FOLIAR APPLICATION OF GA_3 ON GROWTH, YIELD TRAITS AND YIELD OF MUSTARD

A THESIS

By

HOSNA ARA KHATUN

Student ID: 1701253

Session: 2022-2023

Thesis Semester: January-June 2024

MASTER OF SCIENCE (M.S.)

IN

AGRONOMY

DEPARTMENT OF AGRONOMY

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Dedicated To My

Beloved Parents

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June, 2024 *The Author*

ABSTRACT

A field experiment work was conducted at Agronomy research field, Hajee Mohammad Danesh Science and Technology University (HSTU), Dinajpur-5200 during Rabi season from November 2022 to March 2023 to assess the impact of varied GA_3 concentrations on growth, yield traits and yield of mustard. The experiment consisted of two factors where one factor was varieties namely V_1 (BARI Sarisha-15), V_2 (BARI Sarisha-17) and V_3 (BARI Sarisha-19) and another four treatments *e.g.* T_1 = 0 ppm (control), T_2 = 25 ppm GA_3, T_3 = 50 ppm GA_3 and T_4 = 75 ppm $GA_{3.}$ The experiment was designed in Randomized Complete Block Design (RCBD) with three replications. Parameters like plant height (cm), number of branches plant^{-1}(no.), number of leaves plant^{-1} (no.), leaf area (cm^2), number of siliqua plant^{-1} (no.), fresh weight of seed^{-1}(g), dry weight of seed^{-1}(g), total fresh and dry weight plant^{-1} (g), thousand-seed weight (g), seed yield (t ha^{-1}), biological yield (t ha^{-1}), stover yield (t ha^{-1}), and harvest index (%). The highest thousand-seed weight 28.66 g observed was V_1(BARI Sarisha -15) ,Seed yield showed better result with the variety V_2 (BARI Sarisha -17) 1.18 t ha^{-1}, Biological yield showed better performance with the variety V_1 (BARI Sarisha-15) 12.45 t ha^{-1} and the maximum harvest index were recorded in V_2 (BARI Sarisha-17) with 45.16 %.T_3 (50 ppm GA_3) showed best performance than the other treatment in most of the parameters specially in 1000 seed weight (37.72 g) , seed yield (1.26 t ha^{-1}), biological yield (4.43 t ha^{-1}) and harvest index (45.23%). Interaction result showed that BARI Sarisha-17 along with T_3 (50 ppm GA_3) possed the highest seed yield 1.3 t ha^{-1}. But the lowest result of 1000-seed weight (23.85 g), biological yield (2.42 t ha^{1}), seed yield (0.69 t ha^{-1}) and harvest index (28.15%) were obtained from the control. So, it could be concluded that GA_3 at 50 ppm showed better performance than all other treatment.

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LIST OF ABBREVIATIONS

AEZ	-	Agro-Ecological Zone
CF	-	Chemical Fertilizer
FAO	-	Food and Agriculture Organization
BARI	-	Bangladesh Agricultural Research Institute
CF	-	Chemical Fertilizer
CV	-	Coefficient of Variance
LSD	-	Least Significant Difference
RCBD	-	Randomized Complete Block Design
MoP	-	Muriate of Potash
TSP	-	Triple Supper Phosphate
GA_3	-	Gibberellic acid
HI	-	Harvest Index
TGW	-	Thousand Grain Weight
BY	-	Biological Yield
GY	-	Grain Yield
DAS	-	Days After Sowing

CHAPTER I

INTRODUCTION

Mustard (*Brassica campestris*) belongs to the genus Brassica of the family Cruciferae, is mainly a self-pollinating crop, although on an average 7.5 to 30 % out-crossing does occur under natural field conditions (Tarkeshwar *et al.,* 2022).The name is derived from the Latin word "mustum" means that of old wine mixed with the crushed seed makes it one of the most important spices in the world (Narayan *et al.,* 2022). Mustard has 36 chromosomes (2n) and is amphidiploid in nature. Brassica crops is mostly cultivated for edible vegetable oil production. They have a long list of history owing to their cultivation and varied use and has a great contribution in world's agricultural economy. Commonly cultivated species of mustard (Brown mustard) are *B. Juncea ssp. Integrifolia, B. Juncea ssp. juncea, B. Juncea ssp. napiformis and B. Juncea ssp*. (Tiwari and Singh, 2024). It is one of the most important oil crops of the world after soybean and groundnut (FAO, 2012). Mustard widely cultivated as spices as condiments throughout the world both for human consumption and also for livestock feedings. Mustard is the 2nd largest produced oilseed in the world with an area of 37.0 m/ha, with the production of 63.09 m tones and productivity of 11.90q/ha (Tiwari and Singh, 2024).

In Bangladesh, the cultivation of mustard has increased by 40% to 11.52 lakh tonnes during the current fiscal year, according to the (Ministry of Agriculture, 2023). A year ago, the agriculture ministry took an action plan to triple the cultivation of oil crops including mustard, sesame, almond, soybean, and sunflower to meet 40% of the edible oil demand locally. The ministry also set a target to increase the cultivation of oil crops to 23.60 lakh hectares by FY24-25. The annual demand of edible oil in the country is about 24 lakh tonnes. Out of this, only 3 lakh tonnes of mustard, sesame and sunflower are produced locally, which is 12% of the demand. 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). If 40% of the edible oil demand can be met locally, the country can save about Tk10,000 crore annually, according to the Ministry of Agriculture (TBS report, 2023). The country has to meet the rest of the demand through import. Therefore, yield and production of mustard is increased is a need as urgent concern for Bangladesh economy.

Mustard used in food is often a mixture of seeds. Its functional foods having beneficial physiological effects in humans. Out of 100 species of Brassica, the (*Brassica napus* L.) is a high yielding one. Mustard oil contains omega fatty acids, fat-soluble vitamins (viz. A, D, E and K). saturated fats, thiamine, ascorbic acid, iron, potassium, calcium, riboflavin, and β-carotene, which make it more valuable than other edible oils (Konuskan, *et al.*, 2019). Approximately 20-25% protein and 40-45% oil are found in mustard seeds (Mondal and Wahab, 2001). The green leaves of this herb are commonly used as a vegetable. The seeds of mustard are used for making pickles, soups, stews, and hair oil throughout the world. Mustard oil not only plays a great role as a fat substitute in our daily diet but also nourish the economy of the nation. The ordinary people of Bangladesh also use it as medicine against cold. It is widely used as cooking ingredient and condiment. Oil cake produced from mustard is an important food for livestock and also used as organic manure for crop production. Due to the commercial importance of mustard, increasing its production is highly desirable. Mustard cultivation is profitable, but the productivity is currently insufficient to meet the needs of the people. Efforts are currently being made by scientists to enhance the cultivation and production of edible oilseed crops, including mustard. In this regard, mineral nutrients and plant hormones/plant-growth promoters/growth hormones may have roles in enhancing mustard growth and oil production (Rademacher, 2015).

Plant growth regulators such as manipulating plant developments, enhancing yield and quality have been actualized new emerging and efficient plant growth and development. Plant hormones including auxins, gibberellic acid, cytokinin, abscisic acid, Indole Acetic Acid and ethylene are involved in controlling developmental events such as cell division, cell elongation and protein synthesis. Gibberellic acid (GA_3) is a phytohormone that is needed in small amounts at low concentration to accelerate plant growth and development (Saini *et al.*, 2017). The gibberellins stimulate cell division as well as cell elongation. Gibberellins also cause pollen development, pollen tube growth, fruit growth, seed development and germination (Whitehead, 2008). The gibberellic acid (GA_3) has potential to enhance growth, flowering, photosynthesis, nutrient transport and yielding ability of mustard (Khan et al. 2005). So, favorable condition may be induced by applying growth regulator exogenously in proper concentration at a proper time in a specific crop by GA_3. Gibberellic acid is such a plant growth regulator, which can manipulate a variety of growth and development phenomena in various crops. GA_3 enhances growth activities to plant, stimulates stem elongation (Deotale *et al.*, 1998, Abd, 1997; Lee, 1990), and increases dry weight and yield

(Deotale *et al.,* 1998 and Maske *et al.,* 1998). Interestingly, gibberellins (GAs) effectively promoted the seedling emergence, plant growth and development in mungbean (Islam *et al.*, 2023), soybean (Maske *et al.,* 1997), common bean, cowpea and pigeon pea (Khafagi *et al.*, 1986), black gram and horse gram (Chauhan *et al.,* 2009). Furthermore, GAs tend to breakdown seed dormancy and initiate the mobilization endosperm reserves (Mahmoody and Noori, 2014). Likewise, GAs trigger stem elongation by stimulating cell division, flower formation and fruit development in many legume crops (Silva, 2004; Taiz and Zeiger, 2010). Moreover, GA_3 improved crop performance and productivity under normal and sub-optimal growth conditions (Chakraborti and Mukherji, 2003), increased the size and production of grapevine fruit (Abu-Zahra, 2010) and improved the productivity and quality of lily cut flowers (Sajid *et al.*, 2009). Besides, it increased the fiber yield of cotton (Copur *et al.,* 2010) protein content of field peas (Bora and Sarma, 2006), chemical constituents in Croton (Soad *et al.*, 2010), fruit size in Molina (Vwioko and Longe, 2009), floral buds in Jojoba (Prat *et al.*, 2008), and suppressed the undesirable compounds in mungbean (Chakrabarti and Mukherji, 2002). Additionally, GA_3 increased the leaf area index, dry weight, crop growth rate, relative growth rate, net assimilation rate and yield in Allium cepa (Hore *et al.,* 1988), tree species (Naidu and Swamy, 1995), and mungbean (Haque and Haque, 2002; Islam *et al.*, 2021b). More importantly, it increased the pigment content of Vicia faba (Aldesuquy and Gaber, 1993), and the water use efficiency of wheat (Aldesuquy and Ibrahim, 2001) by alleviating the adverse effects of salinity. Another vital role of GA_3 is promotion of photosynthesis by increasing the carboxylase activity of Rubisco in broad bean and soybean (Yuan and Xu, 2001), along with boosting the rates of cyclic and non-cyclic phosphorylations in tree species (Naidu and Swamy, 1995), and regulated the transport of ions in plants (Karmoker, 1984). It increased water uptake in plant tissues, causing cell expansion and diluting the sugars in the tissues under water scant conditions (Salisbury and Ross, 1996). The hydrolysis of starch into reducing sugars by GA_3 led to accumulation of sugar which improved the water balance and osmotic potential of gerbera cut flowers. Moreover, the GA_3 decreased transpiration and triggered transition from juvenile to mature stage along with induction of flowering in cut flowers (Emongor, 2004), as well as sex determination and fruit set establishment in horticultural crops (Taiz and Zeiger, 2004). Likewise, GA_3 tend to boost protein content by increasing nitrate reductase activity in cowpea (Singh and Sharma, 1996), wheat (Aldesuquy and Ibrahim, 2001), black cumin (Shah, 2004), and mungbean (Islam *et al.,* 2021b). It has been reported to be directly linked with the regulation of flower senescence in cut flowers (Halevy and Mayak, 1981). Contrastingly, GA_3 decreased the number of flowers and fruit set by boosting vegetative biomass, which led to higher transmission of photo-assimilates to fruits during the pre-blooming stage of soybean (Birnberg and Brenner, 1987). This findings are supported by King *et al*. (2000), who recorded increased stem growth in Fuschia hibrida and Pharbitis nil, which inhibited flowering.

