of *Brassica campestris* L. (cv-M 27). CCC at different concentrations (50,100,250 and 500 µg/ml) was applied as foliar spray on the plant treated with GA_3 at varying concentrations (100, 250, 500 and 1000 µg/ml). GA_3 was applied as pre-sowing seed soaking treatment. The combined effect of GA_3 and CCC registered better performances in all the parameters than either of the two compounds acted alone. GA_3 (500 µg/ml) in combination with CCC (500 µg/ml) recorded better growth and yield.

Akter *et al*. (2007) conducted an experiment in pot house at the Bangladesh Institute of Nuclear Agriculture (BINA), Mymensingh during November 2003 to February 2004 to evaluate the effects of Gibberellic Acid (GA_3) on growth, and yield of mustard var. Binasarisha-3. Four concentrations viz., 0, 25, 50 and 75 ppm of GA_3 were sprayed on canopy at 30 days after sowing. The results showed that different levels of GA_3 significantly influenced the plant height, number of fertile siliqua/plant, number of seeds/siliqua, number of flowers/plant, setting of siliqua/plant (%), and harvest index. Results revealed that GA_3 at 50 ppm significantly increased plant height, number of fertile siliqua/plant, number of flowers/plant, setting of siliqua/plant (%), dry matter yield, number of seeds/siliqaua, and harvest index, while the number of flowers/plant was significantly increased with the application of 75 ppm GA_3. The highest seed yield/plant was recorded from the application of 50 ppm GA_3 at optimum harvest date. The seed yield/plant was positively correlated with plant height, number of seeds/siliqua, number of fertile siliqua/plant and % of setting siliqua/plant.

The effects of gibberellic acid (GA_3) on growth, physiology and yield of salt-stressed mustard (*Brassica juncea* L. Czern & Coss) cv. Varuna plants were studied by Shah (2007). The stress imposed by 25 or 50 mM NaCl reduced substantially leaf area, dry mass, leaf chlorophyll content, stomatal conductance and net photosynthetic rate 50 days after emergence. At harvest, although other yield components were generally reduced, total seed protein content showed a significant increase. Furthermore, the response was more pronounced at the higher concentration NaCl (50 mM) applied. On the contrary, the application of 10-5 M GA3 appeared to mitigate the adverse effects of salinity stress on the overall performance and productivity of mustard.

Khan *et al*. (2005) carried out an experiment to study the effects of 10 μM GA_3 spray on specific leaf area, plant dry mass, leaf carbon dioxide exchange rate (CER), plant growth rate (PGR), relative growth rate (RGR), net assimilation rate (NAR) and S-use efficiency (SUE) of mustard treated with 0, 100 or 200 mg S kg-1 soil levels. Plants treated with 100 mg S kg^{-1} soil and receiving GA_3 treatment showed increased specific leaf area and dry mass accumulation compared to the control. At 0 mg S kg^{-1} soil, N and S concentrations were reduced. They increased with increasing S supply. GA_3 application significantly increased N and S concentrations further. A two-fold increase in SUE in GA_3-treated plants at 100 mg S kg^{-1} soil was noted in comparison to the control. SUE was not increased under excess S conditions beyond 100 mg S kg^{-}

^{1} soil. The increase in SUE was through increase in the growth, CER and use efficiency of N by the crop due to GA_3 application.

Mustard is cultivated throughout the world for oil in its seeds. It requires high nitrogen input for improved productivity but the nitrogen applied to the soil is not fully utilized by the crops due to various constraints. The objective of the reported research was to determine if foliar- applied gibberellic acid (GA_3) could enhance crop growth and increase nitrogen-use efficiency. A field experiment was conducted during 1997–98in which GA_3 (10^{-5} M) was applied to foliage at 40d after sowing (pre-flowering) to mustard grown with 0, 40(sub-optimal), 80 (optimal) and 120 (supra-optimal) kgN ha^{-1}. Foliar spray of GA_3 was effective only when plants received sufficient N (80 kgN ha^{-1}). GA_3 sprays significantly enhanced plant dry mass, leaf area, carbon dioxide exchange rate, plant growth rate, crop growth rate and relative growth rate. GA_3 -treated plants showed enhanced nitrogen-use efficiency through redistribution of N to seeds (Khan *et al.* 2002a).

In a field trial, the effect of foliar spray of 0 (de-ionized water), 10^{-6},$10^{-5}$and 10^{-4}Mofindole acetic acid (IAA) gibberellic acid (GA_3) and kinetin (KN) at 40 days after sowing (pre-flowering stage) on growth and yield characteristics of mustard *(Brassica juncea* L.) was examined by Khan *et al*. (2002b). GA_3 application at 10^{-5}M concentration was found to be more effective than IAA and KN in promoting shoot length, leaf number, leaf area and plant dry weight at 60 and 80 days after sowing (DAS), net assimilation rate (NAR) at 60-80day interval and yield at harvest. Application of 10^{-5}M GA_3 increased seed yield, oil yield and seed yield merit by 33.3, 31.2 and 50.3% respectively compared to water sprayed control.

Gedam *et al.* (1998) conducted an experiment on bitter gourd plants treated with 15 ppm, 25 ppm or 35 ppm GA_3 50 ppm or 150 ppm NAA, 50 ppm, 100 ppm or 150 ppm ethephon, 100 ppm, 200 ppm or 300 ppm maleic hydrazide, 2 ppm, 4 ppm or 6 ppm boron or with water (control). GA_3 at 35 ppm produced the earliest male flower and NAA at 50 ppm produced the earliest female flower. Fruit maturity was earliest in plants treated with 50 ppm NAA or 4 ppm boron.

Arora *et al.* (1994) reported that flower application of plant growth regulator had significant effect on growth, flowering and yield of long melon. The experiment was conducted during the summer seasons of 1991 and 1992 to study the effect of ethephon, GA_3 maleic hydrazide (MH), and NAA on melon. Growth regulators were applied at the 2-and 4-leaf stages. GA_3 at 25 mg/litre resulted in the longest vine length (3.97m), whereas vine length in controls (water sprayed) was 2.82 m. Ethephon at 250 mg/litre resulted in the highest number of braches/plant (10.8), shortest internode length (8 cm), lowest male : female flower ratio (3.1), fewest days to first female flower (68 days), highest number of female flower/plant (27) and fruits /plant (17.7) and highest plant yield (1.36 kg/plantt). Ethephon at 250 mg/litre also gave the highest fruit yield/ha (29.76 t), while GA_3 at 25 mg/litre gave the lowest (11.08 t).

Light treatment alone is capable of inducing 100% germination of stinkweed seeds (*Thlaspi arvense* L.), but not of wild mustard seeds (*Sinapis arvensis* L.) (*Brassica kaber* (DC.) Wheeler var. pinnatifida (Stokes) Wheeler)). On the contrary, gibberellic acid (GA_3) alone is able to induce complete germination in wild mustard, but effected only a slight promotion of germination of stinkweed seeds. Germination of both species increased with increasing time of immersion in 6% sodium hypochlorite (NaOCl). The NaOCI treatment mimics the effect of acid scarification or dissection in making seeds more porous, removing the barriers to gas exchange and GA, penetration, and increasing sensitivity to light treatment. However, prolonged NaOCI treatment resulted in either poor germination or seed disintegration. Dormancy of a genetically distinct early-flowering strain of stinkweed can be broken only by the combination of NaOCl, GA, and light, indicating a high degree of variability in germination responses to various sets of conditions (Hsiao, 1980).

In India, Kaushik *et al.* (1974) carried out an experiment with the application of GA_3 at 1, 10 or 100 mg/l on tomato plants at 2-leaf stage and then at weekly interval until 5 leaf stage. They reported that GA_3 increased the number and weight of fruits per plant at higher concentration.

Pandey *et al.* (1976) stated that the effects were compared of seed soaking for 24 hrs in solutions of 2, 4-D at 1.5 ppm, MH and NAA, each at 200 ppm and GA_3 at 50 ppm and foliar spraying with 2, 4-D at 0.5-1.0 ppm, applied at the 2 true leaf and 4-5 true leaf stages. The number of pistillate flowers of *Lagenaria cylindrica (Lagenaria aegyptiaca)* was increased by seed treatment with MH and NAA at 200 ppm and by spraying with NAA at 100 and 150 ppm, MH at 100-200 ppm and GA_3 at 10 ppm; staminate flower numbers were decreased by MH at 200 ppm, NAA at 100 ppm and GA_3 at 10 ppm. The ratio of pistillate: staminate flower numbers was increased by all treatments except 2, 4-D and GA_3 at 25 and 50 ppm. Fruit set was enhanced by all treatments except GA_3 at 50 ppm and 2, 4-D. Yields were increased by seed treatment with NAA at 200 ppm and by spraying with NAA and MH at 150 and 200 ppm respectively.

Saleh and Abdul (1980) conducted an experiment with GA_3 (25 and 50 ppm), which were applied 3 times in June to early July. They reported that GA3 stimulated plant growth. It reduced the total number of flowers per plant, but increased the total yield compared to the control. GA_3 also improved fruit quality.

An experiment conducted by Chaurasiy *et al*. (2014) to study the response of cabbage cv. Pride of India to foliar application of PGRs namely GA_3 and NAA with different concentrations. The experiment was laid out in Randomized block design with three replications and seven treatments, the treatments comprised of three levels of each PGRs namely GA_3 (30, 60, 90 ppm) and NAA (40, 80, 120 ppm) along with control. Foliar spray of GA_3 and NAA was given at 30 and 45 DAT of cabbage. Looking to the results, it was noticed that GA_3 60 ppm significantly increased the plant height (33.26 cm), number of leaves (21.48), plant spread (55.59 cm), stem diameter (3.05 cm), plant weight (2.44 kg), head weight (1.73 kg), head diameter (18.88 cm) as well as head yield (51.26 t/ha) than the other treatments and control. Therefore it may be concluded that foliar application GA_3 60 ppm or NAA 80 ppm can be recommended to cabbage growers for obtaining better growth and yield of cabbage.

Majumdar (2013) set an experiment to find out response of gibberellic acid and potash nutrient on growth and yield of late planting cabbage. The experiment consisted of two factors: Factor A: Gibberellic acid (four levels) as- G_0: 0, G_1: 90, G_2: 120, G_3: 150 ppm GA_3 and Factor B: Potassium fertilizer (three levels) as- K_0: 0, K_1: 150 and K_2: 200 kg K_2O. In case of different growth regulators, the highest marketable yield (65.1 t/ha) were found from G_2, while the lowest marketable yield (40.4 t/ha) from G_0. For different levels of potassium fertilizer, the highest marketable yield (64.4 t/ha) were recorded from K_1, whereas the lowest marketable yield (44.6 t/ha) from K_0. Due to interaction effect, the highest marketable yield (75.6 t/ha) were recorded from G_2K_1, whereas the lowest marketable yield (38.4 t/ha) from G_0K_0. The highest benefit cost ratio (2.31) was noted from the combination of G_2K_1 and the lowest (1.24) from G_0K_0. From growth, yield and also economic point of view, it is apparent that the combination of G_2K_1 was suitable for late planting cabbage cultivation.

