FOLIAR APPLICATION OF GA_3 ON GROWTH, YIELD TRAITS AND YIELD OF MUSTARD (*Brassica napus* L.)

A THESIS
BY

MST. FARJANA KHATUN
Student No. 2205069
Session: 2022-23
Thesis Semester: July-December, 2023

MASTER OF SCIENCE (M.S.)
IN
AGRONOMY

DEPARTMENT OF AGRONOMY

HAJEE MOHAMMAD DANESH SCIENCE AND TECHNOLOGY UNIVERSITY, DINAJPUR-5200, BANGLADESH

DECEMBER, 2023

FOLIAR APPLICATION OF GA_3 ON GROWTH, YIELD TRAITS AND YIELD OF MUSTARD (*Brassica napus* L.)

A THESIS
BY

MST. FARJANA KHATUN
Student No. 2205069
Session: 2022-23
Thesis Semester: July-December, 2023

A Thesis Submitted To
The Department of Agronomy
Hajee Mohammad Science and Technology University, Dinajpur

A thesis submitted in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE (M.S.)
IN
AGRONOMY

DEPARTMENT OF AGRONOMY

HAJEE MOHAMMAD DANESH SCIENCE AND TECHNOLOGY UNIVERSITY, DINAJPUR-5200, BANGLADESH

DECEMBER, 2023

FOLIAR APPLICATION OF GA_3 ON GROWTH, YIELD TRAITS AND YIELD OF MUSTARD (*Brassica napus* L.)

A THESIS
BY

MST. FARJANA KHATUN
Student No. 2205069
Session: 2022-23
Thesis Semester: July-December, 2023

Approved as to the style and content by:

(Md. Sohrab Hossain) **Supervisor**	**(Dr. Shams Shaila Islam)** **Co-Supervisor**

(Professor Dr. Md. Mominur Rahman)
Chairman
Examination Committee
&
Chairman

DEPARTMENT OF AGRONOMY

HAJEE MOHAMMAD DANESH SCIENCE AND TECHNOLOGY UNIVERSITY, DINAJPUR-5200, BANGLADESH

DECEMBER, 2023

DEDICATED

TO

MY BELOVED PARENTS

ACKNOWLEDGEMENTS

All praises are due to “**Almighty Allah**” the greatest creator and the supreme authority of this universe, who enabled me to pursue my education in Agriculture and to complete as well as to submit the thesis for the degree of Master of Science (M.S.) in Agronomy.

It is my great pleasure to convey my sincere gratitude, admiration, and respect to my esteemed research supervisor **Md. Sohrab Hossain**, Assistant Professor, Department of Agronomy, Hajee Mohammad Danesh Science and Technology University, Dinajpur for his helpful advice for completion of the work, otherwise it would be too tough to complete the thesis with the stipulated period. Sincere appreciation is also due to his constructive criticism and careful corrections of this manuscript.

I feel proud in expressing my respect and gratefulness to my honorable teacher and research co-supervisor **Dr. Shams Shaila Islam**, Department of Agronomy, Hajee Mohammad Danesh Science and Technology University, Dinajpur for her valuable suggestions, friendly support, sincere help and intellectual instruction during the period of experiment. I am also indebted to him for his encouragement and valuable appreciation in preparation of this thesis.

I express my sincere respect to the Chairman, Professor **Dr. Md. Mominur Rahman** and all the teachers Department of Agronomy, Hajee Mohammad Danesh Science and Technology University, Dinajpur for providing the facilities to conduct the experiment and for their valuable advice and sympathetic consideration in connection with the study.

In addition, I would like to thank all office staff of the Department of Agronomy, Hajee Mohammad Danesh Science and Technology University, Dinajpur for their help during research work.

Finally, I would like to express my sense of gratitude, immense indebtedness to my beloved parents, friends, and all relatives for their everlasting love, patience, unlimited sacrifice, blessing, endless inspiration, and cooperation in completing my M.S. degree.

FOLIAR APPLICATION OF GA_3 ON GROWTH, YIELD TRAITS AND YIELD OF MUSTARD (*Brassica napus* L.)

ABSTRACT

A field experiment work was conducted at the Agronomy research field, Hajee Mohammad Danesh Science and Technology University (HSTU), Dinajpur-5200 during the Rabi season from November 2022 to March 2023 to assess the impact of varied GA_3 concentrations on growth, yield and yield traits of mustard var. BARI Sarisha-18 (Canola type). Six levels of GA_3 concentrations viz. G_0 = 0 ppm (control), G_1 = 15 ppm, G_2 = 30 ppm, G_3 = 45 ppm, G_4 = 60 ppm and G_5 = 75 ppm were applied at the vegetative stage, before and after flowering, and the siliqua formation stage. The experiment was designed in Randomized Complete Block Design (RCBD) with three replications. The results showed that 60 ppm of GA_3 significantly influenced the plant height (cm), number of leaves plant^{-1}, number of flowers plant^{-1}, root length (cm), leaf morphology, total fresh and dry weight plant^{-1} (g), number of branches plant^{-1}, number of siliqua plant^{-1}, number of seed siliqua^{-1}, single siliqua weight (g), siliqua length (cm), thousand-seed weight (g), biological yield (t ha^{-1}), stover yield (t ha^{-1}), seed yield (t ha^{-1}) and harvest index (%). The highest result of thousand-seed weight (4.50 g), biological yield (5.16 t ha^{-1}), stover yield (2.68 t ha^{-1}), seed yield (2.48 t ha^{-1}) and harvest index (48.10%) were obtained from the application of 60 ppm GA_3. But the lowest result of thousand-seed weight (3.80 g), biological yield (4.25 t ha^{-1}), stover yield (2.31 t ha^{-1}), seed yield (1.92 t ha^{-1}) and harvest index (45.17%) were obtained from the control. So, it could be concluded that GA_3 at 60 ppm significantly increased all the parameters of mustard variety BARI Sarisha-18.

Key words: Mustard, GA_3, foliar application, growth and yield.

LIST OF CONTENTS

CONTENTS (Contd.)

CONTENTS (Contd.)

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF ABBREVIATIONS

BARI	Bangladesh Agricultural Research Institute
UNDP	United Nations Development Programme
FAO	Food and Agriculture Organization
DAS	Days After Sowing
AEZ	Agro-Ecological Zone
TSW	Thousand Seed Weight
SRDI	Soil Resource Development Institute
HI	Harvest Index
LS	Level of significance
CV	Co-efficient of Variation
TSP	Triple Super Phosphate
MOP	Muriate of Potash
ANOVA	Analysis of Variance
RCBD	Randomized Complete Block Design
%	Percentage
PGR	Plant Growth Regulator

CHAPTER I

INTRODUCTION

Mustard (*Brassica spp*) is one of the most important oil seed crops throughout the world after soybean and groundnut (FAO, 2012). Mustard belongs to genus *Brassica* under the family Brassicaceae and the genus *Brassica* L. holds the most economically valuable position in the tribe Brassicaceae (Bilal *et al.*, 2015). Mustard oil contains high energy and good source of fat-soluble vitamins (viz. A, D, E and K). Approximately 20-25% protein and 40-45% oil are found in mustard seeds (Mondal and Wahab, 2001). The mustard oil is the most beneficial cooking oil, which also has a sizable amount of ω-3 and ω-6 fatty acids, as well as oleic, linoleic, linolenic, palmitic, and strearic acid fatty acids (Gunstone *et al.*, 1994). In Bangladesh, mustard is the leading oil seed crop, covers about 78% of the total oilseeds acreage and 62% of the total production (BBS, 2020). In the year 2022-23 mustard covered 946632.07 acre of land and the production was 547425.32 metric tons (Mt.) (BBS, 2023). This country regularly imports oil because it produces only 2.80 lac m tons of edible oil annually compared to 9.80 lac m tons of requirement (BBS, 2010). To cover the nation's yearly requirement, Bangladesh imports 7 lac m tons of edible oil annually at a cost of Tk. 64430 million (BBS, 2007).

Bangladesh is facing a huge deficit of edible oil. In view of the importance of this crop, attention has to be given to increase its production in order to meet the huge shortage of cooking oil in the country. In this regard, attention has come to be focused on the use of plant growth regulators such as gibberellic acid (GA_3). Gibberellic acid (GA_3) is a phytohormone that is needed in small quantities at low concentration to accelerate plant growth and development. Gibberellins (GAs) constitute a group of tetracyclic diterpenes that are mostly recognized for their effects on plant morphology, flower and fruit development, stem elongation, and leaf expansion (Yamaguchi, 2008; Chauhan *et al.*, 2010). GA_3 increases xyloglucan endotransglycosylase (XET) activity (Potter and Fry, 1994). By catalyzing the breakage and reconstruction of bonds between xyloglucan residues, this enzyme enhances the extensibility of the wall. These facts contribute to the increase in growth characteristics, particularly plant height. Because GA_3 promotes cell division, multiplication, and expansion, the number of branches plant^{-1} increased when it was administered. It is reported that photosynthetic activity increases with the increased leaf growth due to gibberellic acid application and hence better dry matter accumulation.

These findings confirm the earlier results of (Mal *et al.,* 2018; Mukharjee *et al.*, 2006; and Mithra *et al.,* 2005).

Exogenous application of GA_3 has been shown in several experiments on several plant species to increase crop productivity without compromising key physiological processes (Rahman *et al.*, 2004; Bora and Sarma, 2006). Most plants, including *Brassica campestris*, exhibit increased shoot length due to GA_3 ability to accelerate the rate of elongation (Pressman and Shaked, 1991). In *Lupinus albus*, it was similarly noted that GA_3 treatment increased root length (Sidiras and Karsioti, 1996). In mustard plants, GA_3 enhanced dry matter and the leaf-area index (Khan, 1996), whereas in bean leaves, it boosted the photosynthetic rate (Khan *et al.,* 2002). Gibberellic acid (GA_3) builds up quickly in plants under the influence of biotic (McConn *et al.,* 1997) and abiotic (Lehmann *et al.,* 1995) stresses.

The experiment was conducted due to the following objectives:

- To evaluate the effect of GA_3 on growth, yield and yield contributing characters of mustard
- To find out the suitable GA_3 concentrations on the performance of growth, yield and yield contributing characters of mustard

CHAPTER II

REVIEW OF LITERARTURE

Effect of GA_3 on Growth and Yield of Mustard

Akter *et al.* (2007) carried out a field experiment in Bangladesh Institute of Nuclear Agriculture to assess the impact of Gibberellic Acid (GA_3) on the growth and yield of mustard var. Binasarisha-3. Thirty days after seeding, the canopy was sprayed with four concentrations viz., 0, 25, 50 and 75 ppm of GA_3 were sprayed on canopy at 30 days after sowing. The findings demonstrated a considerable increase in plant height, viable siliqua plant^{-1}, flowers plant^{-1}, siliqua plant^{-1} setting, dry matter yield, seeds siliqua^{-1}, and harvest index at 50 ppm of GA_3.

Saha *et al.* (2021) to assess the impact of Gibberellic Acid (GA_3) on the morphological and biochemical characteristics of mustard (var. BINA shorisha-6). Four concentrations of GA_3- 0, 25, 50, and 75 ppm were sprayed into the canopy. The findings demonstrated that the total dry matter plant^{-1}, total chlorophyll content of leaves, number of major and secondary branches plant^{-1}, root, shoot, and shell dry weight plant^{-1}, and protein and oil content in seeds were all significantly impacted by varying levels of GA_3. There were statistically similar effects between the application rate of 50 ppm and 75 ppm in all studied parameters except total dry matter plant^{-1}, while an increased value was recorded under the former application of GA_3. The research findings concluded that, plant growth, dry matter and biochemical attributes in mustard can be increased through a moderately high dose of GA_3 application.

Sumi *et al*. (2021) conducted a field experiment to assess the “Effect of Gibberellic Acid and Sulphur on Growth and Yield of Mustard (*Brassica juncea* L.). The experiment consisting of four levels (control, 20, 40 and 60 kg ha^{-1}) of sulphur and four levels (control, 25, 50 and 75 ppm) of gibberellic acid there by making 16 treatment combinations, were laid out in Factorial Randomized Block Design and replicated three times. The significant increase in plant height, dry weight, number of branches plant^{-1}, number of siliqua plant^{-1}, number of seeds siliqua^{-1}, test weight, seed yield, stover yield and biological yield of mustard was observed with the application of T11 (40 kg S ha^{-1} +50 ppm GA_3), as compared to control.

Saini *et al.* (2017) observed the "Effect of foliar application of GA_3, on yield and quality of Indian mustard [*Brassica Juncea* (L.) Czern. & Coss.] under sodic soil. 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 and quality contributing traits were maximum recorded with foliar sprayed of GA_3 125ppm followed by foliar sprayed with GA_3 90ppm over rest of the treatments including control, during the investigation.

Nehal *et al.* (2018) conducted an experiment to investigate the "Role of GA_3, SA and ABA on growth and yield of Indian mustard [*Brassica juncea* (L.) Czern. & Coss.] under rainfed condition. The treatments were comprised of foliar spray of three plant growth regulators (PGRs) of different concentrations viz., GA_3 (50 ppm, 100 ppm), Salicylic acid (0.5 mM, 0.7 mM) and ABA (10^{-5} M) along with untreated control (distilled water spray) & spraying was done at 30 DAS. PGRs were applied on the foliage of plant at 30 DAS. Drought was imposed for 30 days by curtailing irrigation at 30 DAS and normal condition plots were irrigated at 30 DAS. Normal and rainfed conditions plots were irrigated at 60 DAS. On the basis of results obtained foliar application of plant growth regulators improved all the growth (dry matter partitioning and relative water content) and yield and yield attributing characters under normal and rainfed conditions. But the effect of SA @ 0.7 mM was more pronounced and mitigate the adverse effect of rainfed condition on mustard.