At present, recent times, many research also works have been conducted in many parts of the world to increase oil seed production by using Gibberellic acids. Thus, the exogenous application of growth regulators like GA_3 may become a viable tool for increasing crop productivity in a biologically viable manner. Therefore, the research work was undertaken to study the effects of various concentrations of GA_3 on yield performance of mustard and to estimate the yield losses due to shattering of siliqua at delayed harvest. With a view to determining the effect GA_3 on growth and yield of mustard, a field study was conducted with the following objectives-

1. To study the effect of GA_3 plant growth regulator on growth, yield of mustard.
2. To determine the suitable treatment dose of GA_3 and best yield performing variety for the growth and yield of mustard.
3. To find out the suitable GA_3 concentrations and variety interaction on the growth, and yield performance of mustard.

CHAPTER II

REVIEW OF LITERATURE

In Bangladesh as well as throughout the world, mustard is one of the most widely grown oil crops. Researchers from several nations, including Bangladesh, paid close attention to the crop. However, a few studies on the impact of plant growth regulators on mustard yield have been conducted. The yield performance of mustard after GA_3 application has received little to no combined study attention. This chapter reviews the literature and research findings pertinent to the current investigation.

2.1 Effect of GA_3 on the growth and yield of mustard

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 T_3 (40 kg S ha^{-1} +50 ppm GA_3), as compared to control.

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.

Buriro *et al.* (2022) noted that the development and yield of canola (*Brassica napus* L.) cenotypes were affected by the foliar application of GA_3. 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 GA_3 5 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.

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.

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^{-1}, number of seeds siliqua^{-1}, number of flowers plant^{-1}, setting of siliqua plant^{-1} (%), and harvest index. Results revealed that GA_3 at 50 ppm significantly increased plant height, number of fertile siliqua plant^{-1}, number of flowers plant^{-1}, setting of siliqua plant^{-1} (%), dry matter yield, number of seeds siliqaua^{-1}, and harvest index, while the number of flowers plant^{-1} was significantly increased with the application of 75 ppm GA_3.

The highest seed yield plant^{-1} was recorded from the application of 50 ppm GA_3 at optimum harvest date. The seed yield plant^{-1} was positively correlated with plant height, number of seeds siliqua^{-1}, number of fertile siliqua plant^{-1} and % of setting siliqua plant^{-1}. The effects of gibberellic acid (GA_3) on growth, physiology and yield of saltstressed 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 GA_3 appeared to mitigate the adverse effects of salinity stress on the overall performance and productivity 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, 60 ppm, 75 ppm, 90 ppm, 125 ppm) 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_3 125 ppm followed by foliar sprayed with GA_3 90 ppm over rest of the treatments including control, during the investigation.

Haifaa *et al*. (2022) stated that the timing and mode of application of Gibberellic acid (GA_3) in rice cultivation to increase grain yield. It focuses on MR219, a popular Indica rice variety, and two commercial GA_3 formulations, ProGibb SG and ProGibb silica Granule. GA_3 was applied at late tillering stage and 10-30% panicle heading stage. The study found that GA_3 application during the early reproductive stage, at 10-30% panicle heading stage, significantly increased grain yield, with over 27% increase over the untreated control. Two GA_3 applications at a 7 days' interval consistently yielded higher grain yields than a single application. However, no significant difference was found in flag leaf characteristics, grain weight, and milling qualities among different treatments. The study concludes that foliar GA_3 application at weekly intervals can significantly increase rice grain yield.

Patil *et al*. (1987) was conducted an experiment 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.

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^{-1}) 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^{-1}) in combination with CCC (500 µg ml^{-1}) recorded better growth and yield.

Singh (2015) conducted an experiment at Gwalior during Rabi season of 2012- 13 to study the effect of mixture of GA_3 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^{-1}).

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-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.

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^{-1}, 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 GA_3 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.

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.

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.

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.

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.

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.

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.

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.

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.

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.

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 mgL^{-1} GA_3), T_5 (150 mgL^{-1} 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 mgL^{-1} GA_3), T9 (150 mM NaCl+150 mgL^{-1} 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 mgL^{-1} GA_3 while glycine betaine was also enhanced by 0.26% in Ujala-2016 at 150 mgL^{-1}. They also noted that 1.0 mM salicylic acid and 150 mgL^{-1} gibberellic acid enhanced significantly various growth parameters. In conclusion, they stated that concentration of 0.1 mM SA and 150 mgL^{-1} 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.

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

The materials and methods followed in this experiment to achieve the intended objectives are described in details in this chapter. For convenience, this chapter has been divided into several sections such as site and soil, climate, crop, land preparation, experimental design, treatments, fertilizer application, seed sowing, intercultural operations, data collection, harvesting, and statistical analysis.

3.1 Location of experimental field

The experiment was conducted in the Agronomy Research Field, Department of Agronomy, Hajee Mohammad Danesh Science and Technology University, Dinajpur-5200, Bangladesh from December 2022 to March 2023. The geographical position of the experimental area and location is between $25^{0}44.574^{//}$N and $88^{o}40.344^{//}$E and 40 m above sea level shown in (Figure 1a and 1b). The property is located in the Agro-ecological Zone-1 (AEZ-1) which is named as Old Himalayan Piedmont Plain (UNDP and FAO, 1988) shown in (Appendix I).

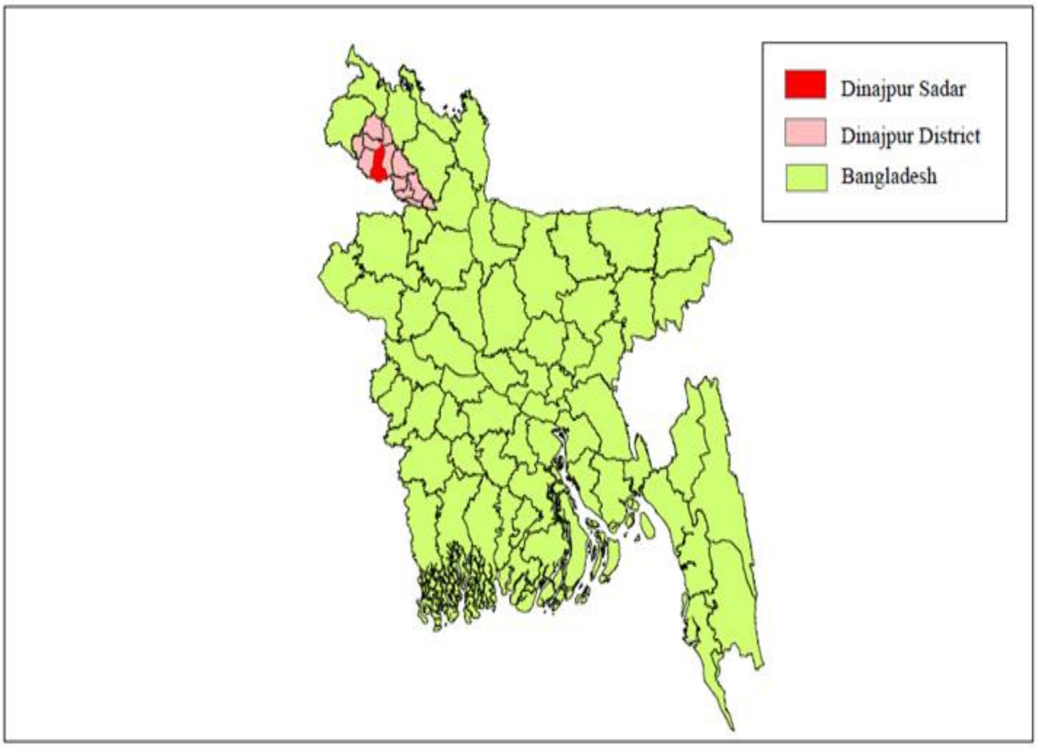


Figure 1 (a) Location of experimental area

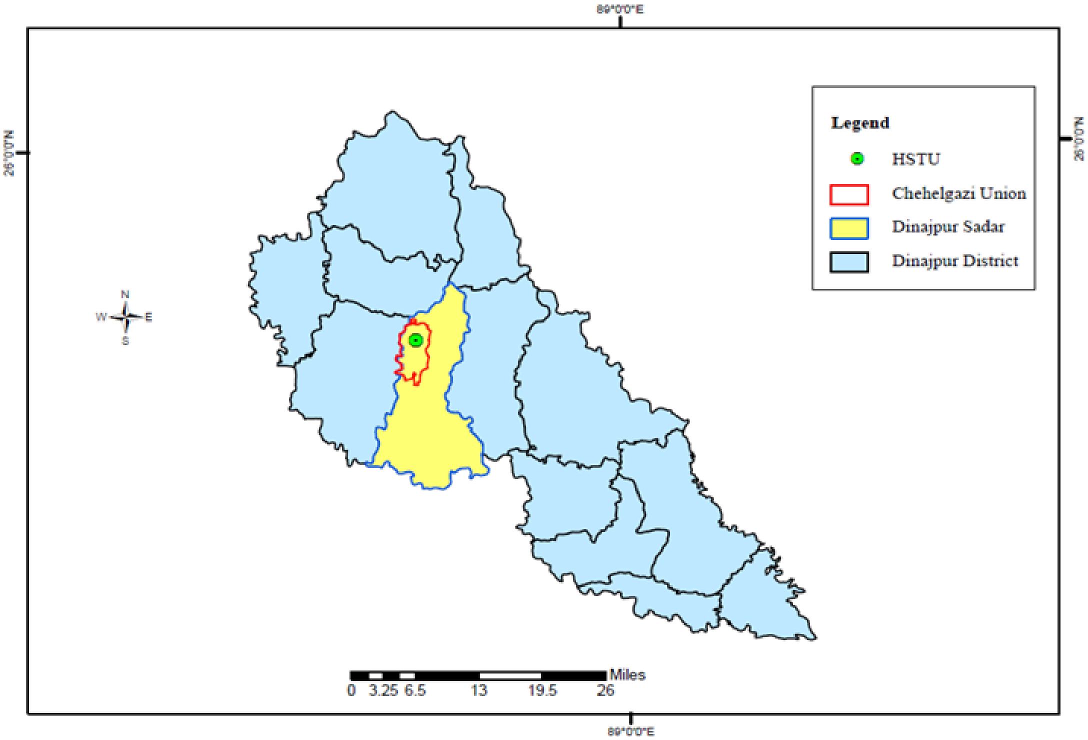
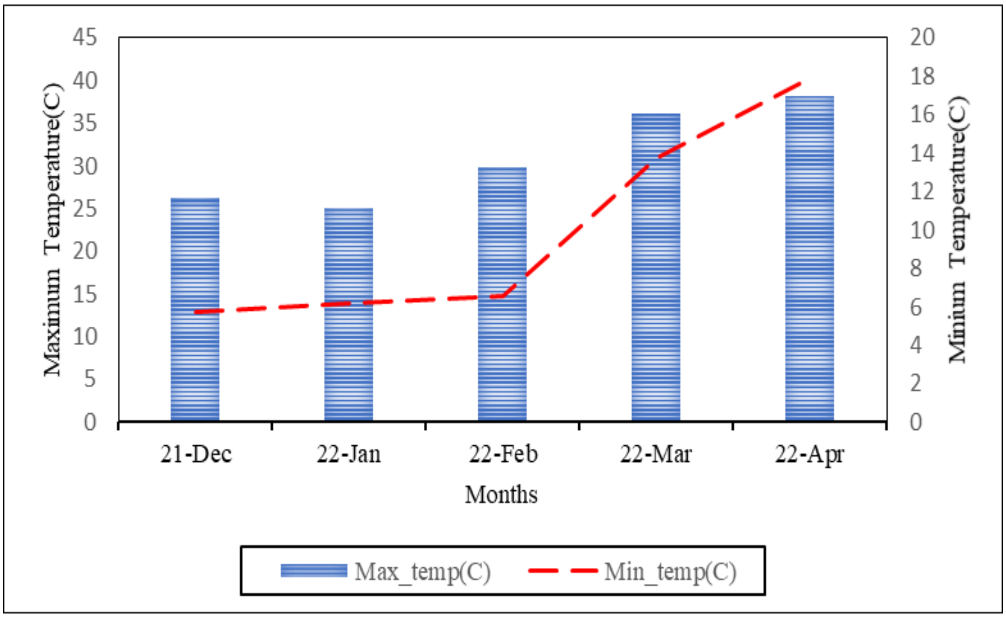