Lina (2015) conducted an experiment to find out the effect of planting time and gibberellic acid on the growth and yield of cabbage. The experiment consisted of two factors: Factor A: Planting time (three levels) as - T_1= 05 Nov; T_2= 20 Nov and T_3= 05 Dec and Factor B: Gibberellic acid (four levels) as- G_0= 0 ppm (control); G_1= 75 ppm; G_2= 95 ppm and G_3= 115 ppm GA_3 respectively. The two factors experiment was laid out in Randomized Complete Block Design with three replications. The variety of cabbage was Atlas-70. Due to different planting time, the maximum thickness of head (13.3 cm) and the highest marketable yield (49.1 t/ha) was obtained from T_2 and the minimum thickness of head (12.5 cm) and the lowest marketable yield (45.9 t/ha) was obtained from T_3. For GA_3, the maximum thickness of head (14.2 cm) and the highest marketable yield (54.7 t/ha) was found from G_2 and the minimum thickness of head (11.4 cm) and the lowest marketable yield (41.2 t/ha) was found from G_0. For combined effect, the maximum thickness of head (14.5 cm) and the highest marketable yield (59.4 t/ha) was found from T_2G_2 and the minimum thickness of head (10.8 cm) and the lowest marketable yield (37.1 t/ha) was found from T_3G_0. Economic analysis revealed that T_2G_2 gave the maximum benefit cost ratio (2.57). So, 20 Nov planting along with 95 ppm GA_3 was the best for growth and yield of cabbage.

Chauhan and Tandel (2009) conducted an experiment in the Agronomy field of N.M. College of Agriculture, Navsari Agricultural University, Navsari during the Rabi season and they showed that spray of GA_3 and NAA significantly influenced the performance of growth, yield and quality characters of cabbage. The best plant growth regulator treatments for growth, yield and quality characters of cabbage was GA_3 100 mg l^{-1} foliar spray at 30 and 45 days after transplanting (DAT) followed by NAA 100 mg l^{-1} foliar spray at 30 and 45 DAT.

The effect of GA_3 and/or NAA (both at 25, 50, 75 or 100 ppm) on the yield and yield parameters of cabbage (cv. Pride of India) was investigated by Dhengle and Bhosale (2008) in the field at Department of Horticulture, college of Agriculture, Parbhani. The highest yield was obtained with GA_3 at 50 ppm followed by NAA at 50 ppm (332.01 and 331.06 q/ha, respectively) Combinations and higher concentrations of plant growth regulators proved less effective.

Dhengle and Bhosale (2007 a) carried out a work during *rabi* 2001-2002 on cabbage cultivar Pride of India at Department of Horticulture, College of Agriculture, Marathwada Agricultural University, Parbhani. Four weeks old seedlings were transplanted and NAA or GA (both at 25, 50, 75 or 100 ppm) along with their combinations and 1 per cent urea was applied at 15 and 30 days after transplanting. 50 ppm GA produced significantly more compact heads and GA 100 + NAA 100 ppm resulted in the highest staying capacity as well as keeping quality. Highest ascorbic acid content resulted from the treatment with 75 ppm NAA.

Studies on influence of GA, NAA, urea sole and in combination on different growth parameters on cabbage (cv. pride of India) were studied by Dhenglel and Bhosale (2007b) at Dept. of Horticulture, Marathwada Agricultural University, Parbhani. Among the various growth regulators and their different concentrations studied, application of GA 50ppm was found significantly superior over most of the treatments fallowed by NAA 50 ppm in terms of plant height, plant spread, circumference of stem, leaf area, fresh and dry weight of plant, root spread, fresh and dry wt. Except in case of average plant spread which was followed by NAA 100 ppm.

Yadav *et al*. (2000) was conducted an experiment in Rajasthan, India, during the rabi season of 1996-97 to investigate the effects of NAA at 50, 100 and 150 ppm, gibberellic acid at 50, 100 and 150 ppm and succinic acid at 250, 500 and 750 ppm, applied at 2 spraying levels (1 or 2 sprays at 30 and 60 days after transplanting), on growth and yield of cabbage cv. Golden Acre. The maximum plant height (28.4 cm) and plant spread (0.187 m2) resulted from 2 sprays with gibberellic acid at 150 ppm. The highest number of open leaves (23.6) and yield (494.78 q/ha) was obtained in the treatment with 2 sprays of gibberellic acid at 100 ppm. Leaf area was highest in 2 sprays of 500 ppm succinic acid.

An experiment was conducted by Dharmender *et al*. (1996) to find out the effect of GA_3 or NAA (both at 25, 50 or 75 ppm) on the yield of cabbage (cv. Pride of India) in the field at Jobner, Rajstan, India. They recorded the highest yield following treatment with GA_3 at 50 ppm followed by NAA at 50 ppm (557.54 and 528.66 q/ha, respectively). They also reported that combination and higher concentrations of plant growth regulators proved less effective and were uneconomic in comparison to control.

The effective concentration of NAA and GA_3 was determined by Islam *et al*. (1993), for promoting growth yield and ascorbic acid content of cabbage. They used 12.5, 25, 50 and 100 ppm of both the NAA and GA_3. They found that ascorbic acid content increased up to 50 ppm when sprayed twice with both the growth regulator, while its content was declined afterwards. They also added that two sprays with 50 ppm GA_3 was suitable both for higher yield and ascorbic acid content of cabbage.

An experiment was conducted by Patil *et al*. (1987) in a field trial with the cultivar Pride applied GA_3 and NAA each at 25, 50, 75 and 100 ppm one month after transplanting. The maximum plant height and head diameter and head weight were noticed with GA_3 at 50 ppm. Significant increase in number of outer and inner leaves was noticed with both GA_3. Head formation and head maturity was 13 and 12 days earlier with 50 ppm GA_3. Maximum number of leaves and maximum yield (63.83 t/ha) were obtained with 50 ppm GA_3.

An experiment was conducted by Islam (1985) at the Bangladesh Agricultural University Farm, Mymensingh with applying various growth regulators (CCC, GA_3, NAA and IBA) at 30 days after transplanting of 32 day old seedlings and found that GA_3 increased the plant height, number of loose leaves per plant, size of leaf and finally the yield.

Mishra and singh (2006) concluded from the study that Krishna and then Kranti hybrid varieties of cabbage performed the best in comparison to Golden Acre and Pride of India. The mixture of GA_3 + NAA growth substances played an important role in increasing the growth, yield net income and quality of cabbage varieties. Krishna treated with 15 ppm GA_3 + NAA concentration brought about the highest production (688.50 q/ha).

Saravaiya *et al.* (2010) carried out an experiment on influence of foliar application of GA_3 and NAA on growth, yield and quality of cabbage (*Brassica oleracea* var. capitata cv. Golden Acre) to assess the response of cabbage to foliar application of PGRs namely, GA_3 and NAA with different concentrations. Total eight treatments comprised of three concentrations of each PGRs namely, GA_3 (5, 10and 15 mg/l) as well as NAA (25, 50 and 75 mg/l) along with distilled water spray and absolute control. The maximum head yield of 29.39 t/ha was noticed in the treatment of foliar application of GA_3 5 mg/l.

Thapa *et al.* (2013) carried out an experiment to determine the effect of GA3, NAA and their combinations (applied as seedling dipping) on growth, yield and quality improvement of sprouting broccoli. GA_3 30 mg/l+ NAA 30 mg/l treatment (T10) showed best result with respect to head weight, head diameter, plant height, plant spread, projected yield, number of sprouts/plant and sprout weight, whereas maximum ascorbic content has been estimated with T9– GA_3 20 mg/l+ NAA 20 mg/l.

Chaurasiy *et al.* (2014) conducted an experiment to study the response of cabbage cv. Pride of India to foliar application of PGRs namely GA_3 and NAA with different concentrations. The treatments comprised of three levels of each PGRs namely GA_3 (30, 60, 90 ppm) and NAA (40, 80, 120 ppm) along with control. Foliar spray of GA_3 and NAA was given at 30 and 45 DAT of cabbage. Looking to the results, it may be concluded that foliar application GA_3 60 ppm or NAA 80 ppm can be recommended to cabbage growers for obtaining better growth and yield of cabbage.

Singh (2015) conducted an experiment at Gwalior during Rabi season of 2012-13 to study the effect of mixture of GA and NAA with four concentrations i.e. 0, 10, 15 and 20 ppm on growth, yield attributes and yield on cabbage varieties, namely Krishna (Hybrid), Kranti (Hybrid), Golden acre and Pride of India. Results revealed that 15 ppm GA_3 + NAA was found most effective growth regulator in increasing the growth, yield attributes and head yield (688.50 q/ha).

CHAPTER III

MATERIALS AND METHODS

The experiment was undertaken during rabi season, November 2016 to February 2017 to yield performance of mustard following the application of GA_3.

3.1 Experimental site

The experiment was carried out at Sher-e-Bangla Agricultural University Farm, Dhaka-1207, Bangladesh. It is located at $90^0 22'$ E longitude and 23°41′ N latitude at an altitude of 8.6 meters above the sea level. The land belongs to Agro-ecological zone of Modhupur Tract, AEZ-28.

3.2 Climatic condition

The experimental area is under the sub-tropical climate that is characterized by less rainfall associated with moderately low temperature during rabi season, (October-March) and high temperature, high humidity and heavy rainfall with occasional gusty winds during kharif season (April-September).

3.3 Soil condition

The soil of experimental area situated to the Modhupur Tract (UNDP, 1988) under the AEZ no. 28 and Tejgoan soil series (FAO, 1988). The soil was sandy loam in texture with pH 5.47 - 5.63. The physical and chemical characteristics of the soil have been presented in Appendix I.

3.4 Materials

3.4.1 Seed

A moderately salinity tolerant and high yielding variety of mustard, BARI Sarisha-14 developed by the Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur and was used as an experimental planting material. The seed was collected from the Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur. Before sowing of the seed in the experimental plot germination test was done in the laboratory and results of percentage of germination was over 95%.

3.4.2 Fertilizers

The recommended doses of Triple super phosphate (TSP) as a source of phosphorus (P), Muriate of Potash (MoP) as a source of Potash (K), Gypsum as a source of Sulpher (S) and Boric acid as a source of Boron (B) were added to the soil of experimental field along with different levels of Nitrogen (N) in the form of Urea and Zinc (Zn) in the form of Zinc Oxide (ZnO).

3.5 Methods

3.5.1 Treatments

Factor A: Two application time of GA_3

S_1 = GA_3 application at vegetative stage

S_2 = GA_3 application at flowering stage

Factor B: 6 level of GA_3

G_0 = 0 ppm

G_{20}= 20 ppm

G_{40} =40 ppm

G_{60} =60 ppm

G_{80} =80 ppm

G_{100} =100 ppm

3.5.2 Treatment combinations

There are 12 treatment combinations of application time of GA_3 and different GA_3 doses used in the experiment under as following:

1. S_1G_0
2. S_1G_{20}
3. S_1G_{40}
4. S_1G_{60}
5. S_1G_{80}
6. S_1G_{100}
7. S_2G_0
8. S_2G_{20}
9. S_2G_{40}
10. S_2G_{60}
11. S_2G_{80}
12. S_2G_{100}

3.5.3 Design and layout

The experiment consisted of 12 treatment combinations and was laid out Randomized Complete Block Design (RCBD) with 3 replications. The total plot number was 12 × 3 = 36. The unit plot size was 3.5 m × 1.5 m = 5.25 m^2. The distance between blocks was 1 m and distance between plots was 0.5 m and plant spacing was 30 cm × 5 cm. The layout of the experiment is presented in Appendix II.

3.5.4 Land preparation

The land was ploughed with a rotary plough and power tiller for four times. Ploughed soil was then brought into desirable fine tilth and leveled by laddering. The weeds were clean properly. The final ploughing and land preparation were done on 16 November, 2016. According to the layout of the experiment the entire experimental area was divided into blocks and prepared the experimental plot for the sowing of rape seed. In addition, irrigation and drainage channels were made around the plot.

3.5.5 Fertilization

In this experiment fertilizers were used according to Bangladesh Agricultural Research Institute (BARI, 2011) recommendation which is given under as follows:

Name of Nutrients	Name of Fertilizers	Rate of Application (kg/ha)
Nitrogen (N)	Urea	300
Phosphorus (P)	Triple Super Phosphate	180
Potash (K)	Muriate of Potash	100
Sulpher (S)	Gypsum	180
Boron (B)	Boric acid	15
Zinc (Zn)	Zinc Oxide	5

The amount of fertilizer in the forms of urea, triple super phosphate, muriate of potash, gypsum, boric acid and zinc oxide required as per plot area were calculated. The triple super phosphate, muriate of potash, gypsum, boric acid was applied during final land preparation. Half of urea and total amount of Zn was also applied in each experimental plot according to treatment and incorporated into soil before sowing seed. Rest of the urea was top dressed after 30 days of sowing (DAS).