Mobin *et al*. (2007) to evaluate the effects of timing [single spray at pre-anthesis (T_1) and at anthesis (T_2) and double spray at pre- + at anthesis (T_3)] and concentration (0, 10^{-6}, 10^{-5}, 10^{-4} M) of exogenous application of GA_3 on growth, dry matter production, nutrient uptake and yield attributes of Indian mustard (*Brassica juncea* L. Czern and Coss) cv. Varuna. The impact of GA_3 application at T_1 was most conspicuous and resulted in a higher growth, efficient translocation and utilization of nutrients although; T_3 was equally effective but is not preferable as it requires the spray at two time intervals. Among different concentrations of GA_3, 10^{-5} M registered the maximum values for all the parameters studied. GA_3 increased partitioning of biomass to the leaves at the expense of appropriation to the stem at 20 DAF. In this way, an appreciation of the timing of foliar application of GA_3 can be used to manage the resources for maximum production of Indian mustard.

Camposilvan *et al.* (2008) conducted a field study to evaluate how irrigation and the rate and timing of GA_3 treatment affected the production and form of lentil plants. In the experimental field of Rosario University (3301 S and 60°53' W) in Argentina, the experiment was conducted using CV Silvina. Regarding the development of lentils (*Lens culinaris* Medikus subsp. culinaris), little is known about if or how GA_3 influences it. In the field, lentils were treated twice with four different GA_3 concentrations, either with or without irrigation. Plant height, number of branches and pods, 100 seed weight, and yield were all impacted by GA_3 concentration. Increased yield and a higher percentage of pods containing two seeds were observed at a dose of 10 $mg \cdot L^{-1}$. The 50 $mg \cdot L^{-1}$ concentration of GA_3 produced more branches. Application of GA_3 at flowering increased yield by 60%. Irrigation produced the greatest number of pods and the highest yield. Lentil production can be increased by applying concentrations of GA_3 between 10 and 50 $mg \cdot L^{-1}$ at flowering.

Yadav *et al.* (2018) conducted a study titled "Effect of seed priming with plant growth regulators on physiological changes of Indian mustard (*Brassica juncea* L. Czern & Coss.) at the Instructional Farm of Narendra Deva University of Agriculture & Technology, Kumarganj Faizabad (U.P.), during the rabi season of 2016–17. Using a randomized block design with eight treatments, three replications, and the variety Narendra rai (NDR-8501). Together with an untreated control, different doses of GA_3 (100 ppm, 150 ppm, 200 ppm) and SA (50 ppm, 100 ppm, 200 ppm) were administered. Before six hours of sowing, the seed was soaked. At maturity and at 40, 60, and 80 DAS, observations were made. Biochemical characteristics were measured, such as the amount of chlorophyll in green leaves and the percentage of oil in dried seeds. Different GA_3 and SA concentrations soaked in seeds affected every characteristic of mustard crop.

Islam *et al.* (2023) according to the plant growth regulators (PGRs) are recognized to be essential players at different phases of plant growth and development in a variety of environmental circumstances. They are basically natural messengers. Recognizing the role PGRs play in stress reduction, they carried out a factorial randomized pot experiment to assess the effectiveness of three PGRs in reducing the effects of NaCl stress in mustard: gibberellic acid (GA_3), salicylic acid (SA), and triacontanol (Tria). Three foliar sprays of PGRs (GA_3, SA, and Tria), each at 5 µM, were given to the foliage of the plants using a hand sprayer, and the plants were exposed to four concentrations of NaCl (0, 50, 100, and 150 mM). Rising NaCl levels were discovered. The spray of GA_3, SA and Tria under stressed-free and stressed conditions improved the aforesaid attributes while decreasing the generation of stress biomarkers. of sprayed PGRs, SA proved to.

Akhtar *et al.* (2021) carried out to assess the role of gibberellic acid (GA_3) and kinetin on germination and ion accumulation in a Bangladesh wheat (*Triticum aestivum* L.) variety, namely Akbar under salt stress conditions. They found increasing salt (NaCl) stress conditions consistently decreased the rate of germination of wheat. Gibberellic acid alone or in combination with kinetin alleviated the inhibitory effects of salinity on germination. However, kinetin alone further decreased the rate of germination under salt stress. Salt (NaCl) stress increased the accumulation of Na^+ and Cl^- while it decreased K^+ accumulation in germinating seeds. Gibberellic acid caused an increase in K^+ accumulation and a decrease in Na^+ and Cl^- accumulation in the germinating seeds. Kinetin increased Cl^- accumulation and decreased K^+ accumulation in salinity stressed wheat seedlings. Therefore, GA_3 prominently relieved salt stress and improved the seed germination of wheat.

Dawar *et al.* (2020) studied the effects of foliar application of gibberellic acid on growth, yield, and economics of blackgram (*Vigna mungo* L.). The field experiment was conducted during the Kharif season of 2018 at the research field of Pulses Research Unit, Washim Road, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola (Maharashtra). Eleven treatments including the management of gibberellic acid (applying 15, 30, 45 ppm GA_3 at flower and pod initiation phases and control) were studied in blackgram. The numbers of pods cluster^{-1}, length of pod (cm), number of grains pod^{-1}, number of pods plant^{-1}, grain yield plant^{-1} (g), grain yield (kg ha^{-1}), and gross monetary returns were all considerably higher with two administrations of 30 ppm GA_3 during the flower and pod initiation stages than with no application of GA_3. The same treatment recorded higher rain water use efficiency and higher gross returns.

Islam *et al.* (2022) conducted an experiment to know the effect of salt stress on morph-physiological and biochemical changes of wheat (*Triticum aestivum* L. var. BARI Gom-26) as well as mitigation of the adverse effect through exogenous application of Ascorbic Acid (AsA), Silicon (Si) and Gibberellic Acid (GA_3), the experiment was conducted at Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh. In the field experiment, they used four levels of salt stress (0, 50, 80, 120 mM NaCl) at 20 days after sowing and grown up to harvest. AsA (2 mM ascorbic acid), Si (200 µM SiO2), GA_3 (100 µM gibberellic acid) were applied by them as foliar spraying at 20 days interval. They revealed that AsA, Siand GA_3 enhanced the germination and growth performance of seedling under salinity stress. Overall, GA_3 significantly increased the seed germination (%) and seedling growth parameters, while silicon mostly improved the fresh weight and chlorophyll (a, b and a+b) and AsA showed better relative water contents with other parameters.

Nizamani *et al.* (2018) reported that the gibberellic acid (GA_3) is a phytohormone that is required at low concentrations and in tiny amounts to promote the growth and development of plants. Thus, growth regulators can be applied exogenously to a particular crop using GA_3 at the appropriate concentration and time to generate favorable conditions. One such plant growth regulator is gibberellic acid, which can be used to control a range of growth and development phenomena in different types of crops. GA_3 increases plant growth and promotes stem elongation. Days to maturity and flowering, plant height, number of branches, length of siliqua plant, number of seeds, siliqua^{-1}, 1000 seeds, seed yield, and oil content under the concentration of GA_3 10 g ha^{-1}, while days to maturity and number of branches^{-1} were observed under the concentration of GA3 5 g ha^{-1} . The present results concluded that Rainbow, Dunckled, Con-II, and Oscar under the concentration of 10 g ha^{-1} GA_3 found the best concentration for yield and yield attributes of canola.

Buriro *et al.* (2022) noted that the development and yield of canola (*Brassica napus* L.) cenotypes were affected by the foliar application of gibberellic acid3. At the Nuclear Institute of Agriculture, Tandojam, an experiment was conducted in 2017–2018 during the rabi season using four promising canola genotypes to ascertain the effect of the GA_3 foliar treatment on canola growth and outputs. It was observed that earlier days to maturity (108.39) was recorded in genotype R00-100/6 and maximum plant height (162.75), branches per plant (10.33), siliquae plant^{-1} (362.24), siliqua length (7.39 cm), seeds siliqua^{-1} (21.49), seed index (4.50 g) and seed yield (1443.08 kg ha^{-1}) was observed with the application of GA_3 5 g ha^{-1} in SURHRAN-2012 and followed by with the Application of GA_3 6 g ha^{-1} genotype R00- 125/12 and Rainbow (P). The final results suggested from the present findings that the variety SURHRAN-2012 x GA35 g ha^{-1} (foliar application) is a suitable combination for getting maximum yield. Such kind of application of GA_3 has been very advantageous in our current research.

Bharathi and Sekar (2015) observed that the experiment on effect of various forms of urea and GA_3 on floral characters of chrysanthemum (*Chrysanthemum morifolium*

Ramat.) was carried out at Department of Horticulture, Faculty of Agriculture, Annamalai University, Tamil Nadu. Forty five days old rooted cutting of the variety "White" grown on a media containing a mixture of one part of sand, one part of red earth and one part of farm yard manure were subjected to four forms of urea (liquid feeding, tarcoated urea, neemcake coated urea and prilled urea) and four levels of GA_3 (water spray, 50 ppm, 75 ppm and 100 ppm). The highest number of flowers per plant (102), maximum spray length (18.40 cm) and flower diameter (5.27 cm) was obtained from the plants supplied with neemcake coated urea and sprayed with 100 ppm of GA_3 at 60, 90 and 120 days after planting.

Afroz *et al.* (2005) carried a study to know the response of mustard (*Brassica juncea* (L.) Czern & Coss cv. Varuna) to presowing seed treatment with sodium chloride (NaCl) was investigated. The plants raised from treated seeds were sprayed with water or 10^{-6} M GA_3 at the 30-day stage. They imbibed seeds in 1 or 10 mM of NaCl resulted in a decrease in dry mass, leaf chlorophyll content, carbonic anhydrase activity (E.C. 4.2.1.1), nitrate reductase activity (E.C. 1.6.6.1) and net photosynthetic rate at the 60-day stage, and pod number and seed yield at harvest. However, spray application of GA_3 neutralized the ill effect of soaking treatment in NaCl (1 or 10 mM).

Abdel and Al-Rawi (2012) conducted a field experiment in Iraq where Baraka, Adlib and Nineveh lentil cultivars were grown during 2010 growing season in order to discriminate the performance differences between these cultivars under rainfall incidences and supplementary irrigation whenever 25, 50. and 75% of soil water available capacity was depleted, and to find out the crucial growth stage for supplementary watering and the possibility of improving plant growth by the aid of GA_3 rates namely 0, 100, and 200 mg U'. They observed that application of GA_3 substantially improved most yield component traits, particularly that found in (200 mg U) which exceeded that of untreated in seed yield plant^{-1} (7.85%) and harvest index (14.94%). Yield improvement brought about by gibberellins applications might be attributed to the role of gibberellins in growth, and flowering performances. Regression analysis revealed that lentil yield components were linearly responded to varying GA_3 rates accept that of biomass which manifested quadratic correlation.

Keykha *et al.* (2014) conducted a field experiment at Islamic and University, Zahedan, Iran to evaluate the effect of salycylic acid and gibberellic acid on some characteristics in mungbean (*Vigna radiata*) and found that both salicylic acid and gibberellic acid affect the grain yield of mungbean significantly.

Sarker (2015) conducted an experiment at the farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, Bangladesh during the period from November 2012 to March 2013 to study the effect of gibberellic acid and sowing date on water relations and yield of lentil (variety: BARI Masur-6) under residual soil moisture condition. The experiment consists of two factors: Factor A: Sowing date (3) – S1= 27 November, S2= 7 December and S3 = 17 December; Factor B: GA_3 application (just before flowering) (3 levels)-G = 0 ppm (Control); G100=100 ppm and G200 = 200 ppm. He recorded that the highest ER (10.89 mg) and RWC (79.12%) was found from G2 (200 ppm GA_3), in contrary lowest ER (5.33 mg) and RWC (70.28%) was found from G0 (control). For 200 ppm GA_3 application days to first flower bud initiation was earlier (42.67 DAS) than 100 ppm GA_3 (43.33 DAS) and control (44.44 DAS). Highest pods $plant^{-1}$ (32.08), thousand seeds weight (18.38 gin), seed yield (0.82 t ha^{-1}) and stover yield (1.13 t ha^{-1}) was found from G200 (200 ppm GA_3). Whereas, lowest pods $plant^{-1}$ (22.04), thousand seeds weight (16.44 g), seed yield (0.69 t ha^{-1}) and stover yield (0.80 t ha-1) was found from G_0 (control). He revealed that yield of BARI Masur-6 can be significantly increased by applying 200 ppm GA_3 and 100 ppm GA_3 for sowing on late.

Vetrano *et al.* (2020) stated that the exogenous supplementation of plant growth regulators, such as gibberellic acid (GA_3), can be effective in increasing plant growth and vigor, thus helping plants to better cope with salt stress. The supplementation of exogenous GA_3 through the MNS allowed plants to substantially counterbalance salt stress by enhancing various morphological and physiological traits, such as biomass accumulation, leaf expansion, stomatal conductance and water and nitrogen use efficiency.