Figure 1(b): Location of experimental field

3.2 Climatic conditions

The climate was subtropical with low temperatures and minimum rainfall from December to April which is the main feature of the Rabi season. The highest maximum temperature was shown in the month of April *i.e.*, 35.0^{0}C. The lowest maximum temperature was shown in January at 24.0^{0}C. While the highest minimum temperature was recorded in the month of April at 18.0^{0}C and the lowest in the month of December at 13.0^{0}C shown in (Figure 2a). Besides, the highest humidity was shown in the month of December 2022 with 1.8% lowest at 1.3% recorded in the month of March 2023. There was no rainfall at the beginning but little bit rain before harvesting the experiment. The highest rainfall month was in April with the data being 80 mm. While very low percentage was shown from December 2021 to February 2022 and the range was between 5-10 mm shown in (Figure 2b).



. **Figure 2(a): Maximum and minimum temperatures between 2022-2023**

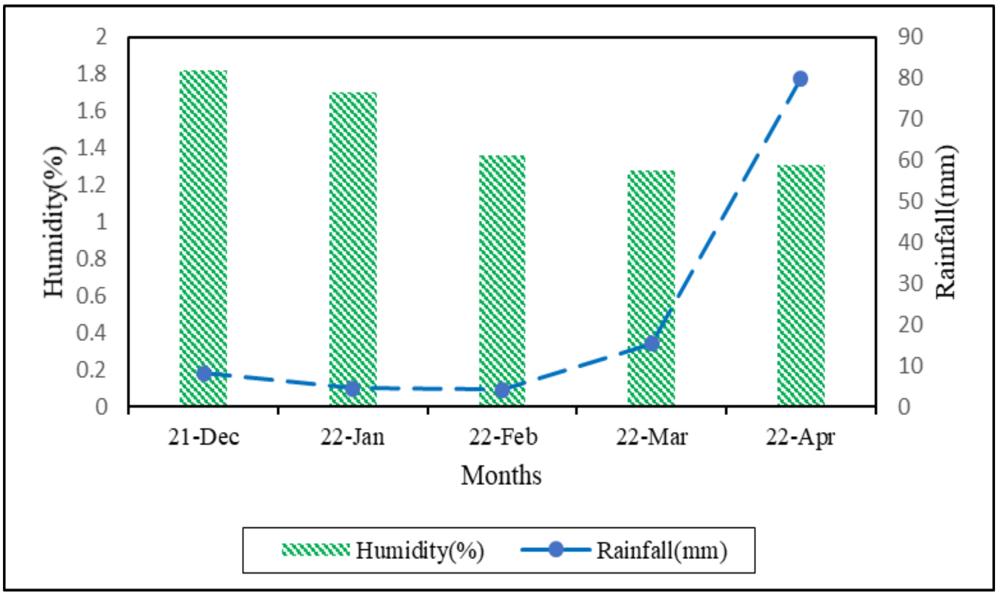


Figure 2(b): relative humidity and rainfall between 2022-2023

3.3 Soil

The soil of the experimental field belongs to the old Himalayan Piedmont Plain (AEZ-1). Initial soil samples were collected randomly from each unit plot at a depth of 0-30 cm before final land preparation and the samples were mixed to make a bulk sample.

Table 1: Soil Physical and Chemical Properties of the experimental location

Parameters measured	units	Soil Layer between (0-40) cm
Soil textural classes	-	Sandy loam
Sand	%	47.60
Silt	%	36.00
clay	%	16.40
Organic matter	%	0.31
Organic carbon	%	0.18
Total N	%	0.007
Total P	%	14.30
Available K	$mgkg^{-1}$	0.05
Available S	$mgkg^{-1}$	18.09
Field capacity	%	10.50
CEC	Meq 100g	1.00
Ec	$mgkg^{-1}$	87.30
pH		6.12

The bulk sample was air dried ground and sieved to remove unwanted materials then preserved in polythene bags for future laboratory studies. After that, Soil analysis was done at the Soil Science department of Hajee Mohammad Danesh Science and Technology University, Dinajpur and Soil Resource Development Institute (SRDI), Dinajpur, Bangladesh. Soil analysis showed that the soil of the experimental plot was sandy loam with good drainage capacity. The experiment plot was medium high land with the pH range of 6.12 *i.e.,* the soil is acidic soil. The soil physical and chemical properties of the experimental site were analyzed before started the experiment and presented in (Table 1).

3.4 Duration of the experiment

The experiment was conducted during the period from 16 December 2022 to 15 March 2023

3.5 Varieties/ planting material

BARI-released recognized varieties namely BARI Sarisha -15, BARI Sarisha-17, and BARI Sarisha-19 were used in this experiment. Seeds were collected from Bangladesh Agricultural Research Institute (BARI), Gazipur, Bangladesh. The planting materials used in this experiment were-

- BARI Sarisha-15
- BARI Sarisha-17
- BARI Sarisha-19

3.6 Main features of the varieties

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

3.6.1 Varietal characteristics of BARI Sarisha-15

- Rabi season, mid October to mid November.
- Short duration variety.
- After harvested Aman and before transplant Boro Rice.
- Erect type plant.
- Plant height (90-100) cm.
- Self-compatible type.

- Considerable yield at adverse weather condition like foggy weather, absence of pollinating agent and rainfall *etc.*, during flowering stage.
- Pod is narrow and taller than BARI Sarisha 14.
- Number of siliqua per plant 70-80
- Number of seeds per silique 20-22.
- Seed yellow in colour.
- 1000-seed weight 3.25-3.50 g.
- Oil content 44-45% in seed.
- Crop duration 80 -85 days.
- Yield 1.55 – 1.65 t ha^{-1}

3.6.2 Varietal characteristics of BARI Sarisha-17

- Developed by hybridization with BARI Sarisha 15 and Sonali Sarisha.
- This variety is suitable for crop pattern Transplant Aman rice-Mustard- Boro rice because of short duration.
- Plant height 95-97 cm.
- Plant don’t lodging.
- Pod per plant 60-65.
- Number of seeds per pod 9-11.
- Flower and seed yellow in colour because of yellow seed colour comparatively 3-4% oil is greater than brown colour seed quality.
- Bold seeded in shape.
- 1000-seed weight 3-3.4 g.
- Moderately resistant to Alternaria blight disease orabancy parasite.
- Moderately drought and salt tolerant (6-8 dSm^{-1}).
- Oil content 40-42% in seed.
- Yield 1.7-1.8 t/ha, 5%-10% greater than BARI Sarisha 14.

3.6.3 Varietal characteristics of BARI Sarisha-19

- Suitable for nationwide cultivation.
- Plant height 88-92 cm.
- Plant comparatively dwarf type.
- Erucic acid content 1.06% in oil.

- Each pod contain 18-19 seeds.
- Seeds are brown in colour.
- Oil content 40-42% in seed.
- Life cycle 86-89 days which is 2-5 days more to BARI Sarisha-17.
- Yield average 2.0 t/ha

3.7 Treatments

Two factors were included in the experiment namely variety and levels of GA_3. The treatments were designated as follows:

Factor A: four levels of Gibberellic acid or GA_3 concentrations were used and three treatments were applied in 2 times.

T_1=0 ppm Gibberellic acid or GA_3 *i.e.*, no GA_3

T_2= 25 ppm Gibberellic acid or GA_3L^{-1} water

T_3= 50 ppm Gibberellic acid or GA_3 L^{-1} water

T_4= 75 ppm Gibberellic acid or GA_3 L^{-1} water

Factor B: Consist of three varieties. Namely

V_1= BARI Sarisha-15

V_2= BARI Sarisha-17

V_3= BARI Sarisha-19

3.8 Experimental design, layout and treatment combination

3.8.1 Experimental design:

The experiment consists of two factorial designs. One is variety and another one is different treatments.

3.8.2 Experimental layout

The experiment was laid out in a Randomized Complete Block Design (RCBD) shown in (Figure 3).

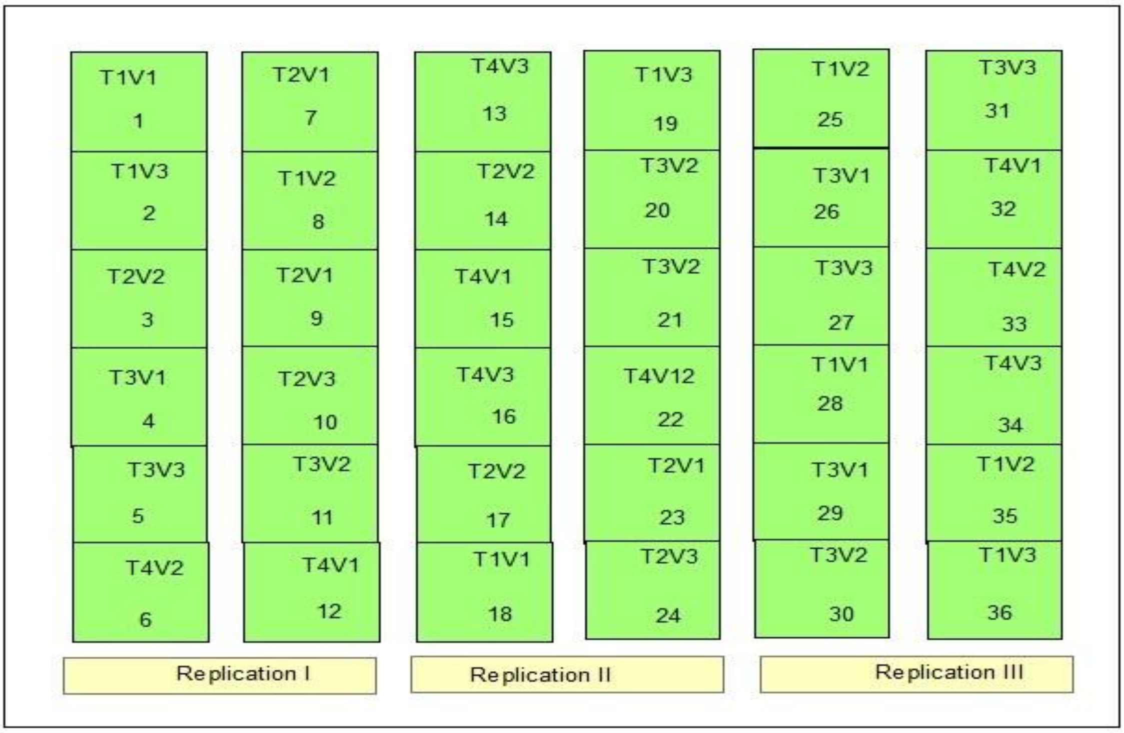


Figure 3: Layout of experimental plot

3.8.3 Treatment combination

The experimental layout and treatment combinations are shown in (Figure 3). The experiment consists of four treatment combinations where each treatment with each varieties replicated three times. The treatments were randomly distributed to the plots within a block. Thus the number of the plot was 3 x 12 = 36. The unit plot size was (4 m x 2.5 m) *i.e.*, 10 m^2. Irrigation and drainage channel was made by maintaining 50 cm width and 30 cm between the blocks and 25 cm wide and 25 cm depth between plots.