3.5.6 Sowing of seed

Sowing was done on 17 November, 2016 in rows 30 cm apart. Seeds were sown continuously in rows at a rate of 8 kg/ha. After sowing, the seeds were covered with the soil and slightly pressed by hand, and applied little amount water for better germination of seeds.

3.5.7 Thinning and weeding

The optimum plant population, 60 plants m^{-2} was maintained by thinning excess plant at 15 DAS. The plant to plant distance was maintained as 5 cm. One weeding with khurpi was given on 25 DAS.

3.5.8 Irrigation

Two irrigations were given as plants required. First irrigation was given immediate after topdressing and second irrigation were applied 60 DAS with watering can. After irrigation when the plots were in zoe condition, spading was done uniformly and carefully to conserve the soil moisture for proper growth and development of plants.

3.5.9 Crop protection

As a preventive measure of aphid infestation, Malathion 57 EC @ 2 ml $litre^{-1}$, Thiamethoxam 25 WG @ o.2g/l, and Dimethoate 30EC @ 1 ml/l of water were applied twice first at 25 DAS and second at 50 DAS.

3.5.10 General observation of the experimental field

The field was investigated frequently in order to reduce losses with weeds competition and insects' infestation and diseases infection.

3.5.11 Harvesting and threshing

Previously randomly selected ten plants, those were considered for the growth analysis was collected from each plot to analyze the yield and yield contributing characters. Rest of the crops was harvested when 80% of the siliquae in terminal raceme turned creamy white in color. After collecting sample plants, harvesting was started on February 15 and completed on February 02, 2017. The harvested crops were tied into bundles and carried to the threshing floor. The crop bundles were sun dried by spreading those on the threshing floor. The seeds were separated from the plants by beating the bundles with bamboo sticks.

3.5.12 Drying and weighing

The seeds and other plant parts collected were dried in the sun for couple of days. Dried seeds and straw of each plot was weighted and subsequently converted into yield kg/ha.

3.6 Data collection

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

1. Plant height (cm)

2. No. of primary branches plant^{-1}
3. Length of siliqua
4. No. of siliquae per plant
5. No. of seed per siliquae
6. Seed weight of 1000 siliqua
7. Yield (t/ha)
8. Straw yield (t ha^{-1})

3.6.1 Plant height (cm)

Plant height was measured five times at harvest. The height of the plant was measured by scale considering the distance from the soil surface to the tip of the randomly ten selected plants and mean value was calculated for each treatment.

3.6.2 Number of primary branches plant^{-1}

The number of primary branches per plant was counted five times at harvest of mustard plants. Mean value of data were calculated and recorded.

3.6.3 Length of siliqua (cm)

The length of siliqua of ten plants was measured from the base of the siliqua to the tip of the siliqua with measuring scale. Mean length of siliqua was calculated and expressed in cm.

3.6.4 Number of siliquae per plant

The number of siliquae from ten plants were counted and calculated as per plant basis.

3.6.5 Number of siliquae per plant

After harvesting ten siliquae was taken from each plant and calculated as per siliqua basis.

3.6.6 Thousand seed weight (g)

A composite sample was taken from the yield of ten plants. The thousand seeds of each plot were counted and weighed with a digital electric balance. The thousand seed weight was recorded in g.

3.6.7 Yield (t ha^{-1})

After threshing, cleaning and drying, total seed from harvested area were recorded and was converted to t/ ha.

3.6.8 Straw yield (t ha^{-1})

Straw yield was determined from the central 3 m^2 of each plot. After threshing, the samples were oven dried to a constant weight and finally converted to t ha^{-1}.

3.7 Data analysis

All the collected data were analyzed following the analysis of variance (ANOVA) technique using CROPSTAT package and the mean differences were adjudged by LSD technique at 5% level of significance (Gomez and Gomez, 1984).

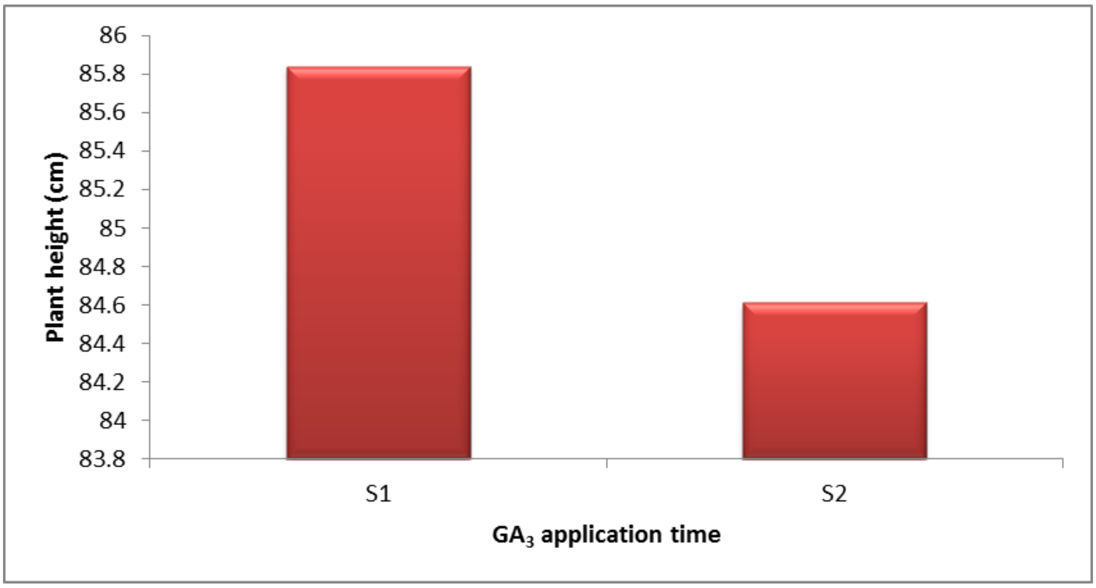
CHAPTER IV
RESULTS AND DISCUSSION

The results obtained with different application time of GA_3 and dose of GA_3 and their combination are presented and discussed in this chapter. Data about morphological parameters, yield contributing characters, seed yield and oil content of mustard have been presented in both Tables and Figures.

4.1 Plant height

4.1.1 Effect of application time of GA_3

The results of this study showed that application time of GA_3 showed effect on mustard plant height as dose dependent manner (Fig. 1). The tallest plant (85.84 cm) was recorded with S_1 treatment. In contrast, the smallest plants were recorded from S_2 and height was 84.61 cm.

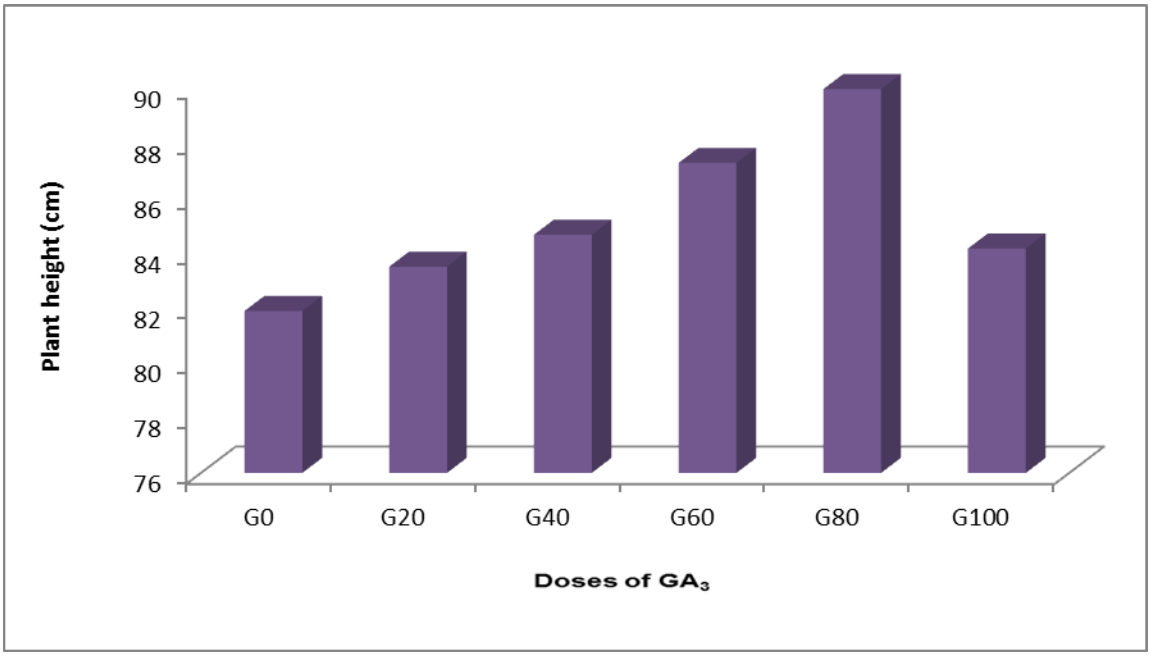


S_1 = GA_3 application at vegetative stage and S_2 = GA_3 application at flowering stage.

Fig.1. Effect of application time of GA_3 on plant height of mustard

4.1.2 Effect of different doses of GA_3

Data pertaining to Fig. 2 revealed that plant height was significantly influenced by different doses of GA_3. However, plant height increased with increasing levels of GA_3 up to certain level. The tallest plant (89.94 cm) was produced with G_{80} and the second height value was produced with G_{60} which is statistically similar to G_{40} and G_{100}.There was no significant difference among G_{20} and G_{100} and the shortest plant (81.88) was found in G_0 condition. G_{80} treated plant showed 9.84% taller than G_0 treated plant. Result indicated that the application of different concentrations of GA_3 had increased the plant height over the control. Significant increase in plant height induced by different levels of GA_3 was observed in rapes (Castro *et al.*, 1989). However, a gradual increase in plant height was noticed up to the application of 80 ppm GA_3. Further increase in concentration (100 ppm GA_3) had resulted in reduced plant height. The increase in plant height with different levels of GA_3 might be due to the fact that cell enlargement was accelerated with the application of gibberellic acid (Hasio *et al.*, 1976).



G_0 = 0 ppm/ha, G_{20} = 20 ppm/ha, G_{40} =40 ppm/ha, G_{60} =60 ppm/ha, G_{80} =80 ppm/ha, G_{100} =100 ppm/ha

Fig.2. Effect of different doses of GA_3 on plant height of mustard

4.1.3 Combined effect of application time of GA_3 and different doses of GA_3

The plant height of mustard significantly increased with the by the interaction between application time of GA_3 and different dose of GA_3 (Table 1). The tallest plant (90.33 cm) was found in S_1G_{80} treatment combination (application of GA_3 at flowering stage with 80 ppm which was statistically similar to S_1G_{40}, S_1G_{60}, S_1G_{100}, S_2G_{40} and S_2G_{80}. There was no significant difference among S_1G_{40}, S_1G_{60}, S_1G_{100}, S_2G_{20}, S_2G_{40}, S_2G_{60} and S_2G_{80}. Again S_1G_{20}, S_1G_{40}, S_1G_{60}, S_1G_{100}, S_2G_{20}, S_2G_{40} and S_2G_{60} were statistically similar. Whereas the shortest plant (81.76 cm) was observed in S_2G_0 treatment (application of GA_3 at flowering stage with 0 ppm treatment combination which was statistically similar to all the treatment except S_1G_{60}, S_1G_{80} and S_2G_{80}. The tallest plant was 10.48% taller than shortest plant.