Bora and Sarma (2006) conducted a study on the effects of pre-soaking treatments of Cycocel [(2-Chloroethyl) trimethyl-ammonium chloride] and Gibberellic acid (GA_3) separately on the growth, yield, and protein content of peas (cv. Aparna and Azad-P^{-1}). The study was done in a randomized block design with three replications. The pH was corrected to 6.0 and fertilizers were applied at the required levels. 10, 100, 250, 500, and 1000 µg mL^{-1} PGR concentrations were employed in conjunction with a control group. Shoot length was measured starting at 7 DAS and every 3 days thereafter. At seven-day intervals, the number of branches from 15 DAS was recorded. On 30 DAS, the amount of chlorophyll was estimated. Characters attributed to yield were recorded on time. Estimates of protein were made using collected seeds. Higher GA_3 concentrations in both kinds reduced the amount of chlorophyll, whereas cycocel enhanced it. The yield characteristics were strongly impacted by both hormones. Maximum pod count per plant, seed production, seed index, and protein content in seeds were achieved in both cultivars when GA_3 was added at 250 µg mL^{-1}. For cvs. Azad-P^{-1} and Aparna, Cycocel documented the greatest number of pods per plant and seed yield at 100 and 250 µg mL, respectively. The highest recorded protein content in seeds was 500 µg/mL of cycocel. The present study clearly shows that judicious application of GA_3 and cycocel can increase yield and protein content in seeds of pea.

Khan *et al.* (2002) reported on a field experiment carried out in 1997–1998 where in 40 days after sowing (pre-flowering), GA_3 (10^{-5} M) was administered to the foliage of mustard grown with 0, 40 (sub-optimal), 80 (optimal), and 120 (supra-optimal) kg N ha^{-1}. Only when plants received enough N (80 kg N ha^{-1}) was foliar spraying of GA_3 beneficial. The application of GA_3 sprays resulted in a considerable increase in plant dry mass, leaf area, carbon dioxide exchange rate, crop growth rate, and relative growth rate. Through the redistribution of nitrogen to seeds, plants treated with GA_3 demonstrated improved nitrogen-use efficiency.

Gurmani *et al.* (2022) found that the used of exogenous application of GA_3 + Si was the best treatment for increasing plant biomass and yield in the presence and absence of NaCl. They found that application of Si or GA_3 enhanced chlorophyll content in the leaves, thereby increasing the net assimilation rate of pea varieties under NaCl stress by increasing the antioxidant enzyme activity. Treatment of Si alone or in combination with GA_3 significantly reduced Na+ movement in both pea varieties. They showed that Si has more prominent role than GA_3 alone to build-up high plant biomass, yield, soluble protein content and reduction of Na+ transport. They concluded that Si can be used as a nutrient for pea under saline or non-saline conditions. Moreover, application of GA_3 has a potential role for increasing salinity tolerance, mostly in sensitive pea varieties.

Rauf *et al.* (2022) conducted a study to know the impact of different concentrations of GA_3 on morpho-physiological and photosynthetic attributes of maize seedlings under salinity stress treatments (no salinity and severe salinity-15 dSm^{-1}). Their GA_3 treatments consisted of 1mM, 2mM, 3mM, 4mM and 5mM GA_3 seed priming and exogenous application in salt condition. They found salt stress particularly at 15 dSm^{-1} reduced the length of shoots and roots, fresh and dry weights, chlorophyll, lycopene, beta-carotine and carotenoid contents in maize plants. Nevertheless, the application of GA_3 improved maize growth under salt stress. Compared with salt, they also found that the 2mM GA_3 treatment (T_4) recorded the highest increase in roots and shoots length, roots fresh and dry weights, shoots fresh and dry weights, chlorophyll content under salt stress compared to other concentrations. Finally they indicated that 2mM GA_3 priming and exogenous application could be used as an effective tool for improving the maize growth and development in salt contaminated soils.

Iqbal *et al.* (2022) reported that the applied of plant growth regulators gibberellic acid (GA_3) and salicylic acid (SA) in the form of foliar spray to two varieties of wheat viz., Anaj-2017 and Ujala-2016 to alleviate the deleterious effects of soil salinity. They applied Salt at the concentration of 150mM after 2 weeks of seed germination. Ten treatments including control were used; T_0 (control), T_1 (150 mM NaCl), T_2 (0.5 mM SA), T_3 (1.0 mM SA), T_4 (100 mg/L GA_3), T_5 (150 mg/L GA_3), T_6 (150 mM NaCl+0.5 mM SA), T_7 (150 mM NaCl+1.0 mM SA), T8 (150 mM NaCl+100 mg/L GA_3), T9 (150 mM NaCl+150 mg/L GA_3). GA_3 and SA were applied after one week of salinity stress and repeated thrice. They revealed that both growth regulators promote the growth of plants treated with salt stress. Anthocyanin was promoted by 0.0035% at 100 mg/L GA_3 while glycine betaine was also enhanced by 0.26% in Ujala-2016 at 150 mg/L. They also noted that 1.0 mM salicylic acid and 150 mg/L gibberellic acid enhanced significantly various growth parameters. In conclusion, they stated that concentration of 0.1 mM SA and 150 mg/L GA_3 along variety Ujala-2016 recommended for the alleviation of salt stress with better growth and yield for future cultivation.

Mukarram *et al.* (2021) investigated whether foliar sprays of 10^{-6} M GA_3 could reverse salinity-implicated constraints in fenugreek plants and to what extent. They suggested that exogenous GA_3 could significantly ($p \leq 0.05$) mitigate the effects of salinity in the fenugreek plants. The treatment they used maximized the growth and yield variables, as well. The activities of various assimilatory enzymes, such as carbonic anhydrase and nitrogen reductase, observed an increment of about 17% each over salt-stressed plants (50 mg L^{-1}). Further metabolomic analyses revealed an upregulated antioxidant defense system with increased activities of superoxide dismutase (18%), catalase (13%), and ascorbate peroxidase (15%). The enhanced proline content (19%) in tandem with upregulated antioxidant enzymes minimized cellular damage by restricting TBARS and

H_2O_2 contents by about 16% and 14%, respectively. They concluded that foliar sprays of 10^{-6} M GA_3 could be used for minimizing the salinity induced growth and yield constraints in the fenugreek crop.

Erbil (2021) carried out an experiment to determine the effect of external giberellic acid applications on then physiological properties and proline level of peanuts under different salt (NaCl) stress conditions on the degree of resistance to salt stress in peanuts. He found that the increased salt applications decreased the leaf chlorophyll content and leaf ions (K, Mg, Ca) content, in contrast, increased the cell membrane permeability, proline content and sodium concentration were determined. The gibberallic asid applied externally against salt stress were determined to have the positive effects on traits; leaf chlorophyll content, ion (K, Na, Mg, Ca) content, cell membrane permeability, proline content.

Sedghi *et al.* (2012) conducted two greenhouse experiments to evaluate the effect of phytohormones on the changes of antioxidant enzymes and carotenoids in petals of pot marigold (*Calendula officinalis* L.) under drought stress. Results showed that the activities of superoxide dismutase and catalase increased 47 and 73% respectively, in petals under water deficit conditions compared with the control plants. Spraying with gibberellic acid (GA_3) and benzyl amino purine (BAP) alleviated drought effects, but application of abscisic acid (ABA), jasmonic acid (JA), salicylic acid (SA) and brassinolid (BR) induced the activity of these enzymes.

Zhu *et al.* (2019) found that the salt-tolerant genotypes and method to explore the interactive amendment effects of exogenous gibberellic acid (GA_3) and salinity on seed germination process of sweet sorghum. They presoaked seeds in different levels of GA_3 water solutions (0,144, 288, and 576 µM) and then cultivated in gradient NaCl solutions (0, 50 and 100 mM). Compared with the effects of 0 µM GA_3 at 0 mM NaCl, they found slight salt stress of 50 mM NaCl improved the cumulative water uptake, germination and germination index, but high salinity level of 100 mM NaCl significantly inhibited these germination traits. However, either 100 mM NaCl or 576 µM GA_3 had significantly negative effects on seed cumulative water uptake, cumulative germination, germination index, and length of germ and radicle. They found appropriate concentration of GA_3 prominently relieved salt stress and improved the seed germination of sorghum seeds, and the optimum concentration for seed germination of sweet sorghum was 288 µM GA_3 at each salinity level.

Álvarez-Méndez *et al.* (2022) carried out a study where papaya seedlings were subjected to salt stress (100 mM NaCl) for 41 d and to exogenous gibberellic acid (GA_3; 0.1 mM) and proline (10 mM) pretreatments to evaluate plant physiological variables linked to stress responses. Analysis of the data showed a general decrease of plant growth parameters induced by solely salt stress compared to control, such as stem height (47%) and thickness (33%) and plant fresh and dry mass (84% and 83%, respectively), as well as a reduction in the stomatal opening (93%), chlorophylls (40%) and carotenoids (71%) concentration. In contrast, they found a significant increase was found in foliar and radicular proline levels under stress (87% and 47%). Exogenous foliar GA_3 or proline respectively induced a better performance of plants under salt stress by increasing stomatal conductance (444% or 350%), stem height (142% or 144%) and plant biomass (49% or 41%) regarding solely stressed plants, and leading to pigments concentrations close to those from control plants. They suggested that exogenous gibberellic acid and proline as growth regulator and osmo-regulator solute, respectively could increase papaya seedlings adaption against salt stress.

CHAPTER III

MATERIALS AND METHODS

This chapter deals with a brief description on the experimental site, climate and weather, planting materials, land preparation, fertilization, experimental design and layout, seed sowing, intercultural operations, harvesting, data collection and statistical analysis etc. The details of this experiment and its methods which are described in this section.

3.1 Description of the experimental site

3.1.1 Location and duration

The experiment was conducted at the research field at the Department of Agronomy of Hajee Mohammad Danesh Science and Technology University, Dinajpur-5200 during the Rabi season from November 2022 to March 2023. Geographically the experimental field is located at 25.63^{o}N and 88.65^{o}E longitude at an altitude of 37.5 m above mean sea level (UNDP and FAO, 1988). The property is located in the Agro-ecological Zone-1 (AEZ-1) which is named as Old Himalayan Piedmont Plain (UNDP and FAO, 1988). (Appendix I).

3.1.2 Soil

The soil of the experimental field belongs to the Old Himalayan Piedmont Plain's Agro-ecological Zone-1 (AEZ-1). The general soil type of the experimental field was non-calcareous dark grey floodplain. The research field was medium-high land with sandy loam textured soil. The initial soil (0-15 cm depth) test revealed that the soil contained 0.10% total nitrogen, 1.06% organic matter, 24.00 µg g^{-1} available phosphorus, 0.26 meq $100g^{-1}$ available potassium, 3.2 µg g^{-1} available sulphur, available boron 0.27 µg g^{-1}, available iron 5.30 µg g^{-1}, available zinc 0.90 µg g^{-1} and pH value of the soil was 5.35. The characteristics of the soil were previously tested in the soil Resource Development Institute (SRDI). Dinajpure-5200 (Appendix II).

3.1.3 Climate and weather

The weather data including temperature, rainfall, and relative humidity during the period of experimentation of Dinajpur district was recorded from the Meteorological Station of Bangladesh Wheat and Maize Research Institute (BWMRI), Nashipur, Dinajpur, Bangladesh are presented in (Appendix III.)

3.1.4 Experimental treatments

The treatments were designated as follows:

Treatment: Six levels of GA_3 Concentrations were used and these six treatments were applied in 4 times.

G_0 = 0 ppm (Control)

G_1 = 15 ppm

G_2 = 30 ppm

G_3 = 45 ppm

G_4 = 60 ppm

G_5 = 75 ppm

3.1.5 Design and Layout

The design of the experiment was conducted in RCBD. There were 6 treatments for one variety with three replications. The total number of experimental units was 18 (6 × 1 × 3). The size each plot was 3 m^2 (2 m × 1.5 m). All the treatments was randomly allocated in the plot. The replication was separated from one another by 1 m spacing.

3.1.6 Planting materials: BARI Sarisha-18 was used in this experiment (Canola type)

The important characteristics of these varieties are mentioned below.
BARI Sarisha-18 (Canola type) is under *B. napus* species of the family Brassicaceae. The plant height is 90-126 cm. There are 80-130 siliqua in each plant and each siliqua contains 28-30 seeds. Plant comparatively dwarf type. Erucic acid content 1.06% in oil. Oil content 40-42% in seed. Field duration of the variety is 95-100 days. The production per hectare is about 2.25 ton (BARI, 2018).

3.2 Procedures of the experiment

3.2.1 Land Preparation

The first plowing of the land took place on November 6, 2022, using a tractor drawn disc plough. Four plowing and harrowing operations using country plough and ladder were necessary to get the ploughed soil into a desired tilth condition. We eradicated the weeds and the stubbles from the previous crops.

3.2.2 Collection of plant material

The seeds were collected from Bangladesh Agricultural Research Institute (BARI), Gazipur. The seeds were healthy, vigorous, well matured and free from other crop seeds and inert materials.

3.2.3 Application of fertilizer

Urea, TSP, MP, Gypsum, Borax and well rotten cow dung were applied to maintain the dose of 250 Kg/ha, 170 Kg/ha, 85 Kg/ha, 150 Kg/ha, 10 Kg/ha and 1000 Kg/ha of urea, TSP, MP, Gypsum, Borax, and cow dung, respectively (BARI, 2018). All manures and fertilizers were added at the time of final pot preparation except urea. Half of urea was applied at the time of final land preparation and another half at 32 days after sowing (DAS).

3.2.4 Sowing of seed

The seeds @ 7 kg ha^{-1} were sown after final land preparation. Line sowing (row to row distance 30 cm and in row seeds were sown manually) procedure was used. After sowing, the seeds were covered with soil and slightly pressed by laddering. The seeds were sown on 7 November, 2022.