3.9 Experimental procedure and crop management

3.9.1 Collection of seed

The varieties were collected from Bangladesh Agricultural Research Institute (BARI), Gazipur, Bangladesh. Before sowing, the seeds were treated with vitavax-200 for germination in the laboratory and the percentage of germination was found to be over 90 % for all the varieties.

3.9.2 Land preparation

The experimental field was first ploughed with a tractor drawn disc plough on 5 December 2022. The clods of the land were hammered to make soil into small pieces. Weeds, stubbles, and crop residues were removed from the land. The final ploughing and land preparation was done on 13 December 2022. The layout was done as per experimental design on 14 December 2022.

3.9.3 Fertilizer application

Fertilizer was applied as a source of N-P-K nutrients viz., 80 kg N_2, 40 kg P_2O_5, and 40 K_2O kg ha^{-1} uniformly distributed through urea, DAP, and MoP. Therefore, the fertilizer requirement was urea=80g/10 m^2 plot; DAP = 40 g/10 m^2 plot, and MoP = 40 g/10 m^2 plot respectively.

3.9.4 Seed rate

The recommended seed rate (7 kg ha^{-1}) *i.e.*, 0.007 kg or 7 g/ 10 m^2 of mustard variety seed was used for a single plot. Therefore, a total of 252 gm or 2.52 kg seed was required for a 3600 m^2 or 36 plot area. Line to line distance was 30 cm. After placing the seeds on line, the seeds were covered with loose friable soil.

3.9.5 Seed sowing

After preparing the line spacing, seeds were sown in line on 16 December 2022 as per the experimental layout.

3.9.6 Treatment (Gibberellic acid or GA_3) Properties

Gibberellic acid (also called gibberellin A3 or GA_3), is important group of a hormone found in plants and fungi. The gibberellins (GAs) are a hormones which exert various effects on promoter and regulator of plant growth. Its chemical formula is $C_{19}H_{22}O_6$. When purified, it is a white to pale-yellow solid (Fig 4). Plants in their normal state produce large amounts of GA_3. Gibberellic acid (GA_3) affects stem elongation, germination, elimination of dormancy, flowering, sex expression, enzyme induction and leaf production.

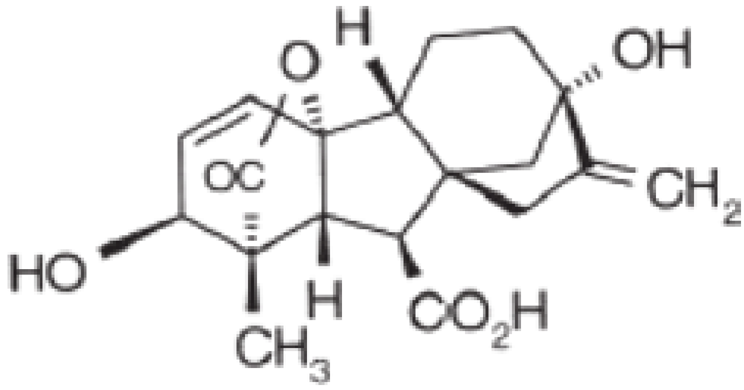


Fig 4: Chemical formula of gibberellic acid (GA_3)

3.9.7 Treatment application

Gibberellic acid (GA_3) foliar application was done by following the treatments. Therefore, the treatments doses were applied as;

Treatments	Application Rate
T_1 = O ppm *i.e.,* Control	No application GA_3
T_2= 25 ppm GA_3 L^{-1} water	25 mg GA_3 mixed with 1 L water
T_3= 50 ppm GA_3 L^{-1} water	50 mg GA_3 mixed with 1 L water
T_4= 75 ppm GA_3 L^{-1} water	75 mg GA_3 mixed with 1 L water

Gibberellic acid was prepared for spraying in the vegetative stage, flowering stage and maturity stage. It was sprayed on leaves in the afternoon by using a hand sprayer.

3.9.8 Intercultural operations

Intercultural operations were done to ensure the normal growth of the crop. Plant protection measures were followed when necessary. The following intercultural operations were followed:

3.9.8.1 Irrigation

Light irrigation was applied after sowing the seeds. After the emergence of the seedlings, three irrigations were given at the different growth stages. The first irrigation was done on 10 January 2023 *i.e.*, (25 DAS); the second irrigation was done on 25 January 2023 (40 DAS) and the third irrigation was done on 10 February 2023 *i.e*., (55 DAS) respectively of sowing in order to maintain enough moisture in the field. During irrigation, care was taken so that water could not flow from one plot to another plot or overflow the boundary of the plots. Excess water in the field was always drained out.

3.9.8.2. Weeding

The plots were infested with some common weeds, namely Durba (Cynodon dactylon), Katanotey (Amaranthus spinosus), SanchiShak (Alternanthera sessilis), Batua (*Chenopodium album*), sushni shak (*Marsilea quadrifolia*), Shetodrone (*Leucas aspera*), Banpalong (*Rumex maritimus*) and Gaghra (*Xanthium indicum*) which were removed by uprooting by hand from the field near about three times during the cropping period.

3.9.8.3 Insect and pest control

There was no infection of disease in the field but the crop was infested with aphids at the time of flowering and was controlled successfully by spraying Ektara @ 0.02 gm L^{-1} water.

3.9.8.4 Harvesting and threshing and weighing

The crop was harvested plot wise when 90% siliqua were matured. After collecting sample plants, harvesting was done on 15 March 2023.The harvested plants were tied into bundles and carried to the threshing floor and processed on 23th March 2023. 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. Then sun dry weight of both seed and straw was recorded for every plot and the weight in the gm plot was converted to t ha $^{-1}$.

3.10 Data collection

15 plants from each plot were selected as random and were tagged for the data collection. Data were recorded on the following crop characteristics:

- Plant height (cm)
- Branch number plant^{-1} (no.)
- Number of leaves plant $^{-1}$ (no.)
- Leaf area (cm^2)
- Number of siliqua plant^{-1} (no.)
- Fresh weight of seed^{-1} (g)
- Dry weight of seed^{-1} (g)
- Fresh weight of plant^{-1} (g)
- Dry weight of plant^{-1} (g)
- Thousand seed weight (g)
- seed yield (t ha^{-1})
- Biological yield (t ha^{-1})
- Stover yield (t ha^{-1})
- Harvest Index (%)

3.11 Methods of recording data

3.11. 1 Plant height (cm)

Plant height was taken three times *i.e.,* 30 DAS, 45 DAS, and at harvesting time. The plant height was measured from the ground level to the base of the plant (top to the soil) to the tip of the tallest leaf in order to obtain an accurate data on the height of plants. From each plot, fifteen plants were selected randomly, and measured the plant height. Always measured the plant height in cm.

3.11.2 Branch number plant^{-1} (no.):

The number of branches was counted plant^{-1} plot^{-1} and counted was done in number.

3.11.3 Number of leaves plant^{-1}:

Fifteen plants were selected randomly from each plot and the number of leaves was counted plant^{-1} and averaged. Number of leaves plant^{-1} was taken at 50 DAS and 75 DAS.

3.11.4. Leaf area

Leaf area measurement is a reliable parameter in studying the impact of environment on plants. Leaves are one of the main plant organs and are responsible for the productivity of a plant. Randomly selected plants from each plot were used to measure the leaf area. Leaf area (A) can be simply calculated by multiplying the product of leaf length (L) and leaf width (W) by a constant. It was recorded in cm.

3.11.5. Number of siliqua plant^{-1}

Number of siliqua plant^{-1} counted from ten randomly selected siliqua from ten sample plants of each plot.

3.11.6 Fresh weight seed^{-1} (g)

Randomly selected fifteen fresh plants were taken out from each plot, then fresh weight of seeds was measured by using a weight balance. Fresh weight seed^{-1} was taken in g.

3.11.7 Dry weight seed^{-1} (g)

Dry weight was taken out from the plants which were selected for dry weight measuring. The fresh seeds were kept in the oven for 2 days *i.e.*, 48 hours, and the weight of those dry seeds was measured in gm.

3.11.8. Fresh weight plant^{-1} (g)

Randomly selected fifteen fresh plants were taken out from each plot, then fresh weight of those plants were measured by using a weight balance. Fresh weight plant^{-1} was taken in gm.

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

Dry weight was taken out from the plants which were selected for dry weight measuring. The fresh plant was kept in the oven for 3 days *i.e.*, 72 hours, and the weight of those dry plants was measured in gm.

3.11.10 Thousand seed weight (g)

Thousand seed from the dry weighted plants were counted per plot and weighed. It was expressed in g.

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

Biological yield is the total biomass produced above the soil. Biological yield was measured by the following formula and expressed in t ha^{-1};

$$Biological\ yield\ = Seed\ Yield\ +\ Straw\ Yield$$

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

After harvesting, the straw from each unit plot was dried in the sun and weighed. The result was expressed as t ha^{-1}. Straw yield was measured by the following formula;

$$\text{Straw yield} = \text{Biological yield} - \text{Seed yield}$$

3.11.13 seed yield (t ha^{-1})

After harvest of the crop, grain from each unit plot was dried and weighed. The result was expressed as t ha' on 14% moisture basis. Seed yield was measured by the following formula;

$$\text{Seed yield} = \text{Biological yield} - \text{Straw yield}$$

3.11.14. Harvest index (%)

Harvest index was determined by dividing the economic yield (seed yield) to the biological yield (seed yield + straw yield) from the same area and then multiplied by 100. It is expressed by the following formula;

$$Harvest\ Index\ (\%) = \frac{Economic\ yield\ (Seed\ Yield)}{Biological\ Yield} \times 100$$

3.12 Data analysis using Statistical programme

The analysis of variance (ANOVA) function, the relationship between Gibberellic acid (GA_3) treatments and mustard variety, with yield attributes of mustard evaluated by the least significant difference (LSD) used for mean comparisons at a 5 % and 1% probability level using statistical programme. Comparison graphs were done by Microsoft Excel programming. Pearson correlation figure was done by programme. Location of the experimental area, experimental research plot, weather graphs were done by using origin pro (2022) software.