Table1. Combined effect of application time of GA_3 and different doses of GA_3 on the plant height

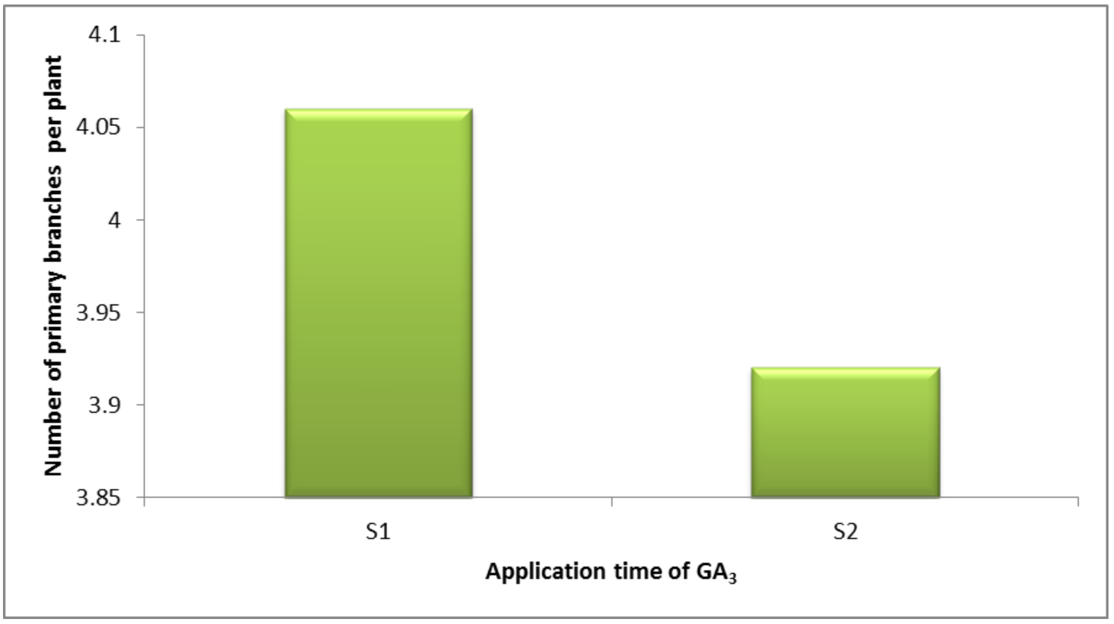
Treatments	**Plant height (cm)**	
S_1G_0	81.99	d
S_1G_{20}	83.11	cd
S_1G_{40}	84.87	abcd
S_1G_{60}	88.79	abc
S_1G_{80}	**90.33**	a
S_1G_{100}	85.95	abcd
S_2G_0	**81.76**	d
S_2G_{20}	83.87	bcd
S_2G_{40}	84.42	bcd
S_2G_{60}	85.73	abcd
S_2G_{80}	89.54	ab
S_2G_{100}	82.35	d
LSD $_{(0.05)}$	5.81	
CV (%)	4.03	

G_0 = 0 ppm, G_{20}= 20 ppm, G_{40} =40 ppm, G_{60} =60 ppm, G_{80} =80 ppm, G_{100} =100 ppm
S_1 = GA_3 application at vegetative stage, S_2 = GA_3 application at flowering stage.

4.2 Number of Primary branches plant^{-1}

4.2.1 Effect of application time of GA_3

The Figure 3, showed that application time of GA_3 had significant effect on number of primary branches per plant. The maximum number of branches per plant (4.08) was produced by S_1. S_2 produced the minimum number of branches per plant (3.89).

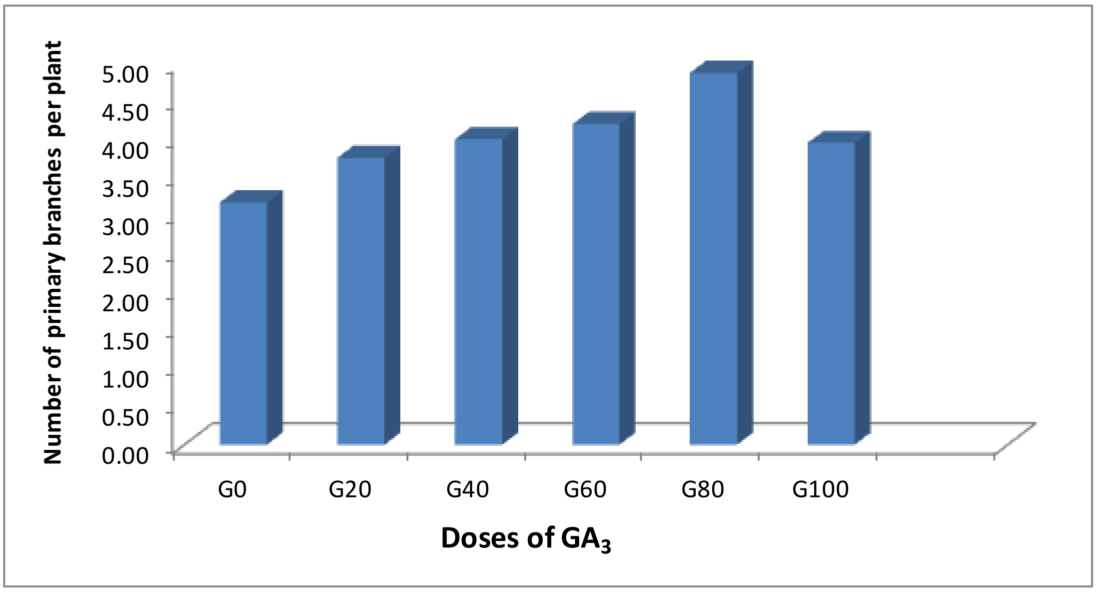


S_1 = GA_3 application at vegetative stage and S_2 = GA_3 application at flowering stage.

Fig. 3. Effect of application time of GA_3 on number of primary branches per plant of mustard.

4.2.2 Effect of different doses of GA_3

The GA_3 influenced significantly on number of primary branches per plant (Fig. 4). The highest number of branches per plant (4.87) was obtained from G_{80} which was statistically similar to G_{60}. The second value was (4.20) from G_{60} which was statistically similar to all the treatment except G_0 and G_{80} and the lowest number of branches per plant (3.17) was obtained from the control, G_0 which is similar to G_{20} and G_{40} and indicating that GA_3 increased number of primary branches per plant^{-1} as dose dependent manner. The height number of primary branches was 53.62% greater than lowest number of primary branches. Significantly higher number of primary and secondary branches plant^{-1} were counted in all the treatments at all stages (40, 60, 80 DAS) of crop growth over control. Higher number of primary and secondary branches plant^{-1} was noted with foliar sprayed of GA_3 90 ppm. (Saini *et al*., 2017).



G_0 = 0 ppm/ha, G_{20} = 20 ppm/ha, G_{40} =40 ppm/ha, G_{60} =60 ppm/ha, G_{80} =80 ppm/ha, G_{100} =100 ppm/ha

Fig. 4. Effect of different doses of GA_3 on number of primary branches per plant of mustard.

4.2.3 Combined effect of application time of GA_3 and different doses of GA_3

Interaction effect between application time of GA_3 and GA_3 was found significant on the number of primary branches per plant (Table 2). The maximum number of branches per plant (5.20) was found in S_1G_{80} treatment combination which was similar to S_2G_{80}. There was no significant difference among all treatment combinations except S_1G_0, S_1G_{20}, S_1G8_0, S_2G_0 and $S_2G_{80.}$ Again there was no significant difference among S_1G_{20}, S_1G_{40}, S_1G_{60}, S_1G_{100}, S_2G_{20}, S_2G_{40}, S_2G_{60} and S_2G_{100}.Whereas the lowest number of branches per plant (3.07) was found in S_2G_0, control treatment which was similar to S_1G_0, S_1G_{20}, S_1G_{40}, S_2G_{20}, S_2G_{40} and S_2G_{100}. For the interaction we showed that height number of primary branches was 69.38% greater than lowest number of primary branches.

Table 2. Combined effect of application time of GA_3 and different doses of GA_3 on the number of primary branches plant^{-1} of mustard

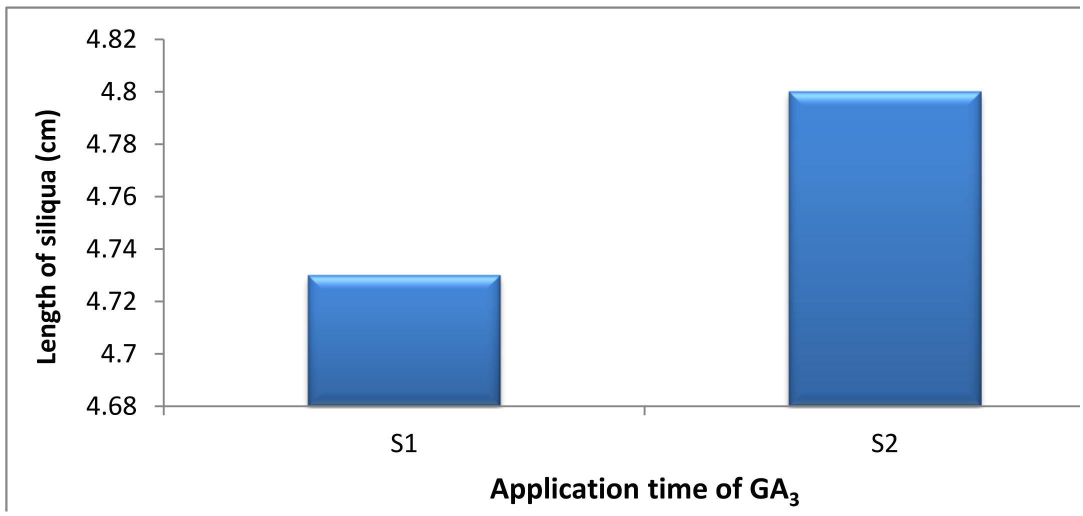
Treatments	**Number of Primary branches per plant**
S_1G_0	3.27 d
S_1G_{20}	3.73 cd
S_1G_{40}	4.03 bcd
S_1G_{60}	4.23 bc
S_1G_{80}	**5.20** a
S_1G_{100}	4.07 bc
S_2G_0	**3.07** d
S_2G_{20}	3.77 bcd
S_2G_{40}	3.97 bcd
S_2G_{60}	4.17 bc
S_2G_{80}	4.53 a
S_2G_{100}	3.83 bcd
LSD $_{(0.05)}$	0.77
CV (%)	11.38

G_0 = 0 ppm, G_{20}= 20 ppm, G_{40} =40 ppm, G_{60} =60 ppm, G_{80} =80 ppm, G_{100} =100 ppm
S_1 = GA_3 application at vegetative stage, S_2 = GA_3 application at flowering stage.

4.3 Length of siliqua

4.3.1 Effect of application time of GA_3

The Application time of GA_3 showed variation in the length of siliqua (Fig. 5). The longest length of siliqua (4.80 cm) was produced by $S_{2,}$ treatment, whereas S_1 produced the shortest length of siliqua (4.73 cm). Ancha and Morgan (1996) reported that the application of GA_3 at flowering resulted in an enlarged pod structure in mustard.