3.2.5 Application of GA_3

GA_3 of different doses were applied at vegetative stage, before and after flowering, and the siliqua formation stage.

3.3 Intercultural operations

3.3.1 Thinning

The seedlings were thinned after 15 days of the emergence of the entire seedlings with special care to maintain constant plant population per plot. After establishment of the seedlings, all healthy seedlings were kept in each plot and rest unhealthy seedlings were removed. Plant populations were kept 55-66 per square meter.

3.3.2 Weeding

The crop was infested with some common weeds, which were controlled by uprooting and removed them from the pot whenever infested during the period of experiment.

3.3.3 Irrigation

First irrigation was done 20-25 days after sowing (before flowering) and second irrigation was done 50-55 day after sowing (pod initiation).

3.3.4 Insect and diseases control

The crop was infested with aphid at the time of flowering and was controlled successfully spraying Amister Top Fungicide 325 SC @ 1ml L^{-1} water and interval was 12-15 day.

3.4 Harvesting and threshing

The crop was harvested plot wise when 90% siliqua were matured. After collecting sample plants, harvesting was done on 23 March 2023. The harvested plants were tied into bundles and carried to the threshing floor. The plants were sun-dried by spreading the bundles on the threshing floor. The seeds were separated from the Stover by beating the bundles with bamboo sticks.

3.5 Drying, cleaning and weighting

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. The straw was also sun dried and weighed the yields of grain and straw $plot^{-1}$ was converted to ha^{-1}.

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 20 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 stover yield $plot^{-1}$ were recorded after cleaning and drying those taken from selected plants which were marked by tag. Final field data were collected at harvesting stage.

Data were recorded on the following crop character

A. Growth parameter

1. Plant height (cm)
2. Number of leaves plant^{-1}
3. Number of flowers plant^{-1}
4. Root length (cm)
5. Leaf area index
6. Total fresh weight plant^{-1} (g)
7. Total dry weight plant^{-1} (g)

B. Yield and yield atributes

1. Number of branches plant^{-1}
2. Number of siliqua plant^{-1}
3. Number of seed siliqua^{-1}
4. Single siliqua weight (g)
5. Siliqua length (cm)
6. Thousand-seed weight (g)
7. Biological yield (tha^{-1})
8. Seed yield (tha^{-1})
9. Stover yield (tha^{-1})
10. Harvest index (%)

3.7 Methods of recording data

3.7.1 Plant height (cm)

The height of the plants was measured in four times (30. 50, 70 DAS and at harvest). The plant height was measured from the base of the plant (top of the soil) to the tip of the tallest leaf in order to obtain an accurate data on the height of plants.

3.7.2 Number of leaves plant^{-1}

Total number of leaves was taken at harvest. All the leaf present on randomly selected plants were counted and average number of leaf plant^{-1} was taken.

3.7.3 Number of flowers plant^{-1}

All the flowers present on randomly selected plants were counted and an average number of flowers plant^{-1} was taken.

3.7.4 Root length (cm)

At first root was cleaned by dipping into the water to remove mud, and then its length was measured using the measuring scale.

3.7.5 Leaf area index

The leaf was dry and clean after being removed from the chosen sample. These dried leaves were measured with the portable handheld leaf area meter.

3.7.6. Total fresh weight and dry weight plant^{-1} (g)

After taking plant height, stem fresh weight were taken and those were kept in open at 80 ^{o}C for three days. Then the dry weight was taken.

3.7.7 Number of branches plant^{-1}

The number of branches plant^{-1} was counted from ten randomly sampled plants. It was done by counting the total number of all sampled plants then the average data were recorded.

3.7.8 Number of siliqua plant^{-1}

Number of siliqua plant^{-1} was counted from randomly selected ten plants after harvest and averaged them to have number of siliqua plant^{-1}.

3.7.9 Number of seeds siliqua^{-1}

The seed sliliqua^{-1} was counted from 10 selected plants and then average seeds number calculated.

3.7.10 Single siliqua weight (g)

After harvesting 10 randomly chosen sample plants from each plot, then the weight of each single siliqua was measured using a digital electrical balance and expressed in grams.

3.7.11 Length of siliqua (cm)

Number of siliquae was recorded from randomly selected 10 sample plants after harvest and mean number was expressed in cm.

3.7.12 Thousand-seed weight (g)

One thousand dried and cleaned seeds were counted randomly from the seed stock and weighed of seeds. Then the weight of 1000 seeds were recorded by means of a digital electrical balance and expressed in gram.

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

The summation of seed yield and above ground stover yield was the biological yield. The biological yield was calculated by using the following formula:

$$\text{Biological yield} = \text{Seed yield} + \text{Stover yield.}$$

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

The stover obtained from the harvested area of each unit plot was dried separately and weight was recorded. These values were expressed in tha^{-1}.

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

Seeds obtained from harvested area of each unit plot were dried in the sun and weighed. The seed weight was expressed in tha^{-1}.

3.7.16 Harvest index (%)

Harvest index is the ratio of seed yield and biological yield (Gardner *et al.,* 1985). It was calculated by using the following formula:

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

3.8 Data Analysis

A computer program called Statistix10 was used to assist in the statistical analysis of the data using the analysis of variance (ANOVA) technique.

CHAPTER IV

RESULTS AND DISCUSSION

The current study examined the foliar application of varied concentrations GA_3 on growth, yield and yield contributing characteristics of mustard plants. The results have been presented and discussed, and possible explanations have been given under the following headings:

4.1 Effect of GA_3 on different growth parameters of mustard variety BARI Sarisha-18

4.1.1 Plant height (cm)

According to the experiment findings, different concentrations of GA_3 had significantly influenced the plant height (Table 1). The tallest plant height was produced with the application of 60 ppm GA_3 (16.30, 35.00, 130.20 and 147.20 cm) was recorded at 30, 50, 70 DAS and at final harvest time respectively. The shortest plant height was observed from the control treatment (13.00, 25.80, 98.23 and 125.00 cm) at 30, 50, 70 DAS and at final harvest time respectively. The results indicated that the application of different concentrations of GA_3 had increased the plant height over the control treatment. Significant increase in plant height induced by different levels of GA_3 was observed in rapes (Castro *et al.*, 1989). But up to 60 ppm GA_3 was applied, a gradual increase in plant height was noticed. Also increase in concentration 75 ppm GA_3 had resulted in reduced plant height.

Gibberellic acid administration may have expedited cell expansion, which might account for the rise in plant height seen with varying amounts of GA_3 (Hasioet *et al.*, 1976). According to Ravat and Makani (2015), GA_3 promotes intermodal length by increasing cell proliferation, elongation, and cell wall plasticity. Additionally, it has been suggested that microtubule elongation may be the cause of axial elongation following GA_3 administration.

Table 01: Effect of GA_3 on the plant height of mustard variety at different DAS

Concentrations of GA_3 (ppm)	Plant height (cm)			
	30 DAS	**50 DAS**	**70 DAS**	**At harvest**
0	13.00 c	25.80 d	98.23 d	125.00 e
15	14.00 bc	29.20 c	107.60 c	131.60 d
30	15.00 ab	31.80 b	115.40 b	137.80 c
45	15.50 ab	33.40 ab	126.47 a	142.60 b
60	16.30 a	35.00 a	130.20 a	147.20 a
75	15.30 ab	32.10 b	117.50 b	139.40 c
LS	*	**	**	**
CV (%)	6.89	4.50	2.36	1.20

Here**,** ** = significantly different at 1% level of probability; * = significantly different at 5% level of probability and NS = Non significance, LS = Level of significance; CV = Co-efficient of variance

4.1.2 Number of leaves plant^{-1}

The number of leaves plant^{-1} of mustard was shown to be significantly impacted by the various concentrations of GA_3. According to the figure 1, the highest number of leaves plant^{-1} (5.33, 10.00 and 36.4) was found with the foliar application of 60 ppm GA_3 at 30, 50, and 70 DAS respectively. On the other hand, the lowest number of leaves plant^{-1} (3.97, 8.60 and 19.20) was recorded by the control at 30, 50, and 70 DAS respectively. Mithra and pathak (2005) were reported that the photosynthetic activity increases with the increased leaf growth due to gibberellic acid application and hence better dry matter accumulation.

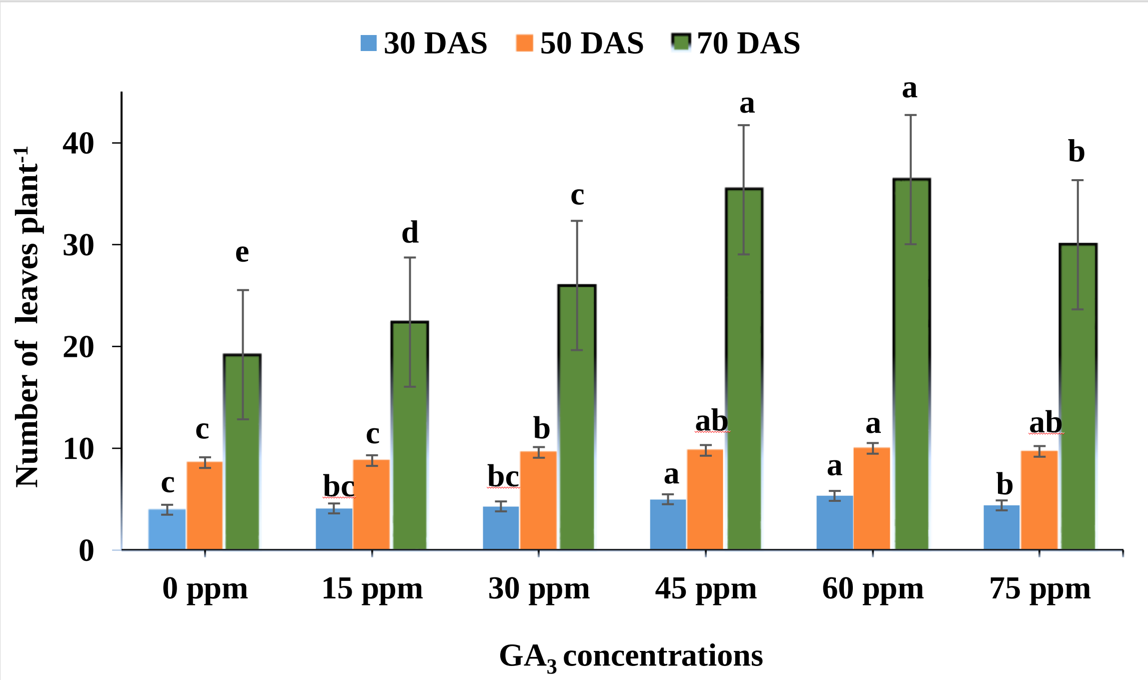


Fig. 1: Effect of different levels of GA_3 concentration on number of leaves plant^{-1} of mustard at different DAS

4.1.3 Number of flowers plant^{-1}

The application of several concentrations of GA_3 had greatly influenced the number of flowers plant^{-1}. The highest number of flowers plant^{-1} (392.00) was observed with the application of 60 ppm of GA_3 concentration (Fig. 2). The lowest number of flowers plant^{-1} (207.78) was produced in the control. Exogenous application of GA_3 has been shown to increase the number of siliqua per plant due to enhanced flowering (Rahman *et al.*, 2004; Bora and Sarma, 2006) .

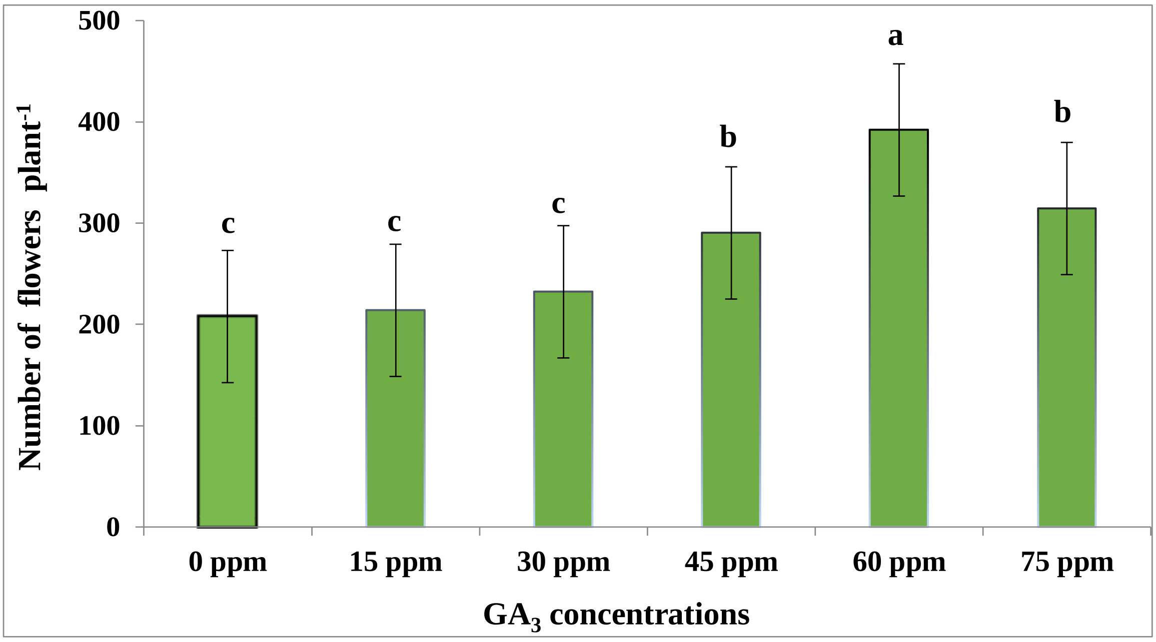


Fig. 2: Effect of different levels of GA_3 concentration on number of flowers plant^{-1} of mustard

4.1.4 Root length (cm)

Different concentration of GA_3 had significant effects on the root length (Table 2). The application of 60 ppm GA_3 recordated in the highest root length (5.34, 15.00, 14.34 and 12.02 cm), which was measured at 30, 50, 70 DAS as well as harvest time and control treatment showed the lowest root length (3.00, 4.50, 7.50 and 8.32 cm) respectively was recorded at 30, 50, 70 DAS and at harvest time. Saha *et al.* (2021) observe that the increase of root length with different levels of GA_3 application may be a mechanism of plant survival by absorbing more moisture through extending their root system into deeper soil.