CHAPTER IV

RESULTS AND DISCUSSION

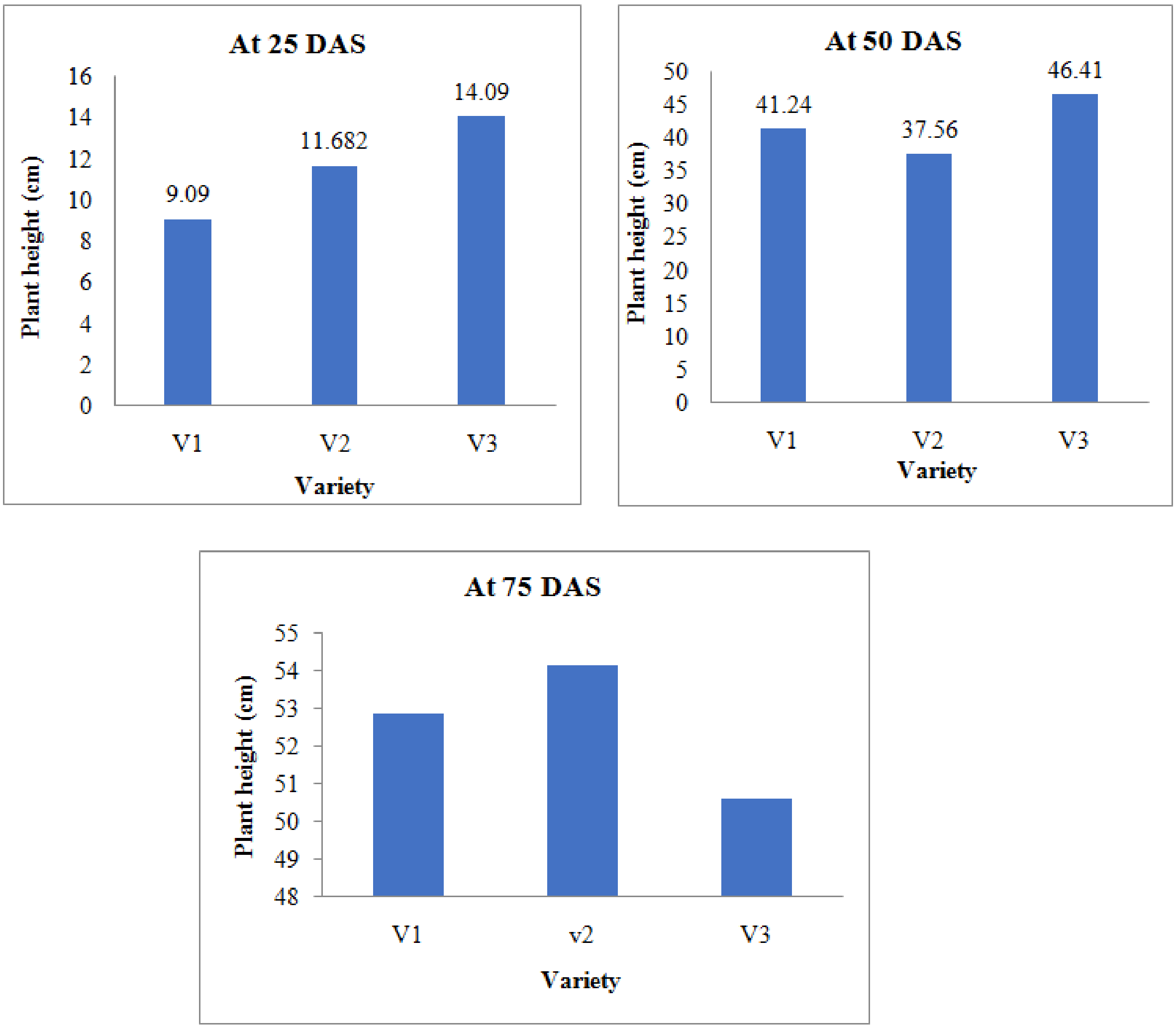
The current study examined the foliar application of varied concentrations GA_3 on growth, yield and yield contributing characteristics of mustard plants. The results have been presented and discussed, and possible explanations have been given under the following headings:

4.1 Effect of GA_3 on different growth parameters of mustard variety

4.1.1 Plant height (cm)

A sort of variation was observed in plant height with the varieties. At 25 DAS maximum height was recorded 14.09 cm from V_3 (BARI Sarisha-19) and lowest was recorded 9.09 cm from V_1 (BARI Sarisha-15) shown in (Figure 5). At 50 DAS maximum height was recorded 46.41 cm from V_3 (BARI Sarisha- 19) and the lowest was recorded 37.56 cm from V_2 (BARI Sarisha-17). At 75 DAS maximum height was recorded 54.13 cm from V_2 (BARI Sarisha-17) and lowest was recorded 50.61 cm from V_3 (BARI Sarisha-19). Differences in plant height between the varieties was statistically non-significant shown in (Figure 5).

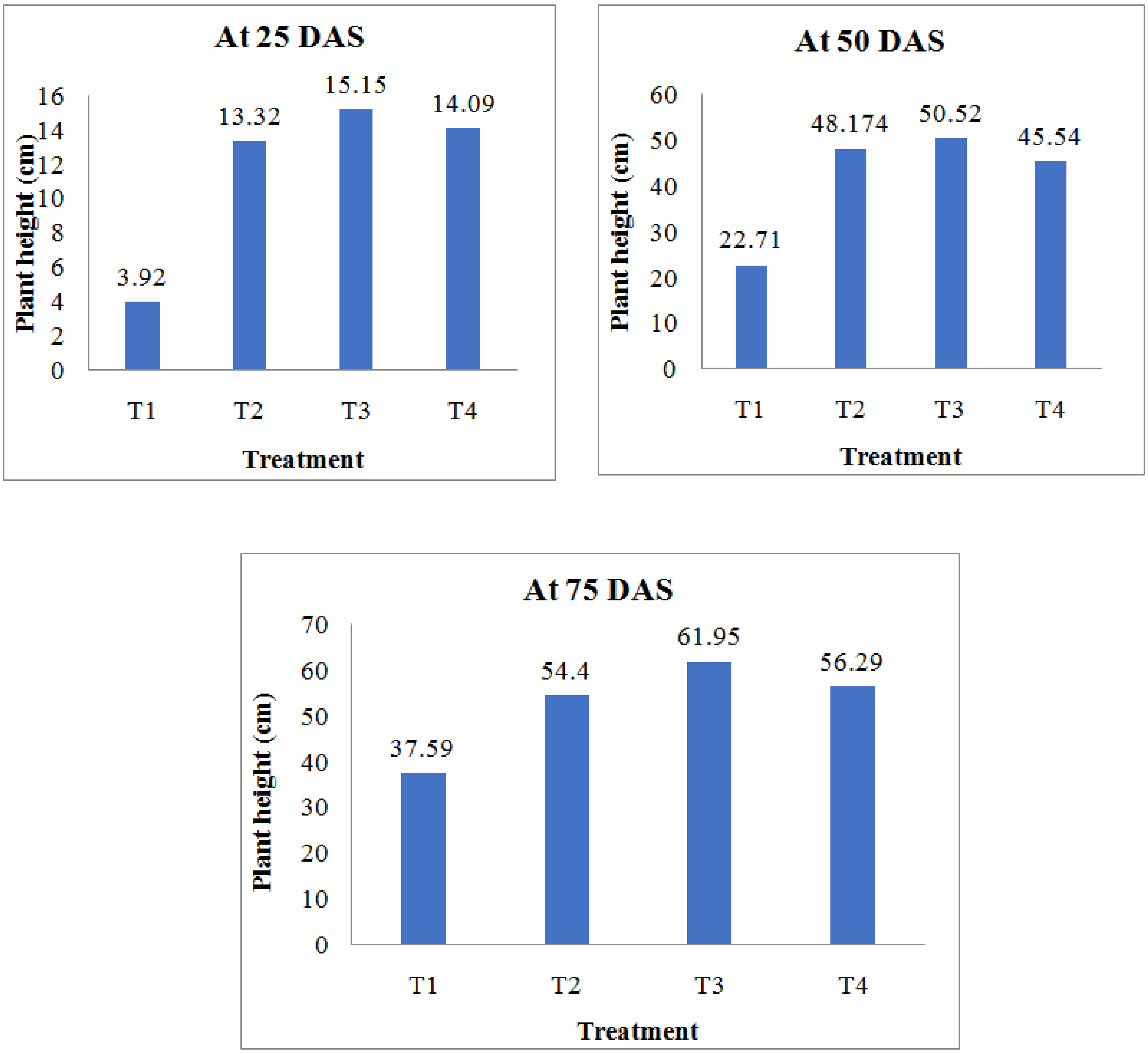
Gibberellic acid administration may have expedited cell expansion, which might account for the rise in plant height seen with varying amounts of GA_3 (Hasioet *et al.*, 1976). According to Ravat and Makani (2015), GA_3 promotes intermodal length by increasing cell proliferation, elongation, and cell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



V_1= BARI Sarisha -15 V_2= BARI Sarisha -17 V_3 = BARI Sarisha -19

Figure 5: Effect of varieties on plant height at 25 DAS, 50 DAS and 75 DAS of mustard

Incase of treatments, plant height varied significantly at 25 DAS, 50 DAS and 75 DAS. At 25 DAS the maximum plant height was obtained 15.15 cm from T_3 (50 ppm GA_3) and the lowest height was 3.92 cm recorded from T_1 control). Plant height 13.32 cm and 14.09 cm was recorded from T_2 (25ppm GA_3), and T_4 (75ppm GA_3) respectively. At 50 DAS the maximum plant height was obtained 50.52 cm from T_3 (50 ppm GA_3) and lowest height was 22.71 cm recorded from T_1 (control). Plant height 48.17 cm and 45.54 cm plant height was recorded from T_2 (25ppm GA_3), and T_4 (75ppm GA_3) respectively. At 75 DAS, the maximum plant height was obtained 61.95 cm from T_3 (50 ppm GA_3) and lowest height was 37.59cm recorded from T_1 (control) 54.4 cm, and 56.29 cm plant height was recorded from T_2 (25ppm GA_3), and T_4 (75ppm GA_3) respectively shown in (Figure 6).



T_1= Control T_3=50 ppm Gibberellic acid

T_2=25 ppm Gibberellic acid T_4=75 ppm Gibberellic acid

Figure 6: Effect of treatments on plant height at 25 DAS, 50 DAS and 75 DAS of mustard

According to the experiment findings, different concentrations of GA_3 had significantly influenced the plant height (Table 2). The tallest plant height was observed at V_3T_3 (BARI Sarisha-19 with 50 ppm GA_3), V_3T_4 (BARI Sarisha-19 with 75 ppm GA_3), V_2T_2 (BARI Sarisha-17 with 25 ppm GA_3) (19.60, 54.93, 63.53 cm) was recorded at 25, 50, 75 DAS and at final harvest time respectively. In plant height induced by different levels of GA_3 was observed in rapes (Castro *et al.*, 1989).

Table 2: Effect of interactions on plant height at 25 DAS, 50 DAS and 75 DAS of Mustard

Interaction	Plant height (cm)		
	25 DAS	50 DAS	75 DAS
T_1V_1	3.337l	22.89k	38.45e
T_1V_2	3.407k	20.86l	37.12e
T_1V_3	5.007j	24.37j	37.2e
T_2V_1	11.487h	46.60e	54.26c
T_2V_2	13.94f	44.44g	63.53a
T_2V_3	14.527d	53.48c	45.41d
T_3V_1	11.717g	53.93b	62.86a
T_3V_2	14.123e	44.80f	63.26a
T_3V_3	19.60a	52.83d	59.70ab
T_4V_1	9.807i	41.54h	55.86bc
T_4V_2	15.26c	40.15i	52.6c
T_4V_3	17.31b	54.93a	60.12ab
LS	*	*	*
LSD	4.34	1.59	5.92
CV	2.78	3.80	3.54

Here** = significantly different at 1% level of probability; * = significantly different at 5% level of probability and NS = Non- significance, LSD = Least Significance Difference; CV = Co-efficient of variance.