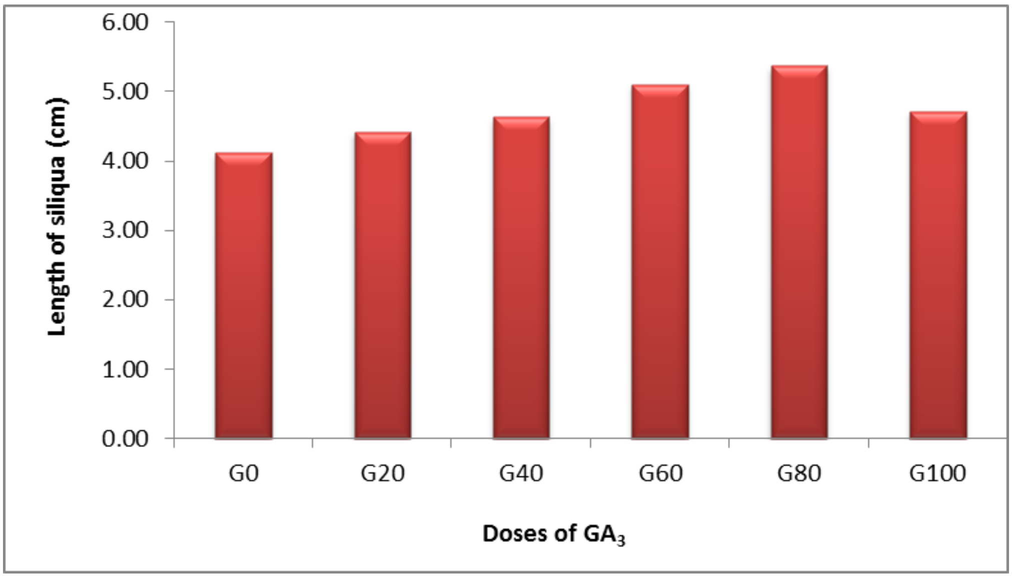


S_1 = GA_3 application at vegetative stage and S_2 = GA_3 application at flowering stage.

Fig. 5. Effect of application time of GA_3 on length of siliqua of mustard

4.3.2 Effect of different doses of GA_3

There was significant difference among the GA_3 treatments in the length of siliqua (Fig. 6). As evident from fig 6, the maximum length of siliqua (5.37 cm) was produced from 80 ppm GA_3. The second height length of siliqua was found in G_{60} which was similar to G_{100}. Again there was no significant difference between G_{20} and G_{40}. The minimum length of siliqua (4.12 cm) was produced in control. The maximum length of siliqua was 30.33% greater than minimum length of siliqua. The result of the present study is similar to the findings of Bouttier and Morgan (1992) who reported that GA_3 at various levels sprayed on mustard showed no positive influence on length of siliqua. But Sayed *et al.* (1997) reported that the application of GA_3 had increased the pod length.



G_0 = 0 ppm/ha, G_{20} = 20 ppm/ha, G_{40} =40 ppm/ha, G_{60} =60 ppm/ha, G_{80} =80 ppm/ha, G_{100} =100 ppm/ha

Fig. 6. **Effect of different doses of GA_3 on length of siliqua of mustard**

4.3.3 Combined effect of application time of GA_3 and different doses of GA_3

Length of siliqua significantly varied among the treatment combinations. The maximum length of siliqua (5.43 cm) was found in S_2G_{80} treatment combination which was similar to S_1G_{60}, S_1G_{80}, S_2G_{60} and S_2G_{100}. There was no significant difference among S_1G_{40}, S_1G_{60}, S_1G_{100} and S_2G_{60}. Again S_1G_{20}, S_1G_{40}, S_1G_{100}, S_2G_{20} and S_2G_{40} were statistically similar. Once again S_1G_{20}, S_2G_0, S_2G_{20} and S_2S_{40} treatment combinations were statistically similar. Whereas the minimum length of siliqua (4.03 cm) was found in S_1G_0 (Table 3) which is similar to S_2G_{20}, S_2G_0 and S_2G_{20}. For treatment combination, maximum length of siliqua was 34.73% greater than minimum length of siliqua.

Table 3. Combined effect of application time of GA_3 and different doses of GA_3 on the length of siliqua of mustard

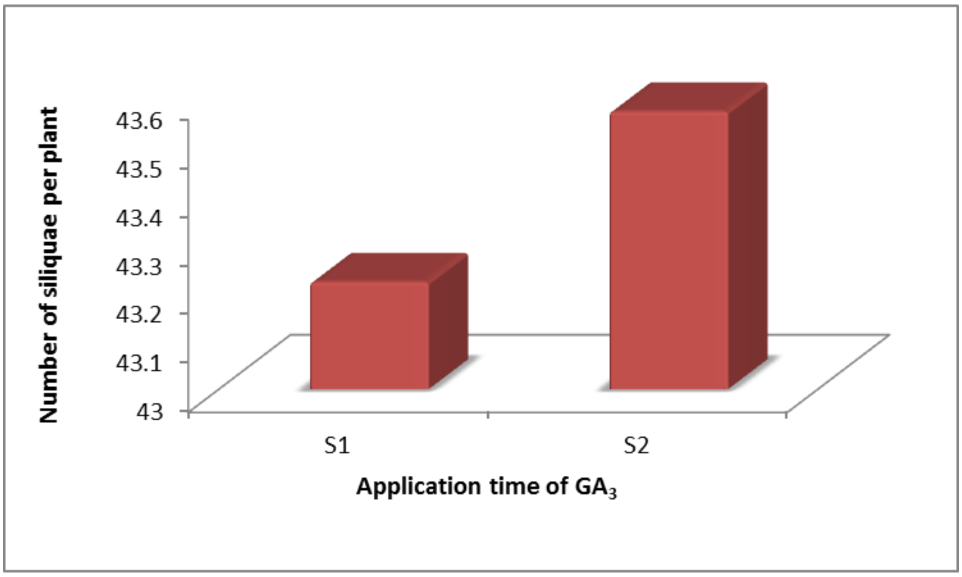
Treatments	**Length of siliqua (cm)**
S_1G_0	**4.03** e
S_1G_{20}	4.50 cde
S_1G_{40}	4.73 bc
S_1G_{60}	5.10 ab
S_1G_{80}	5.30 a
S_1G_{100}	4.70 bc
S_2G_0	4.20 de
S_2G_{20}	4.33 cde
S_2G_{40}	4.53 cd
S_2G_{60}	5.10 ab
S_2G_{80}	**5.43** a
S_2G_{100}	5.23 a
LSD $_{(0.05)}$	0.47
CV (%)	5.83

G_0 = 0 ppm, G_{20}= 20 ppm, G_{40} =40 ppm, G_{60} =60 ppm, G_{80} =80 ppm, G_{100} =100 ppm
S_1 = GA_3 application at vegetative stage, S_2 = GA_3 application at flowering stage.

4.4 Number of siliquae plant^{-1}

4.4.1 Effect of application time of GA_3

The number of siliquae per plant of mustard was influenced application time of GA_3 rates and their interaction. The application time of GA_3 showed significant variation in the number of siliquae per plant (Fig 7). The Maximum number siliquae per plant (43.57) was obtained in plots which received S_2 treatment. The minimum number of siliquae per plant (43.22) produced in S_1 treatment.

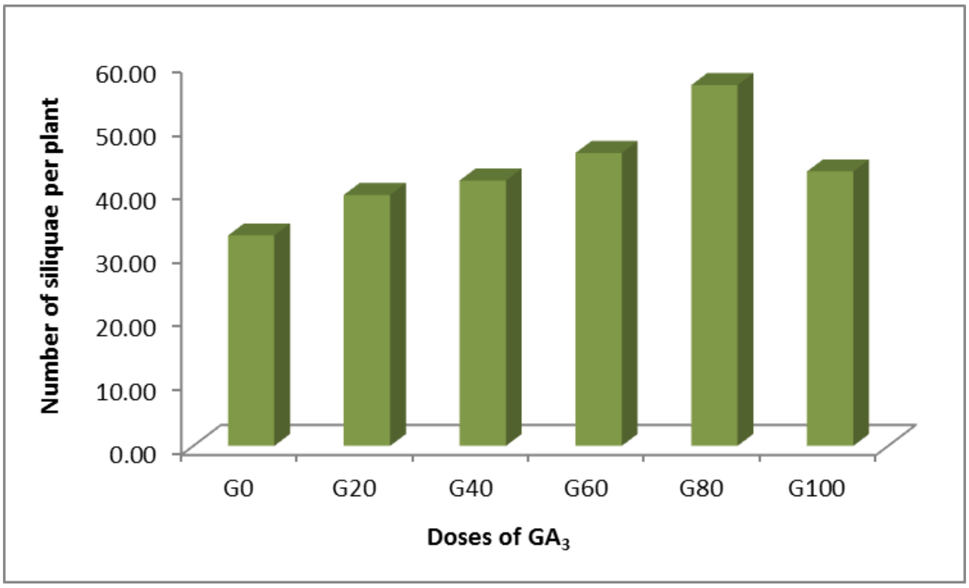


S_1 = GA_3 application at vegetative stage and S_2 = GA_3 application at flowering stage.

Fig. 7. Effect of application time of GA_3 on number of siliquae per plant of mustard

4.4.2 Effect of different doses of GA_3

There was a significant difference among the GA_3 in the number of siliquae per plant (Fig. 8). The maximum number of siliquae per plant (56.75) was produced in G_{80}. The second height number of siliquae was (46.08) found in G_{60} which is similar to G_{40}, G_{60} and G_{100}. And the minimum number of siliquae per plant (33.12) was produced in G_0 or control condition which is statistically similar to G_{20}, G_{40} and G_{100}. Results indicated that 80 ppm GA_3 was the optimum dose for producing the highest number of fertile siliqua/plant. The results showed that as the concentrations of GA_3 was increased; the number of fertile siliqua/plant also increased until the application of 80 ppm GA_3 but was reduced by application of 100 ppm GA_3. The height number of siliqua was 71.34% greater than the lowest number of siliqua. This indicated that GA_3 had direct effect on siliqua formation, but excessive application of GA_3 had detrimental effect on the growth of the crop. The result of the present study is similar to the findings of Khan *et al*. (1998) who observed that application of GA_3 at 80 days after sowing on *Brassica juncea* had increased the number of siliqua/plant.



G_0 = 0 ppm/ha, G_{20} = 20 ppm/ha, G_{40} =40 ppm/ha, G_{60} =60 ppm/ha, G_{80} =80 ppm/ha, G_{100} =100 ppm/ha

Fig.8. Effect of different doses of GA_3 on number of siliquae per plant of mustard

4.4.3 Combined effect of application time of GA_3 and different doses of GA_3

A significant variation among the treatment combinations of application time of GA_3 and GA_3 was varied in number of siliquae per plant (Table 4). The maximum number of siliquae per plant (58.23) was found in S_2 G_{80} which is similar to only one treatment combination S_1G_{80}. There was no significant difference between S_1G_{60} and S_1G_{80}. Also S_1G_{20}, S_1G_{40}, S_1G_{60}, S_1G_{100}, S_2G_{20}, S_2G_{40}, S_2G_{60} and S_2G_{100} were statistically similar. Whereas the minimum number of siliquae per plant (32.83) was found in S_2G_0 treatment combination which was similar to S_1G_0, S_1G_{20}, S_1G_{40}, S_2G_{20} and S_2G_{40} treatment combinations. The height treatment combination was 77.36% greater than lowest treatment combination.