Table 2: Effect of GA_3 on root length of mustard variety at different DAS

Concentrations of GA_3 (ppm)	**Root length (cm)**			
	30 DAS	**50 DAS**	**70 DAS**	**At harvest**
0	3.00 d	4.50 e	7.50 d	8.32 d
15	3.50 cd	7.03 d	8.67 d	8.78 cd
30	4.00 bc	10.17 c	10.00 cd	9.56 bc
45	4.67 ab	13.17 b	12.67 ab	10.62 b
60	5.34 a	15.00 a	14.34 a	12.02 a
75	4.40 b	12.00 b	11.67 bc	10.27 b
LS	**	**	**	**
CV (%)	10.60	7.87	13.08	6.31

Here**,** ** = significantly different at 1% level of probability; * = significantly different at 5% level of probability and NS = Non significance, LS = Level of significance; CV = Co-efficient of variance

4.1.4 Leaf morphology

The effects of different levels of GA_3 influenced the leaf morphology significantly (Table 3). From the results, it was observed that the maximum leaf area (7700.80 mm^2), leaf width (104.05 mm), leaf length (109.08 mm) and leaf width length ratio (1.34) was found from 60 ppm of GA_3 , while the minimum leaf area (3608.30 mm^2), leaf width (61. 82 mm), leaf length (58.77 mm) and leaf width length ratio (0.71) was observed under control. Saran (1992) conducted an experiment with GA_3 at 0, 10 or 100 ppm and also found that chlorophyll content was increased by 10 ppm.

Table 3: Effect of GA_3 on leaf morphology of mustard variety

Concentrations of GA_3 (ppm)	Leaf morphology			
	Leaf Area (mm^2)	Leaf Width (mm)	Leaf Length (mm)	Leaf Width: Leaf Length
0	3608.30 e	61. 82 d	58.77 d	0.71 c
15	4958.50 cd	79.10 c	75.63 c	0.87 bc
30	4501.00 de	88.03 bc	89.01 bc	0.99 abc
45	6376.30 b	96.24 ab	100.07 ab	1.17 ab
60	7700.80 a	104.05 a	109.08 a	1.34 a
75	5971.20 bc	89.13 abc	88.67 bc	1.03 abc
LS	**	**	**	*
CV (%)	12.35	10.18	10.54	19.14

Here**,** ** = significantly different at 1% level of probability; * = significantly different at 5% level of probability and NS = Non significance, LS = Level of significance; CV = Co-efficient of variance

4.1.5 Total fresh and dry weight of plant^{-1} (g)

A significant variation was found in terms of fresh and dry weight due to the application of different levels of GA_3 (Table 4). Among the levels, the highest fresh weight plant^{-1} (3.74, 55.14, 77 g) and dry weight plant^{-1} (0.30, 9.44, 12.56 g) was found with 60 ppm GA_3 at different days after sowing. The lowest fresh weight plant^{-1} (2.29, 25.63, 53.27 g) and dry weight plant^{-1} (0.14, 3.56, 7.53g) was obtained from control at different days after sowing. Application of 10^{-5} M of GA_3 on mustard at 40 or 60 days after sowing significantly increased total dry matter (Khan *et al.*, 1998). Khan *et al.* (2002) observed an increase in total dry matter in *Brassica juncea* with the application of 10^{-5} M GA_3.

Table 4: Effect of GA_3 on total fresh and dry weight plant^{-1} of mustard variety at different DAS

Concentrations of GA_3 (ppm)	Total fresh weight plant^{-1} (g)			Total dry weight plant^{-1} (g)		
	30 DAS	50 DAS	70 DAS	30 DAS	50 DAS	70 DAS
0	2.29 c	25.63 e	53.27 c	0.14 d	3.56 e	7.53 d
15	2.97 bc	32.90 d	66.04 b	0.15 d	4.23 e	8.07 d
30	3.27 ab	39.67 c	69.25 ab	0.18 c	6.23 d	9.38 c
45	3.51 ab	45.99 b	73.82 ab	0.25 b	8.17 b	10.66 b
60	3.74 a	55.14 a	77.00 a	0.30 a	9.44 a	12.56 a
75	3.40 ab	43.53 bc	72.64 ab	0.23 b	7.35 c	10.38 bc
LS	*	**	**	**	**	**
CV (%)	12.70	7.14	7.13	6.56	6.47	6.41

Here**,** ** = significantly different at 1% level of probability; * = significantly different at 5% level of probability and NS = Non significance, LS = Level of significance; CV = Co-efficient of variance

4.1.6 Number of branches plant^{-1}

The application of different concentrations of GA_3 significant influenced the number of branches plant^{-1} (Fig. 3). The results indicated that 60 ppm of GA_3 concentration produced the maximum number of branches plant^{-1} (10.53) which was statistically similar with 45 ppm GA_3 and the minimum number of branches plant^{-1} (3.70) was found at control. The number of branches plant^{-1} increased with the applied GA_3 due to its function of cell division, multiplication and enlargement (Mukharjee and Roy, 2006).

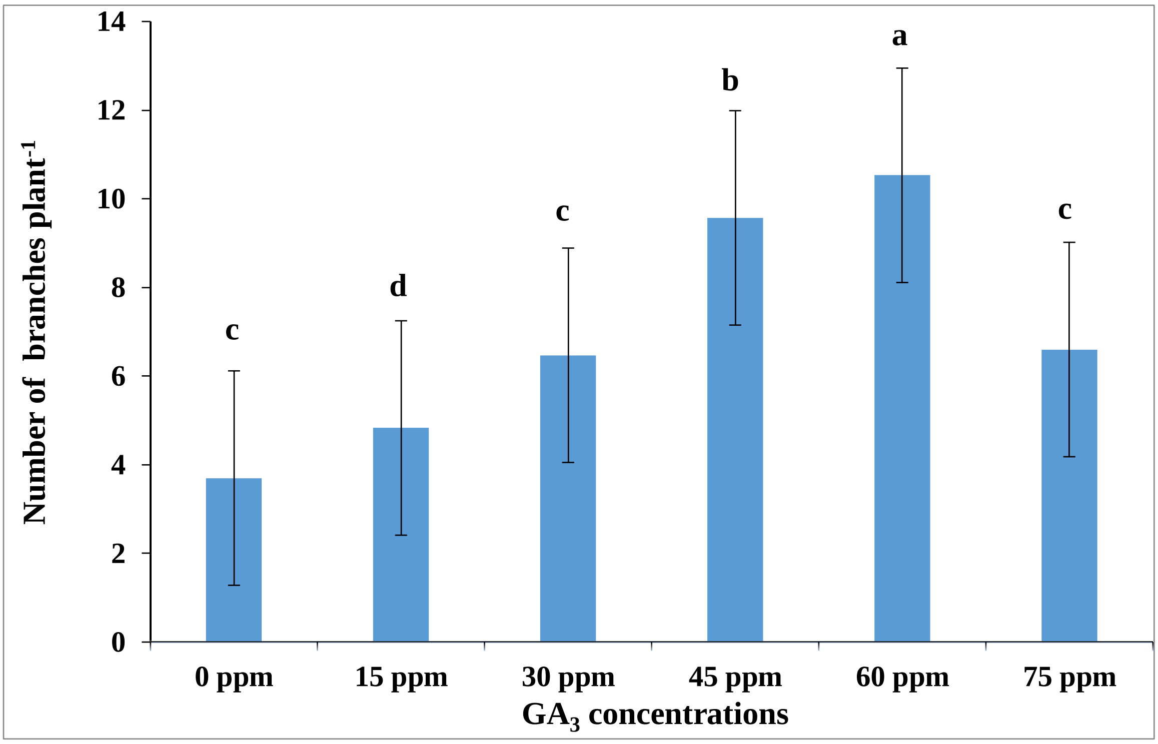


Fig. 3: Effect of different levels of GA_3 concentration on number of branches plant^{-1} of mustard

4.2 Effect of GA_3 on the different yield contributing characters of mustard variety BARI Sarisha-18

4.2.1 Number of siliqua plant^{-1}

The setting of siliqua plant^{-1} was influenced by the application of varying concentration of GA_3. With the application of 60 ppm GA_3 concentration, the highest setting of siliqua plant^{-1} (194.97) was noted, while the lowest setting of siliqua plant^{-1} (65.20) was found under the control (Fig. 4). With the level of GA_3 raised up to 60 ppm, the proportion of siliqua setting increased as well. However, as GA_3 concentration increased further, the percentage of siliqua setting plant^{-1} was reduced. GA_3 might have increased the translocation of assimilates to the reproductive organ which resulted in the maximum number of siliqua plant^{-1} up to certain levels of GA_3 application (Uddin *et al.*, 1986; Kandil, 1983).

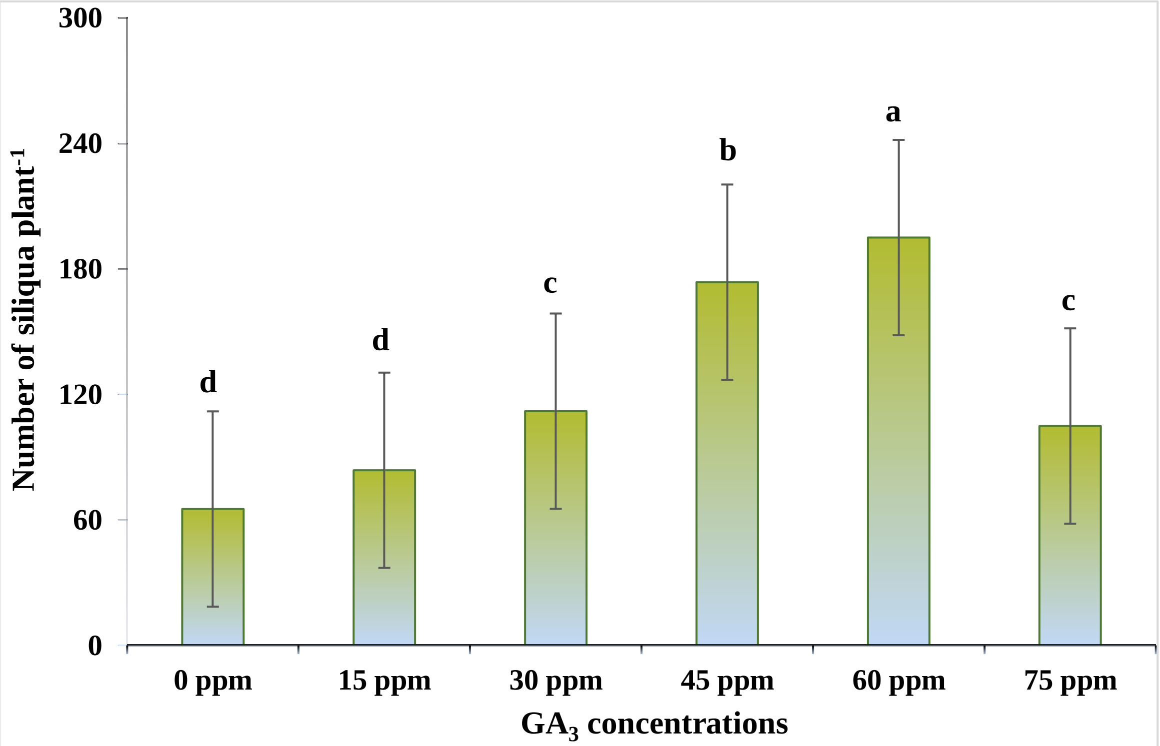


Fig. 4: Effect of different levels of GA_3 concentration on number of siliqua plant^{-1} of mustard

4.2.2 Length of siliqua (cm)

The study findings showed that varying concentrations of GA_3 was a substantial impact on the length of mustard siliqua (Fig. 5). The maximum length of siliqua (7.79 cm) was recorded with the 60 ppm GA_3 concentration. In contrast, the minimum siliqua length (5.29 cm) was obtained from control. Zebarjadi *et al.*, (2011) also found similar result of siliqua length with GA_3 application up to a certain point.