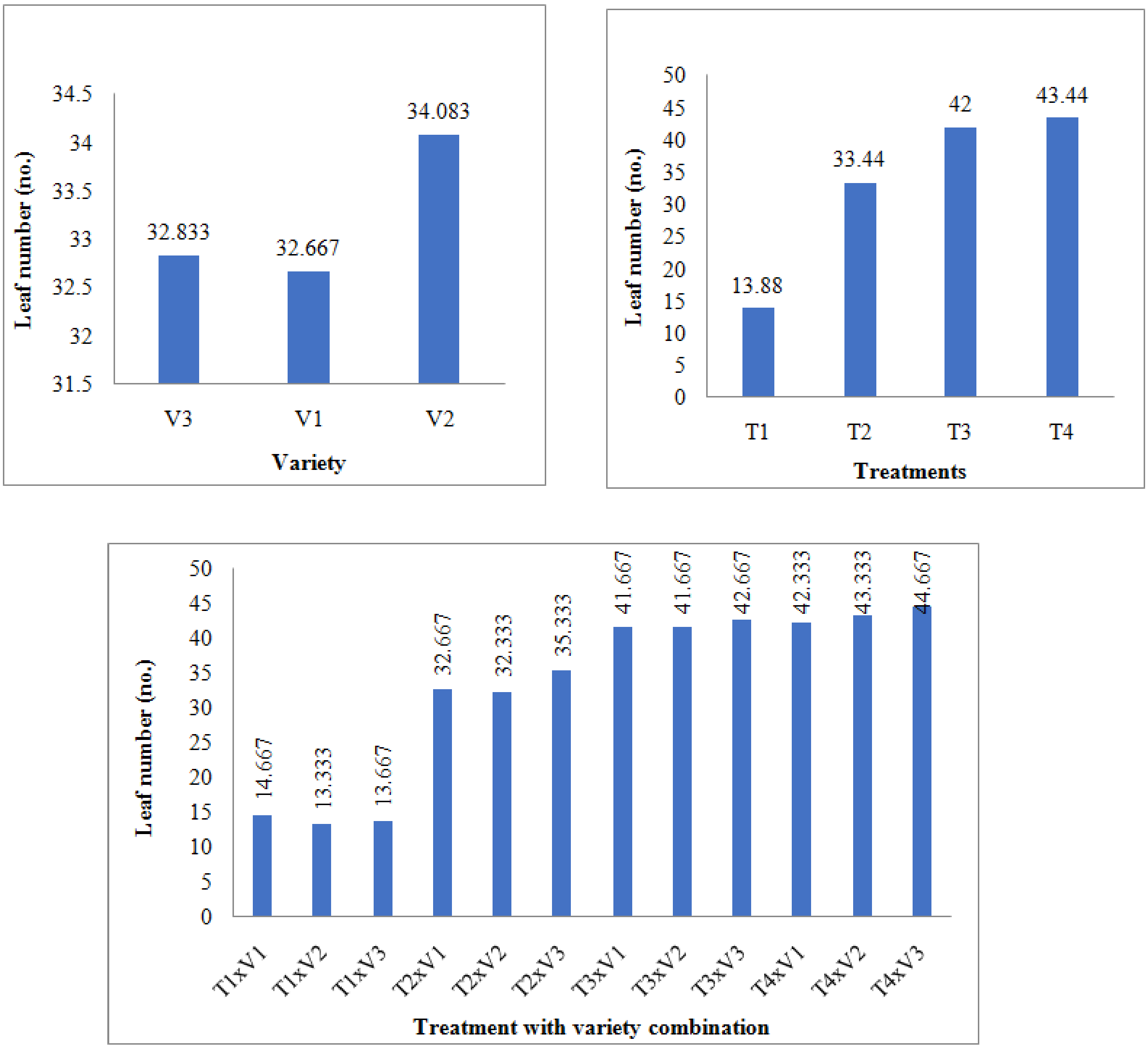
The shortest plant height was observed from V_1T_1 (BARI Sarisha-15 with control), V_2T_1 (BARI Sarisha-17 with control) (3.337, 20.86, 37.12 cm) at 25, 50, 75 DAS (Table 2). The results indicated that the application of different concentrations of GA_3 had increased the plant height over the control treatment.

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 7, the highest number of leaves plant^{-1} 34.083 no was found with V_2 (BARI Sarisha-17) and lowest was recorded 32.667 cm from V_1 (BARI Sarisha-15).

Incase of treatments, leaf number varied significantly at different level of treatment. The maximum leaf number was obtained 43.44 from T_4 (75 ppm GA_3) and the lowest number was 13.38 recorded from T_1 (control). Leaf number 33.44 and 42 was recorded from T_2 (25ppm GA_3), and T_4 (75ppm GA_3) respectively.

According to the experiment findings, different treatment variety interaction of GA_3 had significantly influenced the number of leaf (Figure 7). The maximum number of leaf 44.667 was observed at V_3T_4 (BARI Sarisha-19 with 75 ppm GA_3). The lowest number of leaf was observed from V_2T_1 (BARI Sarisha-17 with control) 13.33 respectively. The results indicated that the application of different concentrations of GA_3 had increased the number of leaf over the control treatment. 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.



V_1= BARI Sarisha -15 V_2= BARI Sarisha -17 V_3 = BARI Sarisha -19

T_1= Control

T_2=25 ppm gibberellic acid

T_3=50 ppm gibberellic acid

T_4=75 ppm gibberellic acid

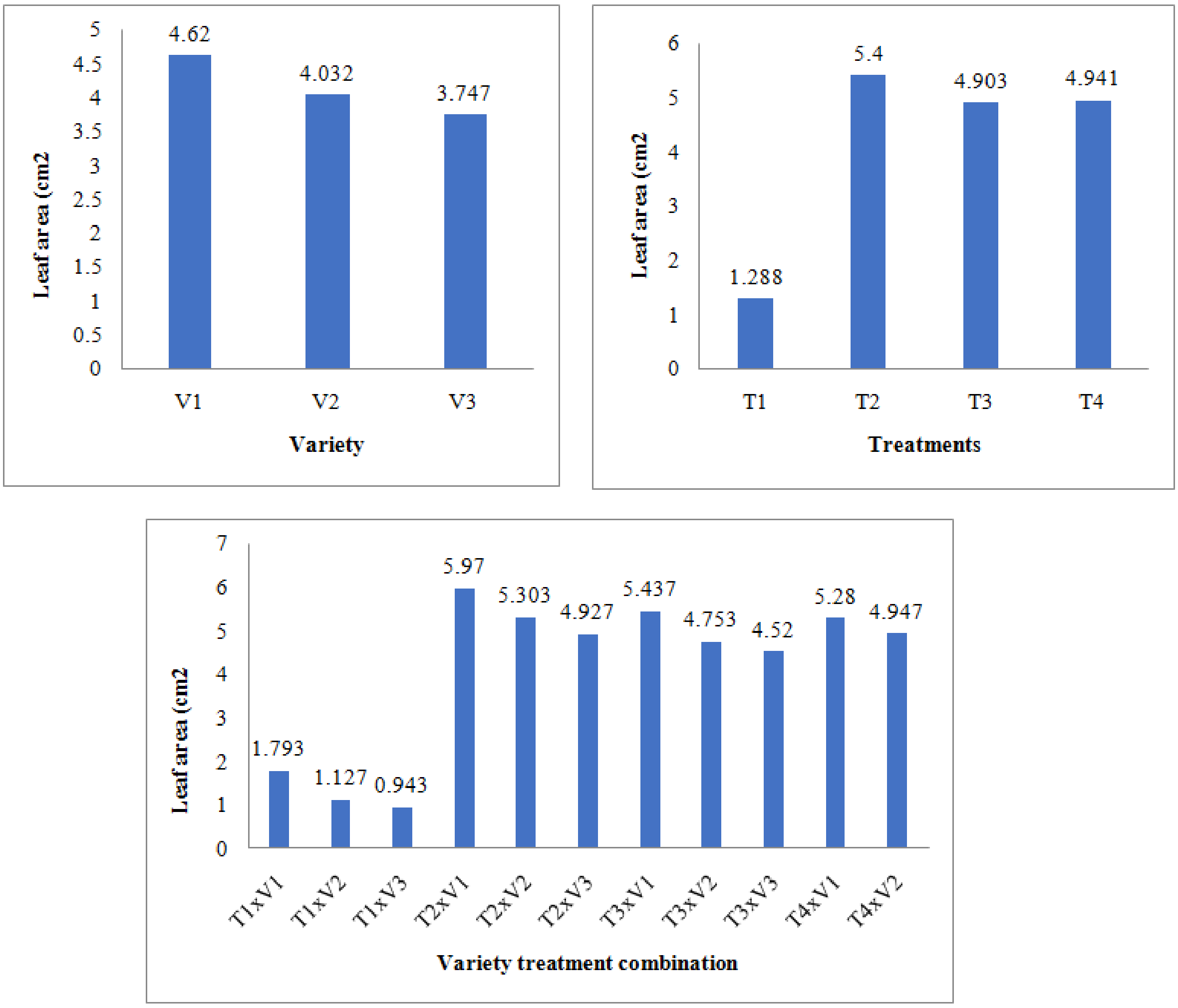
Figure 7: Effect of gibberellic acid on leaf number of mustard

4.1.3 Leaf area plant^{-1}

Leaf area plant^{-1} of mustard was shown to be significantly impacted by the various concentrations of GA_3. According to the figure 8, the highest leaf area plant^{-1} 4.62 cm^2 was found with V_1 (BARI Sarisha-15) and the lowest leaf area plant^{-1} (3.747) cm^2 was found with V_3 (BARI Sarisha -19).

Incase of treatments, leaf area plant^{-1} varied significantly at different level of treatment. The maximum leaf **a**rea plant^{-1} was obtained 5.4 cm^2 from T_2 (25 ppm GA_3) and the lowest leaf area plant^{-1} was 1.288 cm^2 recorded from T_1 (control). Leaf area plant^{-1} 4.903 cm^2 and 4.941 cm^2 was recorded from T_3 (50 ppm GA_3), and T_4 (75ppm GA_3) respectively.

According to the experiment findings, different concentrations of GA_3 had significantly influenced the number of leaf (Figure 8). The highest leaf area plant^{-1} 5.97 cm^2 was observed at V_1T_2 (BARI Sarisha-15 with 25 ppm GA_3). The lowest number of leaf area plant^{-1} 0.943 cm^2 was observed from V_3T_1 (BARI Sarisha-19 with control). The results indicated that the application of different concentrations of GA_3 had increased the number of leaf area plant^{-1} over the control treatment.



V_1= BARI Sarisha -15 V_2= BARI Sarisha -17 V_3 = BARI Sarisha -19

T_1= Control

T_2=25 ppm gibberellic acid

T_3=50 ppm gibberellic acid

T_4=75 ppm gibberellic acid

Figure 8: Effect of Gibberellic (GA_3) acid on leaf area of mustard

4.1.4 Fresh weight 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. In case of variety, fresh weight plant^{-1} was highest in V_3 (BARI Sarisha-19) with 14.36 g and lowest was recorded in V_2 (BARI Sarisha-17) with 13.97 g shown in (Table 3). Fresh weight plant^{-1}shown non-significantly relation with the varieties.

In case of treatment highest fresh weight plant^{-1} was recorded in T_3 (50 ppm GA_3) with 18.87g and the lowest fresh weight plant^{-1} was recorded in T_1 (control) with 6.34g. Fresh weight plant^{-1} recorded in T_2 (25 ppm GA_3) and T_4 (75 ppm GA_3) were 14.41 g and 17.15 g respectively shown in (Table 4).