Table 4. Combined effect of application time of GA_3 and different doses of GA_3 on number of siliqua per plant of mustard

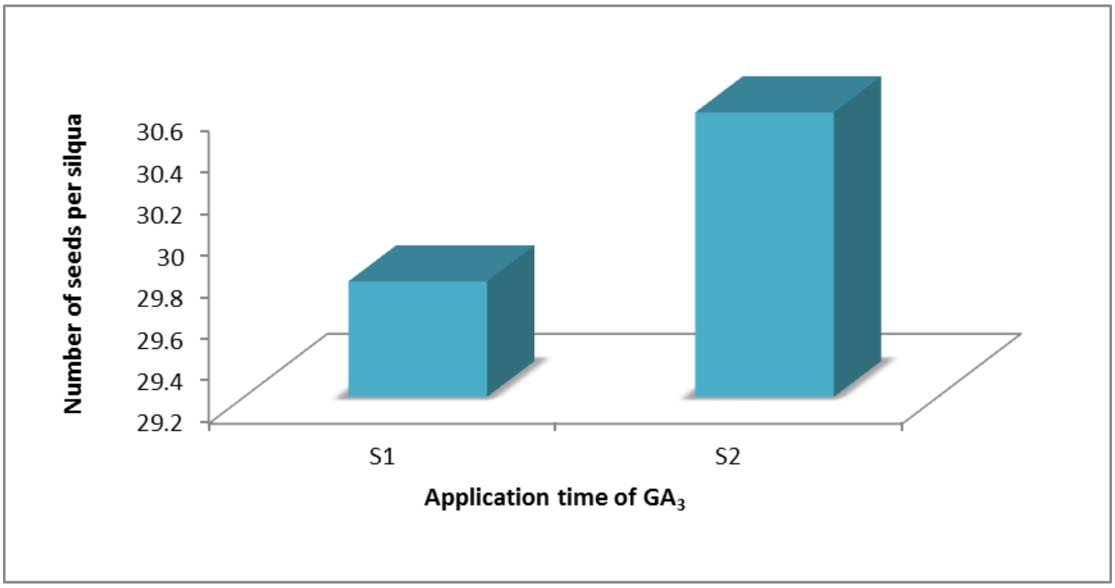
Treatments	**Number of siliqua per plant**
S_1G_0	33.40 d
S_1G_{20}	40.40 cd
S_1G_{40}	41.17 cd
S_1G_{60}	47.03 bc
S_1G_{80}	55.27 ab
S_1G_{100}	42.03 cd
S_2G_0	**32.83** d
S_2G_{20}	38.57 cd
S_2G_{40}	42.33 cd
S_2G_{60}	45.13 c
S_2G_{80}	**58.23** a
S_2G_{100}	44.33 c
LSD $_{(0.05)}$	10.12
CV (%)	8.78

G_0 = 0 ppm, G_{20}= 20 ppm, G_{40} =40 ppm, G_{60} =40 ppm, G_{80} =80 ppm, G_{100} =100 ppm
S_1 = GA_3 application at vegetative stage, S_2 = GA_3 application at flowering stage.

4.5 Number of seeds per siliquae

4.5.1 Effect of application time of GA_3

Number of seeds per siliquae showed significant difference due to variation of application time of GA_3 (Fig. 9). The highest number of seeds per siliquae (30.57) was obtained from S_2 treatment. The lowest number of seeds per siliquae (29.75) was recorded in S_1 treatment.

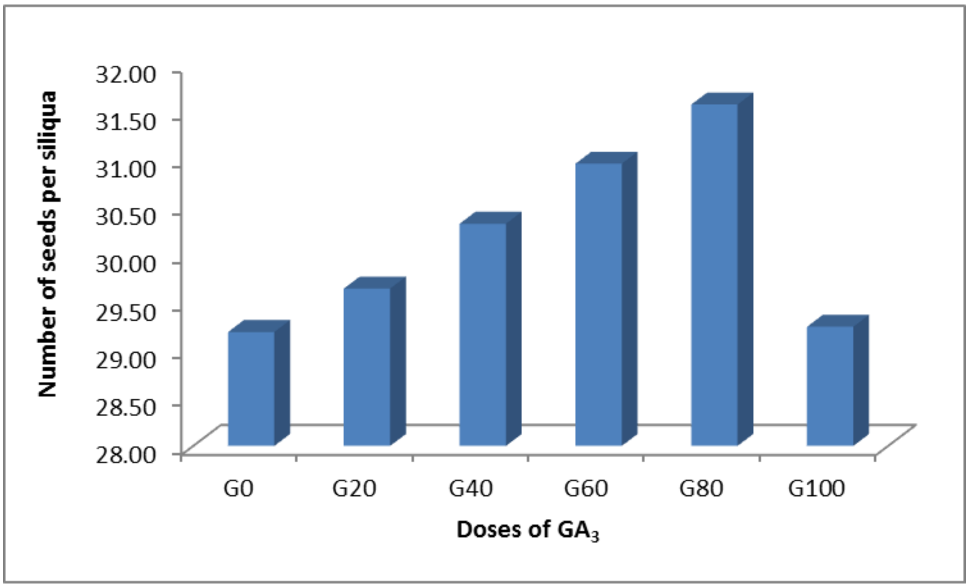


S_1 = GA_3 application at vegetative stage and S_2 = GA_3 application at flowering stage.

Fig. 9. Effect of application time of GA_3 on number of seeds per siliqua of mustard

4.5.2 Effect of different doses of GA_3

The GA_3 showed significant variation in the number of seed per siliquae (Fig. 10). The highest number of seed per siliquae (31.58) was obtained from G_{80} treatment. The second height number of seed per siliqua was obtained from G_{60} which is similar to G_{40}. There was no significant difference between G_{20} and G_{100}. The lowest number of seed per siliquae (29.195) was obtained from control treatment. All of the concentrations of GA_3 produced higher seeds per siliqua over the control. This indicated GA_3 had direct effect on seed formation. The height number of seeds per siliqua was 8.16% greater than lowest number of seeds per siliqua. This result was in agreement with the findings of Bouttier and Morgan (1992). The plant growth regulators like GA_3 have involved information of seeds in the pods and their optimum norshment's have resulted in less number of aborted seeds and thus maximized the survival of fertile seeds per pod in rapes and mustard (Inanaga and Kumura, 1987, Holmberg and German, 1991). Gibberellic acid might increase translocation of assimilates to the seed which increased the number of seeds per plant with the application of different levels of GA_3.



G_0 = 0 ppm/ha, G_{20} = 20 ppm/ha, G_{40} =40 ppm/ha, G_{60} =60 ppm/ha, G_{80} =80 ppm/ha, G_{100} =100 ppm/ha

Fig .10. Effect of different doses of GA_3 on number of seeds per siliqua of mustard

4.5.3 Combined effect of application time of GA_3 and different doses of GA_3

The interaction effect of application time of GA_3 and GA_3 was significant on number of seed per siliquae (Table 5). The highest number of seeds per siliquae (31.85 g) was produced in S_2G_{80} which was statistically similar to S_1G_{80} and S_2G_{60}.There was no significant differences among the treatment combinations of S_1G_{60}, S_2G_{40} and S_2G_{100}. Again S_1G_{40} and S_1G_{60} were statistically similar. Once again S_1G_{40}, S_1G_{60} and S_2G_{20} were statistically similar. Again there was no significant difference among S_1G_0, S_2G_{20} and S_2G_{20}. Furthermore S_1G_0, S_2G_0 and S_2G_{20} were statistically similar. The lowest (28.07) was recorded in the treatment combination of S_1G_{100}. The height treatment combinations was 13.47% greater than lowest treatment combination.

Table 5. Combined effect of application time of GA_3 and different doses of GA_3 on the seeds per siliqua of mustard

Treatments	Number of seeds per siliqua
S_1G_0	29.33 ef
S_1G_{20}	29.71 de
S_1G_{40}	29.97 cd
S_1G_{60}	30.13 bcd
S_1G_{80}	31.31 a
S_1G_{100}	28.07 g
S_2G_0	**29.06** f
S_2G_{20}	29.59 def
S_2G_{40}	30.68 b
S_2G_{60}	31.79 a
S_2G_{80}	**31.85** a
S_2G_{100}	30.43 b
LSD $_{(0.05)}$	0.59
CV (%)	7.17

G_0 = 0 ppm, G_{20}= 20 ppm, G_{40} =40 ppm, G_{60} =60 ppm, G_{80} =80 ppm, G_{100} =100 ppm
S_1 = GA_3 application at vegetative stage, S_2 = GA_3 application at flowering stage.

4.6 Thousand seed weight

4.6.1 Effect of application time of GA_3

The application time of GA_3 influenced significantly on the thousand seed weight (Table 6). The maximum thousand seed weight (2.80 g) was produced by S_2 and S_1 produced the lower thousand seed weight (2.55 g).

Table 6. Effect of application time of GA_3 on thousand seed weight

Treatments	Thousand seed weight (g)
S_1	2.55
S_2	2.80
CV (%)	7.68

S_1 = GA_3 application at vegetative stage, S_2 = GA_3 application at flowering stage

4.6.2 Effect of doses of GA_3

The weight of thousand seed was significantly influenced by GA_3 (Table 7). The highest thousand seed weight (3.45 g) was obtained from G_{80} treatment which was statistically similar to G_{60}. The lowest thousand seed weight (2.19 g) was obtained from without GA_3 which was statistically similar with all the treatment except G_{80}. The height thousand seed weight was 57.53% greater than lowest thousand seed weight. Saran *et al*. (1992) stated that *Brassica juncea* seeds soaked in 0, 25, 50, 75, 100 ppm for 12h before sowing. As a result increased shoot length and 100 seed weight occurred.

Table 7. Effect of doses of GA_3 on thousand seed weight of mustard.

Treatments	Thousand seed weight (g)
G_0	**2.19** b
G_{20}	2.43 b
G_{40}	2.59 b
G_{60}	2.74 ab
G_{80}	**3.45** a
G_{100}	2.64 b
LSD $_{(0.05)}$	0.74
CV (%)	7.68

G_0 = 0 ppm, G_{20}= 20 ppm, G_{40} =40 ppm, G_{60} =60 ppm, G_{80} =80 ppm, G_{100} =100 ppm

4.6.3 Combined effect of application time of GA_3 and different doses of GA_3

Thousand seed weight was significantly influenced by both of application time of GA_3 and GA_3 doses (Table 8). The highest thousand seed weight (3.58 g) was found in S_2G_{80} treatment combination which was statistically similar to S_1G_{80}, S_2G_{60} and S_2G_{100}. Again there was no significant difference among S_1G_{40}, S_1G_{60}, S_1G_{80}, S_2G_{40}, S_2G_{60}, and S_2G_{100} treatment combinations. Once again there was no significant difference among S_1G_{20}, S_1G_{40}, S_1G_{60}, S_1G_{100}, S_2G_0, S_2G_{20}, S_2G_{40} and S_2G_{60}. Whereas the lowest thousand seed weight (2.04 g) was found in S_1G_0 treatment which is statistically similar to all the treatments except S_1G_{80}, S_2G_{80} and S_2G_{100}. The height treatment combination of thousand seed weight was 75.49% greater than lowest treatment combination of thousand seed weight.

Table 8. Combined effect of application time of GA_3 and different doses of GA_3 on yield and yield contributing character of mustard

Treatments	**Thousand seed weight (g)**
S_1G_0	**2.04** d
S_1G_{20}	2.34 cd
S_1G_{40}	2.63 bcd
S_1G_{60}	2.66 bcd
S_1G_{80}	3.32 ab
S_1G_{100}	2.28 cd
S_2G_0	2.34 cd
S_2G_{20}	2.51 cd
S_2G_{40}	2.55 bcd
S_2G_{60}	2.82 abcd
S_2G_{80}	**3.58** a
S_2G_{100}	3.00 abc
LSD $_{(0.05)}$	0.80
CV (%)	7.68

G_0 = 0 ppm, G_{20}= 20 ppm, G_{40} =40 ppm, G_{60} =60 ppm, G_{80} =80 ppm, G_{100} =100 ppm
S_1 = GA_3 application at vegetative stage, S_2 = GA_3 application at flowering stage

4.7 Seed yield (t/ha)

4.7.1 Effect of application time of GA_3

The seed yield of mustard per plot was converted into per hectare and has been expressed in metric tons (Table 9). The application time of GA_3 had significant effect on the yield of seed per hectare. The maximum seed yield of mustard per hectare (0.68 t) was obtained from S_2, whereas the minimum yield of seed per hectare (0.64 t) was obtained from S_1. Khan *et al.* (2002b) found the similar result, in a field trial with GA_3 at 10, 10^{-4}, 10^{-5} M observed an increased yield of *Brasscica juncea* GA_3 at 75 mg/L applied at the pre flowering stage on Indian mustard gave the greatest total seed yield.