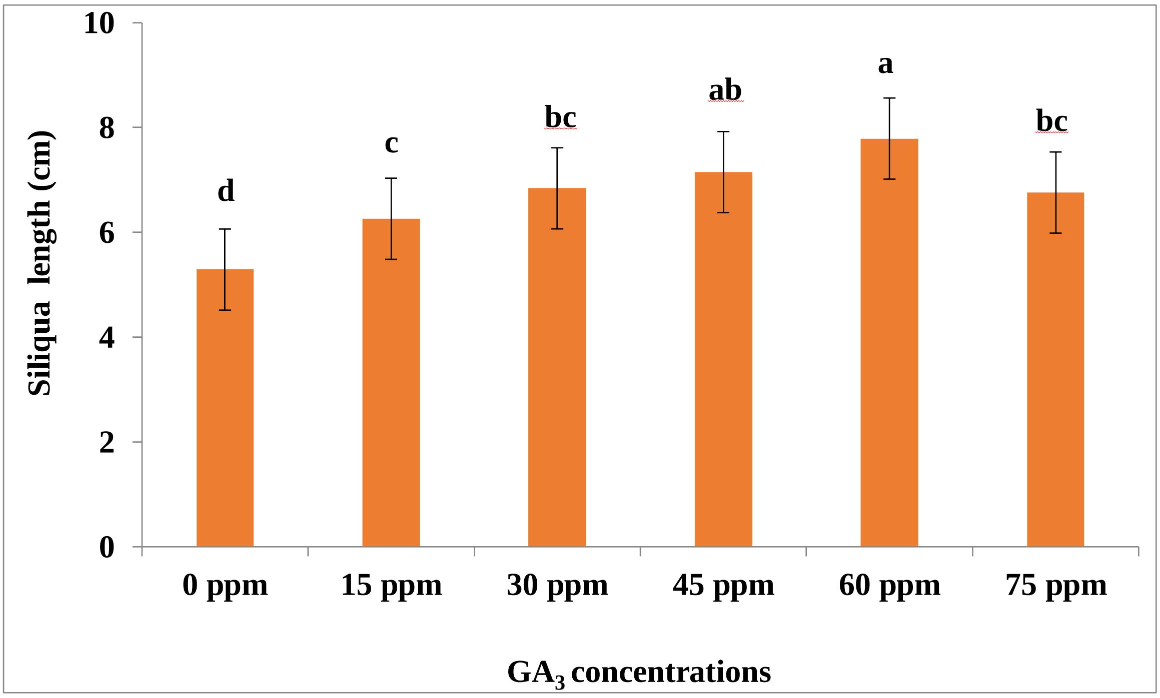


Fig. 5: Effect of different levels of GA_3 concentration on siliqua length (cm)

4.2.3 Single siliqua weight (g)

The application of various GA_3 concentrations had a considerable impact on the single siliqua weight (Fig. 6). At 60 ppm GA_3 concentration, the highest single siliqua weight (0.18 g) was obtained, while the control group recorded the lowest single siliqua weight (0.13g). The maximum single siliqua weight could be produced at a dose of 60 ppm GA_3, which was statistically similar with the 45 ppm GA_3 concentration, according to the results.

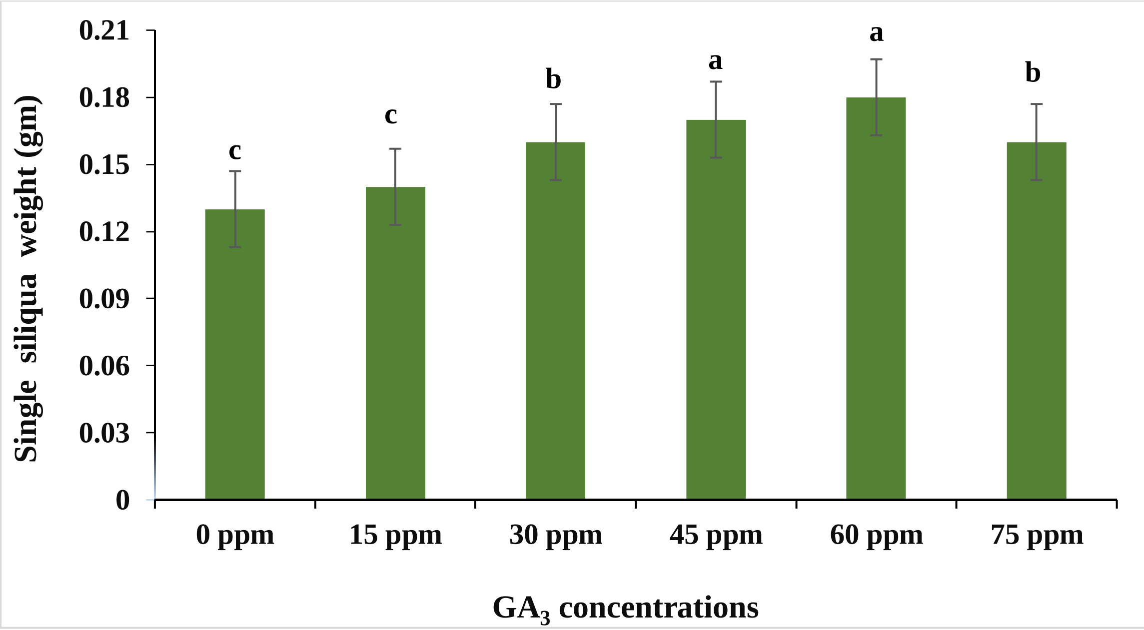


Fig. 6: Effect of different levels of GA_3 concentration on single siliqua weight (g)

4.2.4 Number of seed siliqua^{-1}

Different amounts of GA_3 greatly affected the number of seeds siliqua^{-1} (Fig. 7). The results showed that the maximum number of seeds siliqua^{-1} (27.40) was obtained from 60 ppm GA_3, which was statistically identical to 45 ppm GA_3 while the untreated control had the lowest number of seeds siliqua^{-1} (18.50).

The plant growth regulators like GA_3 might be involved in formation of seeds in the pods and their optimum nourishments have resulted in less number of aborted seeds and thus maximized the survival of fertile seeds siliqua^{-1} in rapes and mustard (Inanaga and Kumura, 1987; Holmberg and German, 1991; Boultior and Morgan, 1992).

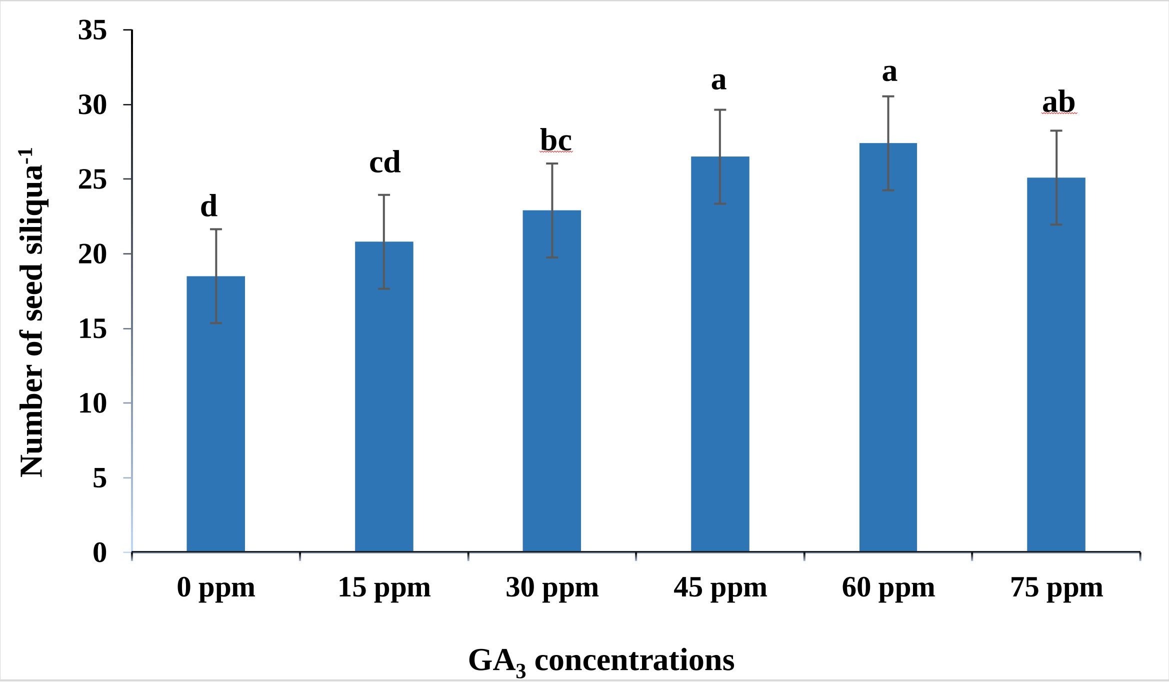


Fig. 7: Effect of different levels of GA_3 concentration on number of seed siliqua^{-1}

4.3 Effect of GA_3 on yield traits and yield parameters of mustard variety BARI Sarisha-18

4.3.1 Thousand-seed weight (g)

The mustard thousand-seed weight was significantly impacted by varying levels of GA_3 concentration (Table 5). The 60 ppm GA_3 had the highest thousand-seed weight (4.50 g), while the control treatment plots yielded the lowest (3.80 g). The highly significant results for thousand seed weight were also supported by the earlier results of (Zebarjadi et al., 2011).

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

Different levels of GA_3 concentrations had significant effect on seed yield (Table 5). The application of 60 ppm GA_3 produced the highest seed yield (2.48 t ha^{-1}) while the control plant produced the lowest seed yield (1.92 t ha^{-1}). The application of 60 ppm of GA_3 was more effective to reduce yield loss due to siliqua shattering. Khan *et al.* (2002) conducted an experiment in a field trial with GA_3 at 0, 10^{-4}, 10^{-5} and 10^{-6} M observed an ^{6} M on 30 days old plants showed increased vegetative growth and seed yield at harvest.

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

Stover yield of mustard for different doses of GA_3 concentration showed statistically significant variation (Table 5). The maximum stover yield (2.68 t ha^{-1}) was recorded from the 60 ppm GA_3 and the minimum stover yield (2.31 t ha^{-1}) was found in the control treatment.

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

A statistically significant variation was found in biological yield of mustard by different levels of GA_3 concentration (Table 5). The maximum biological yield (5.16 t ha^{-1}) was obtained by 60 ppm GA_3. On the other hand, minimum biological yield (4.25 t ha^{-1}) was recorded by 0 ppm GA_3 (control).

4.3.5 Harvest index (%)

The results showed that different concentrations of GA_3 had significant influence on the harvest index (Table 5). The highest harvest index (48.10%) was observed from 60 ppm GA_3 and the lowest harvest index (45.17%) was obtained in 0 ppm GA_3 (control). The higher harvest index indicated that GA_3 application accelerated assimilate supply to sink, which is in agreement with the results of (Gouping and Etmal, 1993). GA_3 at 0-75 mg/L applied at 600 liters/ha at the pre flowering stage on Indian mustard (*Brassica Juncea*) was reported to increase the harvest index (Khan, 1997).

Table 5: Effect of GA_3 on yield traits and yield parameters of mustard

Concentrations of GA_3 (ppm)	Thousand-seed weight (g)	Seed yield (t ha^{-1})	Stover yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
0	3.80 d	1.92 cd	2.31 d	4.25 c	45.17 ab
15	3.94 cd	1.98 d	2.33 d	4.29 c	46.16 b
30	4.12 bcd	2.13 bcd	2.46 c	4.59 b	46.40 ab
45	4.31 ab	2.27 ab	2.55 b	4.82 b	47.12 ab
60	4.50 a	2.48 a	2.68 a	5.16 a	48.10 a
75	4.22 abc	2.17 bc	2.49 bc	4.66 b	46.53 ab
LS	**	**	**	**	NS
CV (%)	4.48	5.37	1.67	3.18	2.46

Here**,** ** = significantly different at 1% level of probability; * = significantly different at 5% level of probability and NS = Non significance, LS = Level of significance; CV = Co-efficient of variance

CHAPTER V

SUMMARY AND CONCLUSION

The experiment work was conducted in the experimental field at the Department of Agronomy, Hajee Mohammad Danesh Science and Technology University (HSTU), Dinajpur-5200 during the Rabi season from November 2022 to March 2023, to assess the impact of varied GA_3 concentrations on mustard growth, yield and yield contributing characters of mustard var. BARI Sarisha-18 (Canola type). The land of the experiment was medium high land belonging to the Agro-ecological Zone "AEZ-1" named as Old Himalayan Piedmont Plain. The experiment was designed in Randomized Complete Block Design (RCBD) with three replications. The total number of experimental unit was 18 (6 × 1 × 3). The size each plot was 3 m^2 (2 m × 1.5 m). The replication was separated from one another by 1 m spacing. Each replication was divided into 6 treatment combinations were allotted at random. The seed of BARI Sarisha-18 was used in this experiment as a variety and foliar application of different GA_3 concentration (0 ppm, 15 ppm, 30 ppm, 45 ppm, 60 ppm and 75 ppm) was used in this experiment as a treatment.

The mustard seed were sown on 7 November, 2022 and the crop was harvested on 23 March, 2023. The data were collected plot wise for plant height (cm), number of leaves $plant^{-1}$, number of flowers $plant^{-1}$, root length (cm), leaf morphology, total fresh weight $plant^{-1}$ (gm), total dry weight of $plant^{-1}$ (gm), number of branches $plant^{-1}$, number of siliqua $plant^{-1}$, number of seeds $siliqua^{-1}$, single siliqua weight (gm), siliqua length (cm), thousand-seed weight (gm), seed yield (t ha^{-1}), stover yield (t ha^{-1}), biological yield (t ha^{-1}) and harvest index (%). All the data statistically analyzed by Statistix10. The results of the experiment are stated bellow:

GA_3 had significant effect, among all the growth parameters like plant height (cm), number of leaves $plant^{-1}$, number of flowers $plant^{-1}$, root length (cm), leaf area index, total fresh and dry weight $plant^{-1}$ and number of branches $plant^{-1}$ was found highest values with the 60 ppm foliar application. Lowest values of these parameters were also recorded from the control treatment.