Table 3: Effect of varieties on fresh weight and dry weight plant $^{-1}$ of mustard

Variety	Fresh weight plant^{-1} (g)	Dry weight plant^{-1} (g)
V_1	14.23a	12.45a
V_2	13.97a	11.87b
V_3	14.36a	12.40a
LS	NS	*
LSD	0.59	0.52
CV	3.60	3.67

In interaction it was shown that highest fresh weight plant^{-1} in V_2T_3 (BARI Sarisha-17 with 50ppm GA_3) 19.34g weight was recorded and the lowest fresh weight plant^{-1} was recorded in V_2T_1 (BARI Sarisha-17 with control) 6.12g. Here, it was also noticed that T_3 (50ppm GA_3) in combination with V_2 (BARI Sarisha-17) showed better performance than T_2 (25ppm GA_3) and T_4 (75 ppm GA_3) in combination with V_1 (BARI Sarisha-15) and $V_{3.}$ (BARI Sarisha-19) shown in (Table 5).

Table 4: Effect of treatments on fresh weight and dry weight of plant^{-1} of mustard

Treatments	Fresh weight plant^{-1} (g)	Dry weight plant^{-1} (g)
T1	6.34d	4.67d
T_2	14.41c	12.37c
T_3	18.87a	16.86a
T_4	17.15b	15.06b
LS	*	*
LSD	0.68	0.60
CV	3.60	3.67

Table 5: Effect of treatment and variety interactions on Fresh weight plant^{-1} and Dry weight plant^{-1}

Interactions	Fresh weight plant^{-1} (g)	Dry weight plant^{-1} (g)
T_1xV_1	6.45e	4.78f
T_1xV_2	6.12e	4.63f
T_1xV_3	6.45e	4.59f
T_2xV_1	15.14c	12.92d
T_2xV_2	13.2d	11.33e
T_2xV_3	14.8c	12.84d
T_3xV_1	18.71a	17.00a
T_3xV_2	19.34a	16.89a
T_3xV_3	18.56a	16.66a
T_4xV_1	16.7b	5.08bc
T_4xV_2	17.22b	14.60c
T_4xV_3	17.54b	15.51b
LS	*	*
LSD	1.18	1.03
CV	3.60	3.67

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 Dry weight plant^{-1} (g)

Result (Table 3) showed that In V_1 (BARI Sarisha-15) with 12.45g dry weight plant^{-1} was recorded highest value and the lowest was recorded in V_2 (BARI Sarisha-17) with 11.87g. In case of treatments the highest value was recorded in T_3 (50 ppm GA_3) with 16.86g and the lowest was recorded in T_1 (control) with 4.67g (Table 4). Among the interactions V_1T_3 ((BARI Sarisha-15 with 50 ppm GA_3) with 17.00 g the highest dry weight plant^{-1} was recorded and the lowest was recorded in V_3T_1 (BARI Sarisha-19 with control) 4.59g shown in (Table 5). 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.

4.1.6 Fresh weight of seed plant^{-1} and dry weight of seed plant $^{-1}$ of mustard

A significant variation was found in terms of total fresh plant^{-1} and total dry weight plant^{-1} due to the application of different levels of GA_3. The highest fresh weight of seed was recorded in V_1 (BARI Sorisha-15) with 21.34g and the lowest was recorded in V_2 (BARI Sorisha-17) 20.02g shown in (Table 6).

Besides, fresh weight of seed varied significantly with the treatments. The highest value was recorded in T_4 (75ppm GA_3) 18.11g and the lowest value was recorded in T_1 (Control) 5.64g shown in (Table 7).

In case of interactions highest fresh weight of seed was obtained in V_2T_3 (BARI Sarisha-17 with 50 ppm GA_3) 39.58g and lowest was recorded in V_1T_1 (BARI Sarisha-15 with control) 23.67g (Table 8). Dry weight of seed /platnt varied non-significantly with the varieties. The highest was recorded in V_2 (BARI Sarisha-17) with 8.17g and the lowest was recorded in V_1 (BARI Sarisha-15) 5.58g (Table 6). On the other hand, Seed dry weight varied significantly with the treatments. The highest value was recorded in T_4 (75 ppm) with 7.08g and the lowest value was recorded in T_1 (control) 1.55g (Table 7). In case of interactions highest dry weight of seed was obtained in V_2T_3 (BARI Sarisha-17 with 50ppm GA_3) 13.33g and lowest was recorded in V_1T_1 (BARI Sarisha-15 with control) and V_3T_1 (BARI Sarisha-19 with Control) 5.12g (Table 8).

Table 6: Effect of varieties on fresh weight and dry weight of seed plant^{-1} of mustard

Variety	Fresh weight of seed plant^{-1} (g)	Dry weight of seed plant^{-1} (g)
V_1	21.34a	5.58b
V_2	20.02a	8.17a
V_3	20.07a	6.92ab
LS	NS	*
LSD	1.32	1.78
CV	455.60	456.52

Table 7: Effect of treatments on fresh weight and dry weight of seed plant^{-1} of mustard

Treatments	Fresh weight of seed (g)	Dry weight of seed (g)
T_1	5.64c	1.55d
T_2	12.59bc	4.53c
T_3	16.55b	6.50b
T_4	18.11a	7.08a
LS	*	*
LSD	3.33	51.32
CV	455.60	456.52

Table 8: Effect of interactions on Fresh weight of seed plant^{-1} and Dry weight of seed plant^{-1}

Interactions	Fresh weight of seed plant^{-1} (g)	Dry weight of seed plant^{-1} (g)
T_1xV_1	23.67d	5.20d
T_1xV_2	24.59d	5.12d
T_1xV_3	24.67d	5.12d
T_2xV_1	37.63c	11.33c
T_2xV_2	36.52c	11.20c
T_2xV_3	36.65c	11.41c
T_3xV_1	39.55a	13.00a
T_3xV_2	39.58a	13.33a
T_3xV_3	39.12a	13.31a
T_4xV_1	38.52b	12.12b
T_4xV_2	38.39b	12.00b
T_4xV_3	38.45b	12.10b
LS	*	*
LSD	4.56	3.98
CV	3.60	5.42

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

4.2 Effect of GA_3 on the different yield contributing characters of mustard variety

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 (Table 9). With the application of GA_3, the highest setting of siliqua plant^{-1} 57.92 was observed at V_3 (BARI Sarisha-19). While the lowest setting of siliqua plant^{-1} 57.08 was observed at V_1 (BARI Sarisha-15) shown in (Table 9).

Besides, siliqua plant^{-1} varied significantly with the treatments. The highest value was recorded in T_3 (50 ppm GA_3) 73.55 no and the lowest value was recorded in T_1 (Control) 19.33 no (Table 10).

In case of interactions highest siliqua plant^{-1} was obtained in V_2T_3 (BARI Sarisha-17 with 50 ppm GA_3) 74.0 no and lowest was recorded in V_2T_1 (BARI Sarisha-17 with control) 18.66 no (Table 11). With the level of GA_3 raised up to 50 ppm, the proportion of siliqua setting increased as well.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).

4.2.2 Number of seed siliqua^{-1}

Different amounts of GA_3 greatly affected the number of seeds siliqua^{-1}. The results showed that the maximum number of seeds siliqua^{-1} 18.17 no was obtained from V_2 (BARI Sarisha 17) and lowest seeds siliqua^{-1} 15.58 no was obtained from V_1 (BARI Sarisha -15) shown in (Table 9). Besides, Seed siliqua^{-1} varied significantly with the treatments. The highest value was recorded in T_4 (75ppm GA_3) 21.33 no and the lowest value was recorded in T_1 (Control) 8.55 no (Table 10).

In case of interactions highest seed siliqua^{-1}was obtained in V_2T_3 (BARI Sarisha-17 with 50 ppm GA_3) 22.0 no and lowest was recorded in V_2T_1 (BARI Sarisha-17 with control) 8.33 no (Table 11). 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).

Table 9: Effect of varieties on seed siliqua $^{-1}$ and siliqua plant^{-1}

Variety	Seeds siliqua^{-1} (no.)	Siliqua plant^{-1} (no.)
V_1	15.58^{b}	57.08^{a}
V_2	18.17^{a}	57.833^{a}
V_3	16.92^{ab}	57.92^{a}
LS	*	NS
LSD	1.78	2.11
CV	21.76	18.94

In a column, bearing NS do not differ significantly at 5% level of significance
**= Significant at 1% level of probability
*= Significant at 5% level of probability
LS=Level of significance
CV=Co-efficient of variance
LSD= Least Significant Difference
V_2= BARI Sarisha -17
V_1= BARI Sarisha -15
V_3= BARI Sarisha -19

Table 10: Effect of treatments on seed siliqua $^{-1}$ and siliqua plant^{-1} of mustard

Treatments	Seeds siliqua^{-1} (no.)	Siliqua plant^{-1} (no.)
T_1	8.55^{c}	19.33^{c}
T_2	18.11^{b}	66.0^{b}
T_3	19.55^{ab}	73.55^{a}
T_4	21.33^{a}	71.55^{a}
LS	*	*
LSD	2.82	3.33
CV	21.76	18.94

In a column, bearing NS do not differ significantly at 5% level of significance
**= Significant at 1% level of probability
*= Significant at 5% level of probability
LS=Level of significance
CV=Co-efficient of variance
LSD= Least Significant Difference
T_1= Control
T_2=25 ppm GA_3
T_3=50 ppm GA_3
T_4=75 ppm GA_3

Table 11: Effect of interactions on siliqua plant^{-1} and seed siliqua $^{-1}$ of mustard

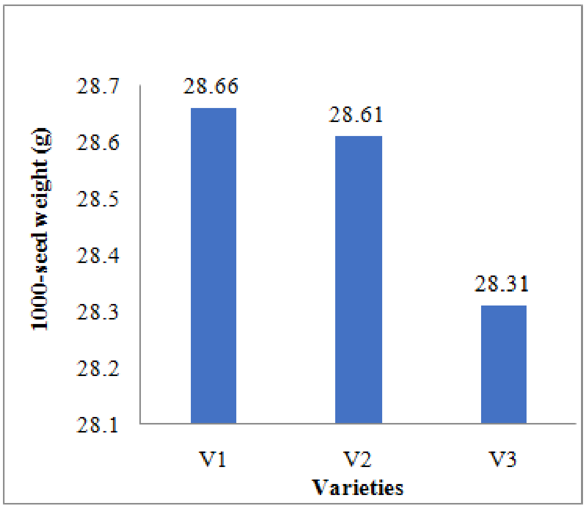
Interactions	Siliqua plant^{-1} (no.)	Seeds siliqua^{-1} (no.)
T_1xV_1	19.66c	8.67d
T_1xV_2	18.66c	8.33d
T_1xV_3	19.66c	8.67d
T_2xV_1	64.33b	16.0c
T_2xV_2	66.0ab	21.33ab
T_2xV_3	67.66ab	17.0bc
T_3xV_1	73.66a	16.33c
T_3xV_2	74.0a	22.0a
T_3xV_3	73.0ab	20.33ab
T_4xV_1	70.66ab	21.33ab
T_4xV_2	72.66ab	21.0ab
T_4xV_3	71.33ab	21.67a
LS	*	*
LSD	4.56	3.98
CV	8.89	15.42