Table 9. Effect of application time of GA_3 on seed yield of mustard.

Treatments	**Seed yield (t/ha)**
S_1	0.64
S_2	0.68
CV (%)	7.49

S_1 = GA_3 application at vegetative stage, S_2 = GA_3 application at flowering stage

4.7.2 Effect of doses of GA_3

The total yield of mustard varied significantly due to the application of different levels of GA_3 (Table 10). The highest yield of seed (0.87 t/ha) was obtained from G_{80} which was statistically similar to G_{60}. Again there was no significant difference among G_{20}, G_{40}, G_{60} and G_{100}. Whereas G_0 gave the lowest (0.47 t/ha) yield of mustard which was statistically similar to G_{20}.The height yield was 85.10% greater than the lowest yield. The results showed that as the levels of GA_3 was increased; the seed yield was also increased up to the application of 80 ppm GA_3. The amount beyond 80 ppm had resulted in decreased seed yield/plant. This was because of the application of 80ppm GA_3 which had produced more effective plant height, siliqua per plant, number of seeds per siliqua and the highest 1000-seed weight than other treatments resulting higher seed yield. This indicated that GA_3 had direct effect on seed yield. The results of the present study was similar to the findings of Jagadeeswqari *et al.* (1998) who stated that foliar application of GA_3 increases seed yield significantly. It was also supported by Hossain (1974) who applied 50, 100 and 200 ppm GA_3, which increases seed yield per plant with higher concentration. The application of 50 ppm of GA_3 was more effective to reduce yield loss due to siliqua shattering. Hayat *et al*. (2001) conducted an experiment with GA_3 at 10^{-6}M on 30 day old plants in mustard and observed that GA_3 increased vegetative growth and seed yield at harvest. Khan *et al*. (1998) observed in a field experiment of *Brassica juncea* with 10^{-5} M GA_3 at 40, 60, or 80 days after sowing and found that application of GA_3 at 40 or 60 days sowing significantly increased seed yield.

Table 10. Effect of doses of GA_3 on seed yield of mustard.

Treatments	Seed yield (t/ha)
G_0	**0.47** c
G_{20}	0.59 bc
G_{40}	0.67 b
G_{60}	0.72 ab
G_{80}	**0.87** a
G_{100}	0.66 b
LSD $_{(0.05)}$	0.18
CV (%)	7.49

G_0 = 0 ppm, G_{20}= 20 ppm, G_{40} =40 ppm, G_{60} =60 ppm, G_{80} =80 ppm, G_{100} =100 ppm

4.7.3 Combined effect of application time of GA_3 and different doses of GA_3

The combined effect of application time of GA_3 and GA_3 doses was significant on yield of seed per hectare (Table 11). The highest yield (0.90 t/ha) was obtained from S_2G_{80} treatment combination which is statistically similar to S_1G_{60}, S_1G_{80}, S_2G_{60} and S_2G_{100}. Again there was no significant difference among S_1G_{40}, S_1G_{60}, S_1G_{80}, S_2G_{40}, S_2G_{60} and S_2G_{100}. Once again there was no significant difference among all the treatment except S_1G_0, S_1G_{80}, S_2G_0 and S_2G_{80}. Furthermore there was no significant difference among S_2G_0, S_1G_{20}, S_1G_{40}, S_1G_{100}, S_2G_{20} and S_2G_{40}. The lowest yield (0.44t/ha) was obtained from S_1G_0 treatment which is similar to S_2G_0, S_1G_{20}, S_1G_{100} and S_2G_{20}. The height treatment combination of yield was 104.54% greater than the lowest treatment combination of yield.

Table 11. Combined effect of application time of GA_3 and different doses of GA_3 on yield and yield contributing character of mustard.

Treatments	**Seed yield (t/ha)**
S_1G_0	**0.44** e
S_1G_{20}	0.61 cde
S_1G_{40}	0.66 bcd
S_1G_{60}	0.72 abc
S_1G_{80}	0.83 ab
S_1G_{100}	0.58 cde
S_2G_0	0.49 de
S_2G_{20}	0.56 cde
S_2G_{40}	0.67 bcd
S_2G_{60}	0.71 abc
S_2G_{80}	**0.90** a
S_2G_{100}	0.74 abc
LSD $_{(0.05)}$	0.21
CV (%)	7.49

G_0 = 0 ppm, G_{20}= 20 ppm, G_{40} =40 ppm, G_{60} =60 ppm, G_{80} =80 ppm, G_{100} =100 ppm
S_1 = GA_3 application at vegetative stage, S_2 = GA_3 application at flowering stage

4.8 Straw yield

4.8.1 Effect of application time of GA_3

The straw yield of mustard per plot was converted into per hectare, and has been expressed in metric tons (Table 12). The application time of GA_3 had significant effect on the yield of seed per hectare. The maximum yield of straw per hectare (1.28 t) was obtained from S_2, whereas the minimum yield of straw per hectare (1.16 t) was obtained from S_1.

Table 12. Effect of application time of GA_3 on straw yield of mustard

Treatments	**Straw yield (t/ha)**
S_1	1.16
S_2	1.28
CV (%)	9.88

S_1 = GA_3 application at vegetative stage, S_2 = GA_3 application at flowering stage

4.8.2 Effect of doses of GA_3

The straw yield of mustard varied significantly due to the application of different levels of GA_3 (Table 13). The highest yield of straw (1.57 t/ha) was obtained from G_{80} which is statistically similar to G_{100}. There was no significant difference among G_{40}, G_{60} and G_{100}. Again there was no significant difference between G_{20} and G_{40}. The lowest straw yield was (0.92 t/ha) found in G_0 which had no significant differences with G_{20}. The height treatment of straw yield was 61.85% greater than the lowest treatment of straw yield.

Similar result was found by Saini *et al.* (2017) that straw yield was increased with the increase of concentration up to certain level. Statistically significant plant straw yield was recorded in all the treatments over control. Maximum straw yield was recorded with foliar sprayed with GA_3 125ppm (24.95, 69.09, 182.10 and 190.44) at 40, 60, 80 DAS and at maturity stage, respectively, followed by foliar sprayed of GA_3 90ppm over control.

Table 13. Effect of doses of GA_3 on Straw yield of mustard

Treatments	Straw yield (t/ha)
G_0	**0.92** d
G_{20}	0.99 cd
G_{40}	1.18 bc
G_{60}	1.29 b
G_{80}	**1.57** a
G_{100}	1.30 ab
LSD $_{(0.05)}$	0.27
CV (%)	9.88

G_0 = 0 ppm, G_{20}= 20 ppm, G_{40} =40 ppm, G_{60} =60 ppm, G_{80} =80 ppm, G_{100} =100 ppm

4.8.3 Combined effect of application time of GA_3 and different doses of GA_3

The combined effect of application time of GA_3 and GA_3 doses was significant on yield of straw per hectare (Table 14). The highest yield of straw per hectare (1.67 tones) was obtained from S_2G_{80} treatment combination which was statistically similar to S_1G_{40}, S_1G_{60}, S_1G_{80}, S_2G_{40}, S_2G_{60} and S_2G_{100}. The lowest yield of straw per hectare (0.89 tones) was obtained from S_1G_0 treatment which is statistically similar to all the treatment except S_1G_{80}, S_2G_{80} and $S_2G_{100.}$ The height treatment combination of straw yield was 87.64% greater than the lowest treatment combination of straw yield.

Table 14. Combined effect of application time of GA_3 and different doses of GA_3 on straw yield of mustard.

Treatments	**Straw yield (t/ha)**
S_1G_0	**0.89** b
S_1G_{20}	0.93 b
S_1G_{40}	1.27 ab
S_1G_{60}	1.29 ab
S_1G_{80}	1.46 a
S_1G_{100}	1.15 b
S_2G_0	0.95 b
S_2G_{20}	1.05 b
S_2G_{40}	1.28 ab
S_2G_{60}	1.28 ab
S_2G_{80}	**1.67** a
S_2G_{100}	1.46 a
LSD $_{(0.05)}$	0.40
CV (%)	9.88

G_0 = 0 ppm, G_{20}= 20 ppm, G_{40} =40 ppm, G_{60} =60 ppm, G_{80} =80 ppm, G_{100} =100 ppm
S_1 = GA_3 application at vegetative stage, S_2 = GA_3 application at flowering stage.

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted at the experimental field of Sher-e-Bangla Agricultural University, Dhaka during the rabi season from November 2016 to February 2017 to yield performance of rapeseed following the application of GA_3. In this experiment, the treatment consisted of two application time of GA_3 viz. S_1 = GA_3 application at vegetative stage and S_2 = GA_3 application at flowering stage, and six different levels of GA_3 viz. G_0 = 0 ppm, G_{20}= 20 ppm, G_{40} =40 ppm, G_{60} =60 ppm, G_{80} =80 ppm, and G_{100} =100 ppm. The experiment was laid out in Randomized Complete Block Design (RCBD) (factorial) with three replications. The amount of fertilizers in the form of urea, triple super phosphate, muriate of potash, gypsum, zinc oxide and boric acid as a source of N, P, K, S, Zn and B respectively were applied according to the area of experimental unit plot. The collected data were statistically analyzed for evaluation of the treatment effect. Results showed that a significant variation among the treatments in respect a majority of the observed parameters.

The results showed that application time of GA_3 showed effect on mustard all parameter. The tallest plant (85.84 cm) was recorded with S_1 treatment. The maximum number of branches per plant (4.08) was recorded with S_1 treatment. The maximum length of siliqua (4.80 cm), number siliquae per plant (43.57) was produced by S_2. The highest number of seeds per siliqua (30.57) was obtained from S_2 treatment. The application time of GA_3 had significant effect on the yield of seed per hectare. The maximum yield of seed per hectare (0.68 t) was obtained from S_2, whereas the minimum yield of seed per hectare (0.65 t) was obtained from S_1. The maximum yield of straw per hectare (1.28 t) was obtained from S_2.

The GA_3 showed significant variation in plant height. The tallest plant (89.94 cm) was produced with G_{80}. The highest number of branches per plant (4.87) was obtained from G_{80}. The maximum length of siliqua (5.37 cm) was produced from 80 ppm GA_3. The maximum number of siliquae per plant (56.75) was produced in G_{80}. The GA_3 showed significant variation in the number of seeds per siliquae. The highest number of seeds per siliquae (31.58) was obtained from G_{80} treatment. The maximum thousand seed weight (2.80 g) was produced by S_2. The weight of thousand seed was significantly influenced by GA_3. The highest thousand seed weight (3.45 g) was obtained from G_{80} treatment. The total yield of mustard varied significantly due to the application of different levels of GA_3. The highest yield of seed (0.87 t/ha) was obtained from $G_{80,}$ while G_0 gave the lowest (0.47 t/ha) yield of mustard. The straw yield of mustard varied significantly due to the application of different levels of GA_3 (Table 6). The highest yield of straw (1.57 t/ha) was obtained from $G_{80.}$

All parameter of mustard significantly increased with the interaction between application time of GA_3 and different doses of GA_3. The tallest plant (90.33 cm) was found in S_1G_{80} treatment combination (application of GA_3 at flowering stage with 80 ppm. The maximum number of branches per plant (5.20) was found in S_1G_{80} treatment combination. The maximum length of siliqua (5.43cm) was found in S_2G_{80} treatment combination. The maximum number of siliquae per plant (58.23) was found in S_2G_{80}. The highest number of seeds per siliquae (31.85g) was produced in S_2G_{80}. The highest thousand seed weight (3.58g) was found in S_2G_{80} treatment combination. The highest yield of seed per hectare (0.90 tones) was obtained from S_2G_{80} treatment combination. The lowest yield of seed per hectare (0.44tones) was obtained from S_1G_0 treatment. The highest yield of straw per hectare (1.67 tones) was obtained from S_2G_{80} treatment combination.