The yield contributing traits in mustard plants were significantly impacted by GA_3 application. The highest setting of siliqua plant^{-1} (194.97) was noted with the application of 60 ppm GA_3 concentration, while the lowest setting of siliqua plant^{-1} (65.2) was found under the control treatment. The maximum length of siliquae (7.79 cm) was recorded with the 60 ppm GA_3 concentration and the minimum siliquae length (5.29 cm) was obtained from control. Again, the highest single siliqua weight (0.18 g), the maximum number of seeds siliqua^{-1} (27.4) and the highest thousand seed weight (4.50 g) were obtained from 60 ppm of GA_3 concentration. Minimum values of these parameters were found in control.

The yield parameters were also significantly impacted by varying GA_3 concentration. The highest seed yield (2.48 t ha^{-1}), the maximum stover yield (2.68 t ha^{-1}), the maximum biological yield (5.16 t ha^{-1}) and the highest harvest index (48.10%) were found from 60 ppm of GA_3 concentration. But the lowest seed yield (1.92 t ha^{-1}), the minimum stover yield (2.31 t ha^{-1}), the lowest thousand seed weight (3.80 g), minimum biological yield (4.25 t ha^{-1}), and the lowest harvest index (45.17%) were recorded from the control.

Considering the above results of this experiment, it may be summarized that growth, yield and yield contributing characters of mustard are positively correlated with GA_3 application. Therefore, the present experimental results suggest that the application of 60 ppm GA_3 had positive impact on growth and yield of mustard. The yield loss had been reduced by the application of 60 ppm GA_3. So, the application of 60 ppm GA_3 seems to have the possibility to increase the yield of mustard.

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

- Such study is needed in different agro-ecological zones (AEZ) of Bangladesh to investigate regional adaptability and other performance.
- It needs to conduct more researches of GA_3 application to investigate the growth and yield BARI Sarisha- 18.
- It needs to conduct more advanced and related experiments with other varieties of mustard and also in different climate and soil condition.

REFERENCES

Abdel, C. G. and I. M. T. Al-Rawi. 2012. The influence of varying gibberellic acid on growth and yield of three lentil (*Lens culinaris* Medik Sub Species Culinaris) cultivars grown under supplementary irrigation. Int. J. Environ. Water. 1(2): 137-153.

Afroz, S., F. Mohammad, S. Hayat and M. H. Siddiqui. 2005. Exogenous application of gibberellic acid counteracts the ill effect of sodium chloride in mustard. Turkish. J. Biochem. 29(4): 233-236.

Akhtar, N., A. Karim, S. Afrin and F. Hossain. 2021. Effects of gibberellic acid and kinetin on germination and ion accumulation in a bangladesh wheat variety under salt stress conditions. Eur. J. Bioph. 9(2): 86-91.

Akter, A., E. Ali, M. M. Z. Islam, R. Karim and A. H. M. Razzaque. 2007. Effect of GA_3 on growth and yield of mustard. Int. J. Susta. Crop Prod. 2(2): 16-20.

Álvarez-Méndez, S. J., A. Urbano-Gálvez and J. Mahouachi. 2022. Mitigation of salt stress damages in Carica papaya L. seedlings through exogenous pretreatments of gibberellic acid and proline. Chil. J. Agri. Res. 82(1): 167-176.

BARI. 2018. Bangladesh Agricultural Research Institute. Annual Report for 2017-2018 Gazipur-1701, Bangladesh. pp. 1- 385.

BBS (Bangladesh Bureau of Statistics). 2007. Statistical Year Book of Bangladesh. Bangladesh Bureau of Statistics. Statistics Division, Ministry of Planning, Government of Bangladesh.

BBS (Bangladesh Bureau of Statistics). 2010. Statistical Year Book of Bangladesh. Bangladesh Bureau of Statistics. Statistics Division, Ministry of Planning, Government of Bangladesh.

BBS (Bangladesh Bureau of Statistics). 2020. Statistical Year Book of Bangladesh. Bangladesh Bureau of Statistics. Statistics Division, Ministry of Planning, Government of Bangladesh. p. 172.

BBS (Bangladesh Bureau of Statistics). 2023. Yearbook of agricultural statistics, Bangladesh Bureau of Statistics. Statistics and Informatics Division (SID), Ministry of Planning, Government of the People's Republic of Bangladesh.

Bharathi, S. and K. Sekar. 2015. Effect of various forms of urea and GA_3 on floral characters of chrysanthemum (*Chrysanthemum morifolium* Ramat). Int. J. Environ. Agric. Res. 1: 6-11.

Bilal, M., S. A. Khan, H. Raza, F. Ali, S. H. Khan, N. Ali and J. Khan. 2015. Evaluation of some indigenous rapeseed genotypes for adaptability and yield traits in the agro-climatic conditions of Mansehra. Int. J. Biosci. 7(5): 127-135.

Bora, R. K. and C. M. Sarma. 2006. Effect of gibberellic acid and cycocel on growth, yield and protein content of pea. Asian J. Plant Sci. 5(2): 324-330.

Boultior, C. and D. G. Morgan. 1992. Development of oilseed rape buds, flowers and pods invitro. J. Expt. Bot. 43(253): 1089-1096.

Buriro, K. A., N. S. Soomro, M. A. Siddiqui, M. S. Chang, J. K. Sootaher, G. M. Nangraj and N. A. Majeedano. 2022. Effects of Foliar Application of Gibberellic-$Acid_3$ on the Growth and Yield of Canola (*Brassica napus* L.) Genotypes. Bio. Sci. Revi. 4(1): 12-25.

Camposilvan, S., O. Milanesi, G. Stellin, A. Pettenazzo, L. Zancan and L. D'Antiga. 2008. Liver and cardiac function in the long term after Fontan operation. The Annals of thoracic surgery. 86(1): 177-182.

Castro, P. R. C., E. S. Evangelista, E. Melotto and E. Rodrigues. 1989. Action of growth regulators on rape (*Brassica napus* L.). Revi. de Agri. 64 (1): 35-44.

Chauhan, J. S., Y. K. Tomar, A. Badoni, N. I. Singh, S. Ali and L. Debarati. 2010). Morphology, germination and early seedling growth in *Phaseolus mungo* L. with reference to the influence of various plant growth substances. J. Amer. Sci. 6(1): 34-41.

Dawar, R., M. D. Giri, A. K. Meena, G. Patidar and S. Rathod. 2020. Effect of foliar application of gibberellic acid on growth, yield and economics of blackgram. J. Pharmacogn. Phytochem. 9(4): 3184-3190.

Erbil, E. 2021. The effects of gibberellic acid (GA_3) applications on the physiological features of groundnut (*Arachis hypogaea* L.) under different salt (NaCI) stress conditions. Legume Research-An Int. J. 44(10): 1159-1163.

FAO. 1988. Food and Agriculture Organization. Land resources Appraisal of Bangladesh for Agricultural development. Report 2, Agro ecological Regions of Bangladesh. p. 212-21.

FAO. 2012. Food and Agricultural Organization of the United Nations. Rome, Italy.

Gardner, M. P. 1985. Mood states and consumer behavior: A critical review. J. Consum. Res. 12(3): 281-300.

Gouping, C. and E. Etmal. 1993. Efficiency of application of ABT on maize. 2nd international training course on new type plant growth regulators. Held in. 10-25.

Gunstone, F. D., J. L. Harwood and F. B. Padley. 1994. The Lipid Handbook (2nd ed.). Chapman and Hall, Chemical Database, London. p. 119.

Gurmani, A. R., X. Wang, M. Rafique, M. Jawad, A. R. Khan, Q. U. Khan and S. Fiaz. 2022. Exogenous application of gibberellic acid and silicon to promote salinity tolerance in pea (*Pisum sativum* L.) through Na+ exclusion. Saudi J. Biol. Sci. 29(6): 103-305.

Hasioet, T. C., E. Acevedo, E. Fereres and W. D. Henderson. 1976. Effect of plant growth regulator an Brassica sp. Phil. Trans. R. Soc. Bot. 27(5): 275-500.

Hayat, T., A. M. Siddiqui and S. Asghar. 2001. Some simple flows of an Oldroyd-B fluid. Int. J. Engi. Sci. 39(2): 135-147.

Holmberg, F. and G. Eduardo. 1991. Effect of growth retardants, (Chlormequat, triapentenol) under four nitrogen fertilization levels in spring rape (*Brassica napus* L. ssp. *oleifera*).). p. 118.

Inanaga, S. and A. Kumura. 1987. Regulation of oil yields components of rape seed. p. 161-167.

Iqbal, M. S., M. Zahoor, M. Akbar, K. S. Ahmad, S. A. Hussain, S. Munir and M. Islam. 2022. Alleviating the deleterious effects of salt stress on wheat (*Triticum* *aestivum* L.) By foliar application of gibberellic acid and salicylic acid. Applied Ecolo. Enviro. Res. 20(1): 119-134.

Islam, S., P. K. Biswas, A. K. M. R. Amin, M. Fujita, A. K. Paul, J. A. Mahmud, and M. Hasanuzzaman. 2022. Germination and Growth Performance of Seedlings Of Ascorbic Acid, Silicon and Gibberellic Acid Treated Secondary Seed of Wheat Under Salt Stress. Bangladesh Agron. J. 25(1): 115-128.

Islam, S., S. H. Shah, F. J. Corpas, S. Alamri and F. Mohammad. 2023. Plant growth regulators mediated mitigation of salt-induced toxicities in mustard (*Brassica juncea* L.) by modifying the inherent defense system. Plant Physiolo. Biochem. 196: 1002-1018.

Kandil, A. A. 1983. Effects of sowing date of yield yield components and some agronomic characters of oilseed rape (*Brassica napus* L.). In: 6th Rapeseed Conf., Paris, France. p. 297.

Keykha, M., H. R. Ganjali and H. R. Mobasser. 2014. Effect of salicylic acid and gibberellic acid on some characteristics in mungbean (*Vigna radiata*). Int. J. Biosci. 5(11): 70-75.

Khan, M. S. K. 1997. Effect of different levels of nitrogen on growth, yield and quality of wheat. Bangladesh J. Crop Sci. 8: 10-19.

Khan, N. A., R. Mir, M. Khan, S. Javid and L. Samiullah. 2002. Effects of gibberellic acid spray on nitrogen yield efficiency of mustard grown with different nitrogen levels. Plant Growth Regul. 38: 243-247.

Khan, N. A. 1996. Effect of gibberellic acid on carbonic anhydrase, photosynthesis, growth and yield of mustard. Bio. Planta. 38: 145-147.

Khan, N. A., H. R. Ansari and Sanullah. 1998. Effect of GA_3 spray during ontogeny of mustard on growth, nutrient uptake and yield characteristics. J. Agron. Corp Sci.181(1): 61-63.

Lehmann, J., R. Atzorn, C. Bruckner, S. Reinbothe, J. Leopold, C. Wasternack and B. Parthier. 1995. Accumulation of jasmonate, abscisic acid, specific transcripts and proteins in osmotically stressed barley leaf segments. Planta. 197: 156-162.

Mal, D., V. Thakur and S. Datta. 2018. Effect of different plant growth regulators (GA_3 and NAA) on growth and yield parameters of radish (*Raphanus sativus* L.) Var. Pusa Reshmi. J. Pharmacogn. Phytochem. 7(3): 3434-3437.

McConn, M., R. A. Creelman, E. Bell, J. E. Mullet and J. Browse. 1997. Jasmonate is essential for insect defense in Arabidopsis. Proceedings of the National Academy of Sciences. 94(10): 5473-5477.

Milanesi, L. A., M. A. Espósito, E. A. Martín, F. S. López-Anido, S. M. García and E. L. Cointry. 2008. Rate and time of GA_3 application and irrigation on plant morphology and yield of lentil. Int. J. Veg. Sci. 14(2): 139-147.

Mitra, S. K. and S. C. Pathak. 2005. Effect of different plant growth regulators on growth, yield and quality of radish. J. Horti. Sci. 41(3):118-120.

Mobin, M. and N. A. Khan. 2007. Photosynthetic activity, pigment composition and antioxidative response of two mustard (*Brassica juncea*) cultivars differing in photosynthetic capacity subjected to cadmium stress. J. Plant Physiol. 164(5): 601-610.

Mondal, M. R. I. and M. A. Wahhab. 2001. Production technology of oil crops. Oil seed Res. Centre. Bangladesh agricultural Research Institute, Joydebpur, Gazipur. Bangladesh. P. 4

Mukarram, M., F. Mohammad, M. Naeem and M. M. A. Khan. 2021. Exogenous gibberellic acid supplementation renders growth and yield protection against salinity induced oxidative damage through upregulating antioxidant metabolism in Fenugreek (*Trigonella foenum-graceum* L.). Fenugreek: biology and applications. 99-117.

Mukherjee, S., S. Samanta, B. C. Roy and A. Bhaumik. 2006. Efficient allylic oxidation of cyclohexene catalyzed by immobilized Schiff base complex using peroxides as oxidants. Applied Catalysis A: General. 301(1): 79-88.

Nehal, N., A. Khan, N. Sharma, S. K. Tripathi and M. Singh. 2018. Role of GA_3, SA and ABA on growth and yield of Indian mustard [*Brassica juncea* (L.) Czern. & Coss.] under rainfed condition. J. Pharmacogn. Phytochem. 7(2S): 199-203.

Nizamani, M. R., M. A. Ansari, M. A. Siddiqui G. S. Nizamani, F. Nizamani, M. Naz and M. Asad. 2018. Effect of gibberellic acid on yield and yield attributes of canola (*Brassica napus* L.) varieties. Indian J. Sci. Res. 6(8): 863-80.

Potter, I. and S. C. Fry. 1994. Changes in xyloglucan endotransglycosylase (XET) activity during hormoneinduced growth in lettuce and cucumber hypocotyls and spinach cell suspension cultures. J. Exp. BoT. 1703-1710.

Pressman, E. and R. Shaked. 1991. Regulation of stem elongation in Chinese cabbage by inflorescence removal and application of growth regulators. J. Plant Growth Regul. 10:225-228.

Rahman, M. S., M. N. Islam, A. Tahar and M. A. Karim. 2004. Influence GA, and MH and their time of spray on morphology, yield contributing characters and yield of Soybean. Asian J. Plant Sci. 3: 602-609.

Rauf, F., M. A. Ullah, M. H. Kabir, M. A. Mia and M. S. Rhaman. 2022. Gibberellic Acid Enhances the Germination and Growth of Maize under Salinity Stress. Asian Plant Res. J. 10(3): 5-15.

Ravat, A. K. and M. Nirav. 2015. Influence of plant growth regulators on growth, seed yield and seed quality in okra [*Abelmoschus esculentus* (L.) Moench] cv. GAO-5 under middle Gujarat condition. Int. J. Agri. Sci. 11(1): 151-157.

Saha, D., M. M. Rahman, M. A. Hossain, M. A. Rahman, A. C. Das and M. Saha. 2021. Morphological and Biochemical Attributes of Mustard as Influenced by Different Concentrations of Gibberellic Acid (GA_3). American J. Agric. Sci. Eng. Technol. 5(1): 103-109.

Saini, P. K., R. K. Yadav and M. Pratap. 2017. Effect of foliar application of GA_3 on yield and quality of Indian mustard [*Brassica juncea* (L.) Czern. & Coss.] under sodic soil. Int. J. Curr. Microbiol. App. Sci. 6(12): 4156-4159.

Saran, B., B. K. Sinha, A. K. Sharma and A. S. Mehta. 1992. Effect of pre sowing treatment in GA_3 on growth, yield and chlorophyll in mustard New Agriculturist. 3 (1): 59-60.

Sarker, S. 2015. Effect of Sowing Date and Gibberellic Acid on Water Relations and Yield of Lentil under Residual Soil Moisture Condition. MS Thesis. Department of Agronomy. Sher-e-Bangla Agricultural University.

Sedghi, M., R. S. Sharifi, A. R. Pirzad and B. Amanpour-Balaneji. 2012. Phytohormonal regulation of antioxidant systems in petals of drought stressed pot marigold (*Calendula officinalis* L.). J. Agr. Sci. Technol. 14: 869-878.

Sidiras, N. and S. Karsioti. 1996. Effects of seed size and seed substances of lupins on seedling emergence and root system development in relation to sowing depth, soil water and gibberellin. J. Agron. Crop Sci. 177(2): 73-83.

Sumi, P., S. C. Meena, R. H. Meena and J. Choudhary. 2021. Effect of gibberellic acid and sulphur on growth and yield of mustard (*Brassica juncea* L.). J. Pharm. Innov. 10(8): 1214-1217.

Uddin, M. M., A. Samad, M. R. Khan, S. Begum and M. A. Salam. 1986. Effect of sowing dates on the yield and some of its components of mustard and rapeseed. Bangladesh. J. Sci. Ind. Res. 21 (1-4): 160-165.

Vetrano, F., A. Moncada and A. Miceli. 2020. Use of gibberellic acid to increase the salt tolerance of leaf lettuce and rocket grown in a floating system. Agronomy. 10(4): 505.

Yadav, T. R., P. K. Saini, R. K. Yadav and R. Bhahadur. 2018. Effect of seed priming with plant growth regulators on physiological changes of Indian mustard (*Brassica juncea* L. Czern & Coss.). J. Pharmacogn. Phytochem. 7(2S): 355-358.

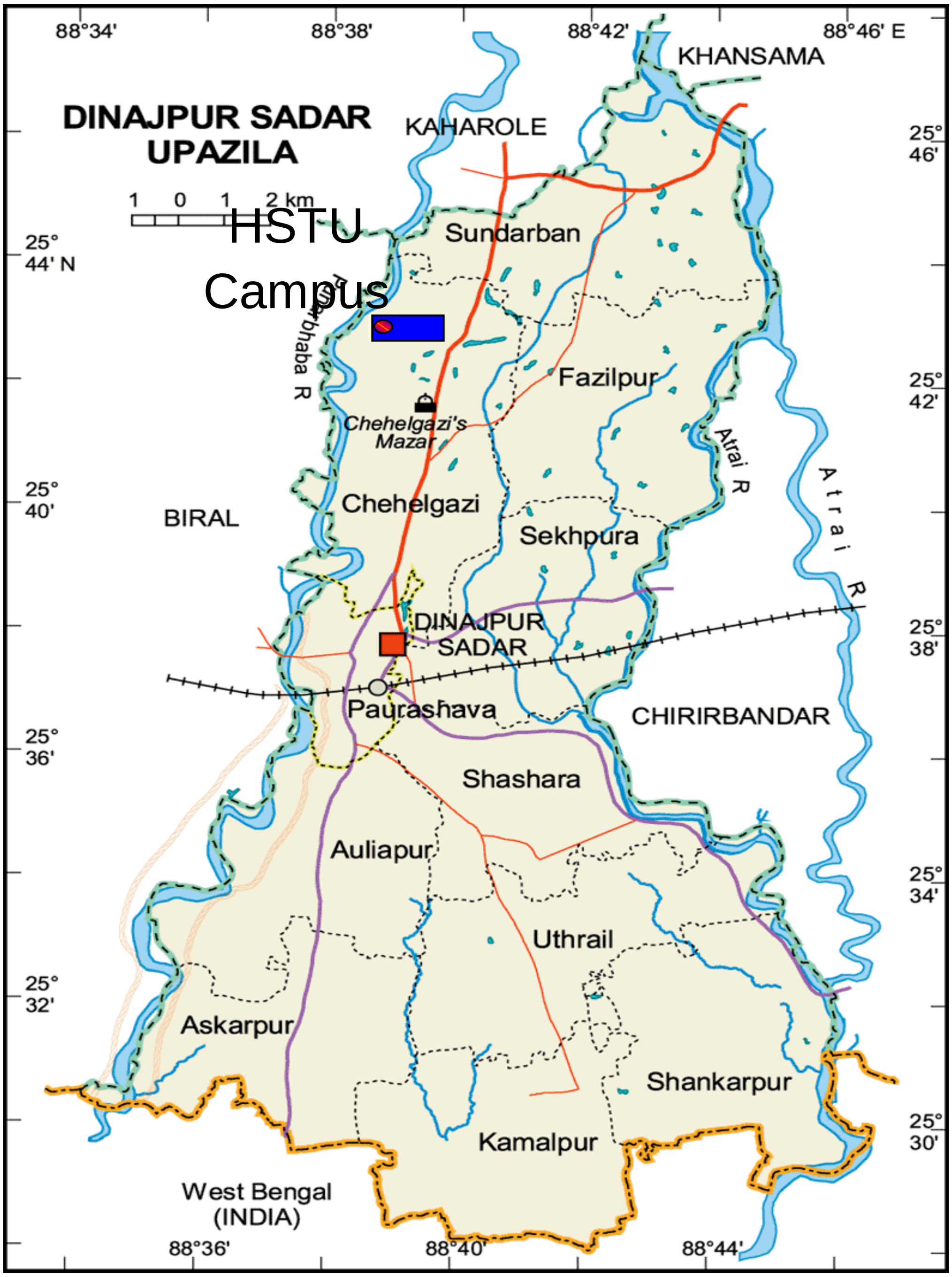
Yamaguchi, S. 2008. Gibberellin metabolism and its regulation. Annu. Rev. Plant Biol. 59: 225-251.

Zebarjadi, A., M. Kakaei and A. Mostafaie. 2011. Genetic variability of some traits in Rapeseed (*Brassica napus* L.) under drought stress and non-stress conditions. Biharean Biologist. 5(2): 127-31.

Zhu, G., L. An, X. Jiao, X. Chen, G. Zhou and N. McLaughlin. 2019. Effects of gibberellic acid on water uptake and germination of sweet sorghum seeds under salinity stress. Chil. J. Agri. Res. 79(3): 415-424

APPENDICES

Appendix I. Location of the experimental site (map of Dinajpur Sadar Upazila showing the research plot).



Appendix II. The physical and chemical properties of soil in the experimental field, HSTU, Sadar, Dinajpur-5200

Soil characters	Physical and chemical properties
Texture	
Sand (%)	65
Silt (%)	30
Clay (%)	5
Textural class	Sandy loam
CEC (me q 100 g^{-1})	8.07
pH	5.35
Organic matter (%)	1.06
Total nitrogen (%)	0.10
Sodium (me q 100 g^{-1})	0.06
Calcium (me q 100 g^{-1})	1.30
Magnesium (me q 100 g^{-1})	0.40
Potassium (me q 100g^{-1})	0.26
Phosphorus (µg g^{-1})	24.0
Sulphur (µg g^{-1})	3.2
Boron (µg g^{-1})	0.27
Iron (µg g^{-1})	5.30
Zinc (µg g^{-1})	0.90

Source: Soil Resources Development Institute (SRDI), Dinajpur-5200

Appendix III. Distribution of monthly temperature, rainfall and relative humidity of the experimental site during the period from December to April, 2023

Month	Relative humidity (%)	Temperature		Total rainfall (mm)
		Minimum (ºC)	Maximum (ºC)	
December	62	12.10	26.4	7.00
January	55	11.23	21.58	5.00
February	61	16.96	25.68	9.45
March	69	22.36	28.35	11.25
April	72	24.55	30.27	19.25

Source: Bangladesh Wheat and Maize Research Institute, Nashipur, Dinajpur.

Appendix IV. ANOVA Table for effect of GA_3 on plant height of mustard variety

Plant height (cm)

Sources of variation	Degrees of Freedom	Mean Square Value			
		30 DAS	50 DAS	70 DAS	At harvest
Replication	2	0.13500	8.6400	0.405	0.015
Treatments	5	4.13700	32.1650	419.973	188.720
Error	10	1.04700	1.9720	7.500	2.723

Appendix V. ANOVA Table for the effect of GA_3 on number of leaves plant^{-1} of mustard variety

Sources of variation	Degrees of Freedom	Mean Square Value		
		30 DAS	50 DAS	70 DAS
Replication	2	0.35167	0.02667	7.482
Treatments	5	0.86233	0.98900	145.076
Error	10	0.04100	0.03067	2.226

Appendix VI. ANOVA Table for the effect of GA_3 on root length of mustard variety

Root length (cm)

Sources of variation	Degrees of Freedom	Mean Square Value			
		30 DAS	50 DAS	70 DAS	At harvest
Replication	2	0.26000	0.9756	0.0972	0.65387
Treatments	5	2.09833	46.5156	19.6806	5.40920
Error	10	0.19333	0.6589	1.9972	0.39223

Appendix VII. ANOVA Table for the effect of GA_3 on leaf area index of mustard variety

Sources of variation	Degrees of Freedom	Mean Square Value			
		Leaf Area (mm^2)	Leaf Width (mm)	Leaf Length (mm)	Leaf Width: Leaf Length
Replication	2	5250752	122.124	1065.22	0.38805
Treatments	5	6420653	645.471	954.66	0.14465
Error	10	46781	77.376	83.80	0.03799

Appendix VIII. ANOVA Table for the effect of GA_3 on total fresh weight $plant^{-1}$ of mustard variety

Fresh weight (gm)

Sources of variation	Degrees of Freedom	Mean Square Value		
		30 DAS	50 DAS	70 DAS
Replication	2	0.04974	12.013	0.758
Treatments	5	0.78315	319.928	213.705
Error	10	0.16462	8.353	23.954

Appendix IX. ANOVA Table for the effect of GA_3 on total dry weight $plant^{-1}$ of mustard variety

Dry weight (gm)

Sources of variation	Degrees of Freedom	Mean Square Value		
		30 DAS	50 DAS	70 DAS
Replication	2	0.00107	0.5828	1.7931
Treatments	5	0.01169	15.6146	10.2046
Error	10	0.00019	0.1765	0.3912

Appendix X. ANOVA Table for effect of GA_3 on number of flowers plant^{-1} and number of branches plant^{-1} of mustard variety

Sources of variation	Degrees of Freedom	Mean Square Value	
		number of flower plant^{-1}	number of branch plant^{-1}
Replication	2	941.8	0.0800
Treatments	5	15337.6	21.0517
Error	10	455.8	0.1607

Appendix XI. ANOVA Table for the effect of GA_3 on different yield contributing characters of mustard variety

Sources of variation	Degrees of Freedom	Mean Square Value			
		Number of siliqua plant^{-1}	Length of siliqua (cm)	Single siliqua weight (g)	Number of seed siliqua^{-1}
Replication	2	532.65	0.47602	2.667	1.3067
Treatments	5	7844.40	2.15609	9.134	35.6480
Error	10	108.17	0.18862	4.500	1.7547

Appendix XII. ANOVA Table for the effect of GA_3 on yield parameters of mustard variety

Sources of variation	Degrees of Freedom	Mean Square Value				
		Thousand Grain Weight (g)	Biological Yield (t ha^{-1})	Straw Yield (t ha^{-1})	Grain Yield (t ha^{-1})	Harvest Index (%)
Replication	2	0.00572	0.29482	0.14415	0.02667	3.95309
Treatments	5	0.19493	0.34769	0.05772	0.12329	2.88946
Error	10	0.03458	0.02170	0.00171	0.01343	1.30935

Appendix XIII. Some experimental photography