Considering the above results, it may be summarized that growth, seed yield contributing parameters of rapeseed are positively correlated with application time of GA_3 and different level of GA_3. Therefore, the present experimental results suggest that the combined use of GA_3 application at flowering stage and 80 ppm along with recommended doses of other fertilizer would be beneficial to increase the seed yield of rapeseed variety BARI sarisha-14 under the climatic and edaphic condition of Sher-e-Bangla Agricultural University, Dhaka.

Considering the situation of the present experiment, further studies in the following areas may be suggested:

1. In this study the GA_3 was applied at vegetative (pre-flowering) and flowering stages. Further trials including the application at the early vegetative (seedling) stage should be carried out.
2. This study was made using the mustard variety BARI sorisha-14. Further trials are required to include the widely used varieties of mustard in Bangladesh.

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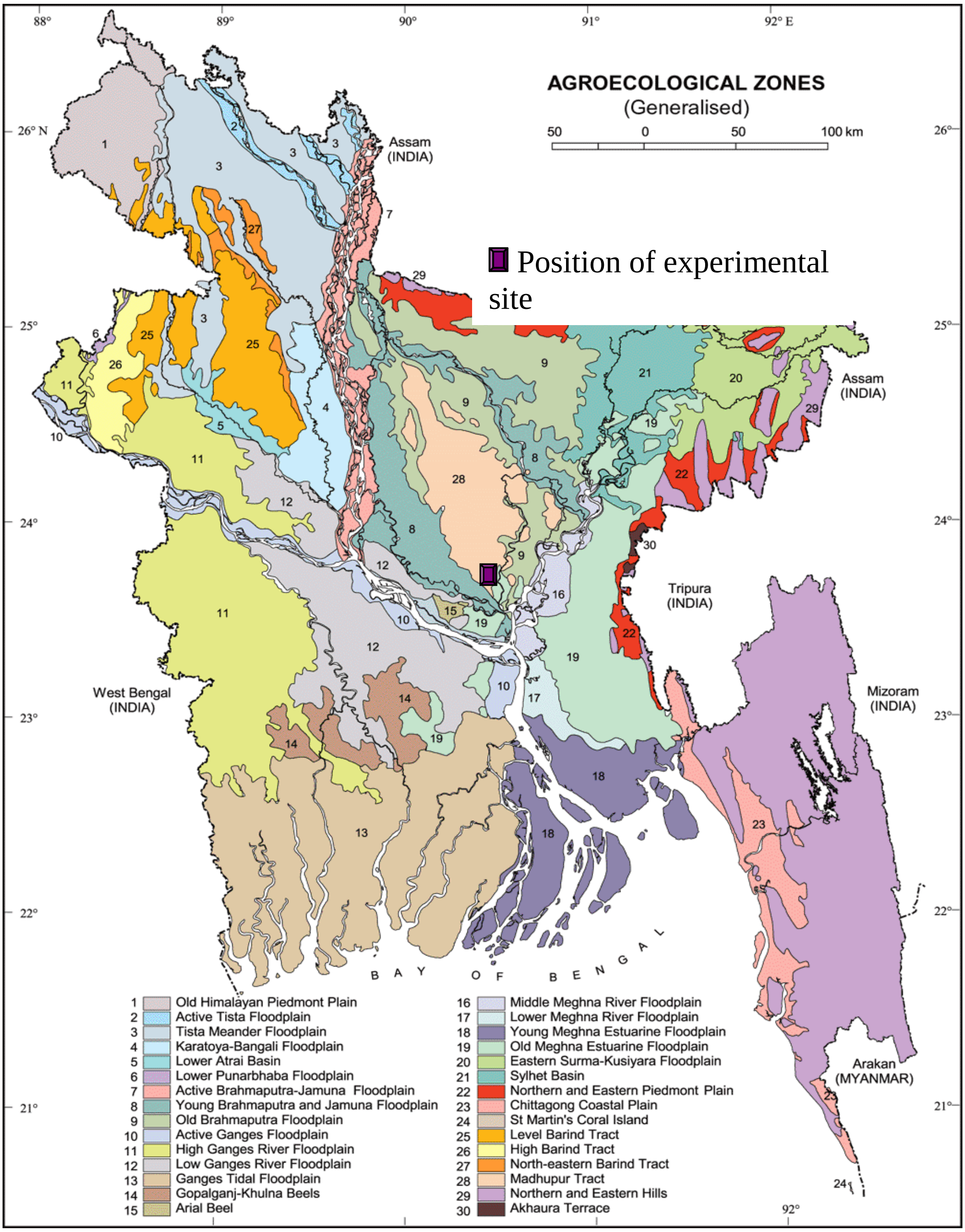
APPENDICES

Appendix I. Map showing the experimental site under study



Appendix II. Monthly average air temperature, relative humidity and total rainfall of the experimental site during 2016-2017

Months	Air temperature (°C)		Relative humidity (%)	Total rainfall (mm)
	Maximum	Minimum		
November	26.98	14.88	71.15	00
December	25.78	14.21	68.30	00
January	25.00	13.46	69.53	00
February	29.50	18.49	50.31	00
March	33.80	20.28	44.95	00

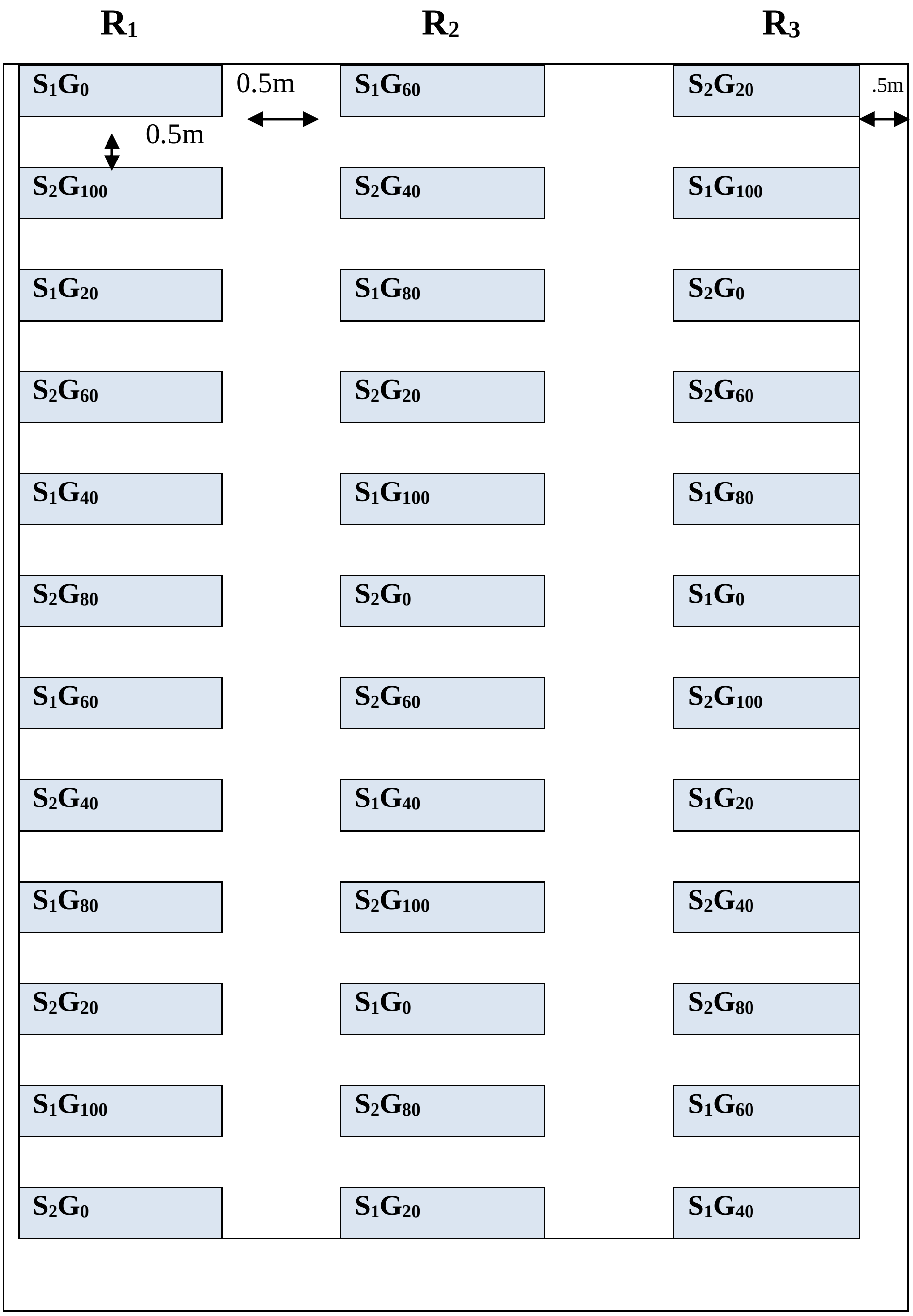
Source: Bangladesh Mateorological Department (climate and weather division), Agargaon, Dhaka

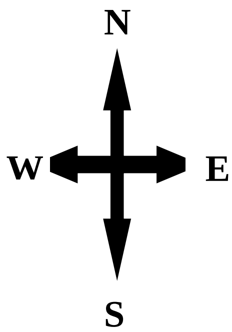
Appendix III. Chemical properties of the soil of experiment field seed before sowing.

CHARACTERISTICS	**VALUE**
pH	5.70
Organic matter (%)	2.35
Total N (%)	0.12
K (me/100 g soil)	0.17
P (Mg/g soil)	8.90
S (Mg/g soil)	30.55
B (Mg/g soil)	0.62
Fe (Mg/g soil)	310.40
Zn (Mg/g soil)	4.82

Source: Soil Resource Development Institute (SRDI), Krishi Khamar Sharak, Dhaka

Appendix IV. Layout and design of the experimental plot





Factor A: Two application time of GA_3
S_1 = GA_3 application at vegetative stage
S_2 = GA_3 application at flowering stage
Factor B: 6 level of GA_3
G_0 = 0 ppm
G_{20} = 20 ppm
G_{40} = 40 ppm
G_{60} = 60 ppm
G_{80} = 80 ppm
G_{100} =100 ppm

Unit plot size:
3.5m x 1.5m

Appendix V: Analysis of variance of the data plant height, number of primary branches per plant, length of siliqua, number of siliqua per plant and number of seed per siliqua of rapeseed as influenced by time of GA_3 and different levels of GA_3

Sources of Variation	Degrees of freedom	Mean Square				
		Plant height	Number of primary branches per plant	Length of siliqua	Number of siliqua per plant	Number of seeds per siliqua
Replication	2	53.25	0.121	0.111	14.524	29.153
Factor A	1	11.96	0.16	0.004	2.668	5.921
Factor B	5	39.563*	1.824*	1.261*	369.4*	3.629*
AB	5	15.664*	0.169*	0.146*	8.022*	3.59*
Error	22	11.791	0.206	0.077	35.75	4.676

*significant at 5% level of probability

Appendix VI: Analysis of variance of the yield and yield contributing character of rapeseed as influenced by time of GA_3 and different levels of GA_3

Sources of Variation	**Degrees of freedom**	Mean Square		
		Thousand seed weight	**Seed yield (t/ha)**	**Stover yield (t/ha)**
Replication	2	0.423	0.046	0.423
Factor A	1	0.589	0.007	0.021
Factor B	5	0.969*	0.106*	0.26*
AB	5	0.222*	0.007*	0.116*
Error	22	0.223	0.015	0.156

*significant at 5% level of probability

PICTURES

Picture 1. Land preparation

Picture 2. Fertilizer application during land preparation

Picture 3. Seedling at 3 days

Picture 4. Irrigation rapeseed field

Picture 5. At flowering stage

Picture 6. Siliqua of rapeseed

Picture 7: Seed of BARI sarisha-14