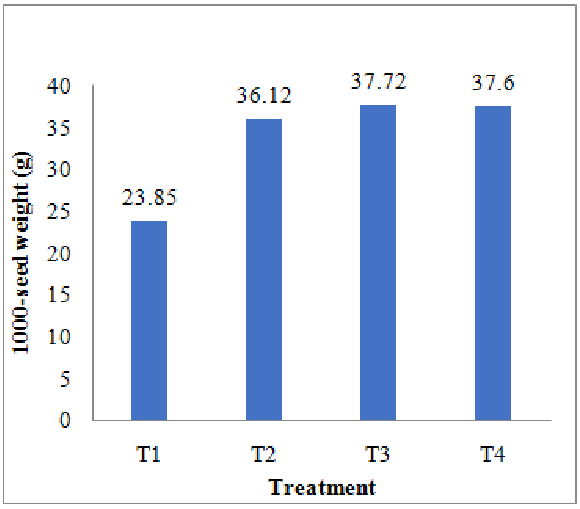
Here, ** = significantly different at 1% level of probability; * = significantly different at 5% level of probability and NS =Non significance, LS = Level of significance; CV = Co-efficient of variance

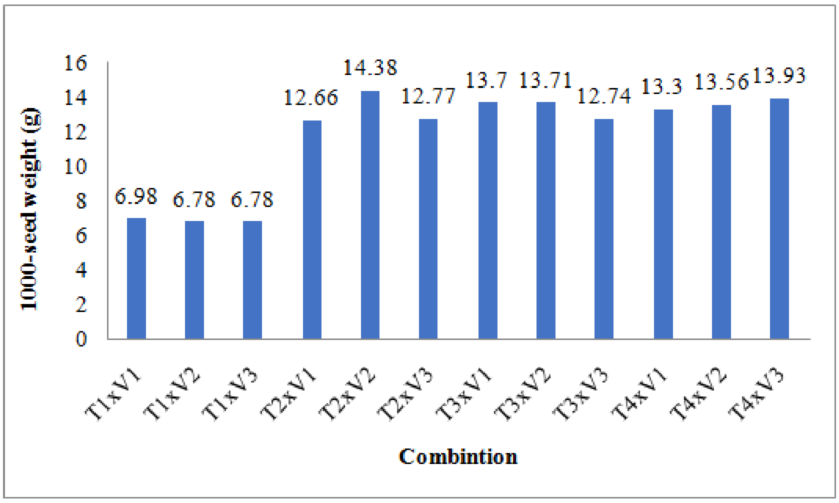
4.2.3 Thousand seed weight (g)

The mustard 1000-seed weight was significantly impacted by varying levels of GA_3 concentration (Fig 9). The highest thousand seed weight 28.66g observed was V_1 (BARI Sarisha -15) and the lowest thousand seed weight 28.31g observed was V_3 (BARI Sarisha -19).

On the other hand, 1000-seed weight varied significantly with the treatments. The highest value 37.72 g was recorded in T_3 (50 ppm GA_3) and the lowest value 23.85 g was recorded in T_1 (control). In case of T_2 (25 ppm) and T_4 (75 ppm) thousand seed weight were recorded 36.42 g, and 37.6 g respectively (Figure 9).







V_1= BARI Sarisha -15 V_2= BARI Sarisha -17 V_3 = BARI Sarisha -19

T_1= Control T_3=50 ppm gibberellic acid

T_2=25 ppm gibberellic acid T_4=75 ppm gibberellic acid

Figure 9: Effect of Gibberellic acid on 1000 seed weight plant^{-1} of mustard

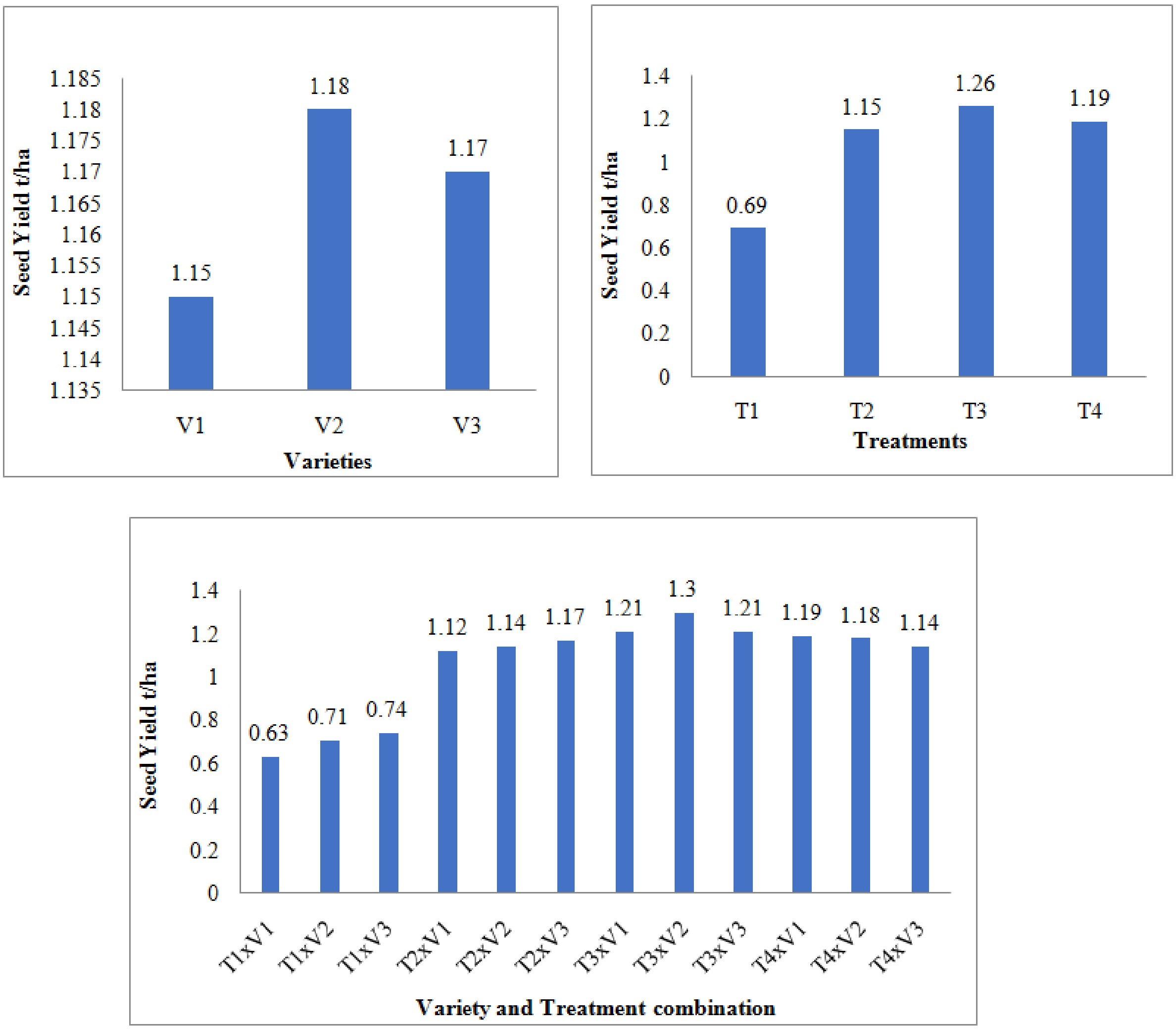
In case of interactions highest thousand seed weight was obtained in V_2T_2 (BARI Sarisha -17 with 25 ppm GA_3) 14.38g and lowest was recorded in V_2T_1 (BARI Sarisha -17 with control) and V_3T_1 (BARI Sarisha -19 with control treatment) 6.78g (Fig 9). The highly significant results for thousand seed weight were also supported by the earlier results of (Zebarjadi *et al.*, 2011).

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

Different levels of GA_3 concentrations had significant effect on seed yield (Fig 10). Seed yield varied significantly with the variety. V_2 (BARI Sarisha -17) with 1.18 t ha^{-1} showed better result than V_1 (BARI Sarisha -15) 1.15 t ha^{-1}.

Besides, significant difference was also found with the treatments. Highest Seed yield was obtained in T_3 (50 ppm GA_3) with 1.26 t ha^{-1} and lowest was recorded in T_1 (control) with 0.69 t ha^{-1}. T_2 (25 ppm GA_3) 1.15 t ha^{-1} and T_4 (75ppm GA_3) 1.19 t ha^{-1} were varied non-significantly (Fig 10).

In case of interactions, we can see significant difference.The highest yield was recorded in V_2T_3 (BARI Sarisha-17 with 50 ppm GA_3) 1.3 t ha^{-1} and lowest was recorded in V_1T_1 (BARI Sarisha-15 with Control) 0.63 t ha-1 shown in (Fig 10). 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 on 30 days old plants showed increased vegetative growth and seed yield at harvest.



V_1= BARI Sarisha -15 V_2= BARI Sarisha -17 V_3 = BARI Sarisha -19

T_1= Control

T_2=25 ppm gibberellic acid

T_3=50 ppm gibberellic acid

T_4=75 ppm gibberellic acid

Figure 10: Effect of gibberellic acid on seed yield of mustard

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

Straw yield was significantly different with the varieties. Highest straw yield was recorded in V_2 (BARI Sarisha-17) with 2.74 t ha^{-1} and lowest was obtained in V_1 (BARI Sarisha-15) with 2.39 t ha^{-1} (Table12).

For treatments, it varies significantly. The highest straw yield was obtained in T_3 (50 ppm GA_3) with 3.01 t ha^{-1} and lowest was obtained in T_1 (control) 1.72 t ha^{-1} (Table13).

In case of interaction, the highest straw yield was recorded V_2T_3 (BARI Sarisha-17 with 50 ppm GA_3) 3.48 t ha^{-1} and lowest was obtained in V_2T_1 (BARI Sarisha-17 with control) 1.63 t ha^{-1} (Table14**)**.

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

Result showed that V_1 (BARI Sarisha-15) with 12.45 t ha^{-1} showed better performance over V_2 (BARI Sarisha -17) with 11.87 t ha^{-1} which were significantly different with each other (Table12**)**.

On the other hand, significant differences were experienced with treatments. Highest value was recorded in T_3 (50 ppm GA_3) with 4.43 t ha^{-1} and lowest was recorded in T_1 (control) 2.42 t ha^{1} (Table13**)**.

In case of interaction highest straw yield was recorded V_2T_3 (BARI Sarisha-17 with 50 ppm GA_3) 4.89 t ha^{-1} and lowest was obtained in V_2T_1 (BARI Sarisha-17 with control) 2.34 t ha^{-1} (Table14**).**

Table 12: Effect of varieties on Straw yield and Biological yield of mustard

Variety	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})
V_1	2.39ab	12.45a
V_2	2.74a	11.87b
V_3	2.54ab	12.40a
LS	*	*
LSD	0.27	0.52
CV	9.09	3.67

In a column, bearing NS do not differ significantly at 5% level of significance
**= Significant at 1% level of probability *= Significant at 5% level of probability
LS=Level of significance CV=Co-efficient of variance
LSD= Least Significant Difference V_2= BARI Sarisha -17
V_1= BARI Sarisha -15 V_3= BARI Sarisha -19

Table 13: Effect of treatments on Straw yield and Biological yield of mustard

Treatments	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})
T_1	1.72c	2.42c
T_2	2.72b	3.87b
T_3	3.01a	4.43a
T_4	3.01b	4.02a
LS	*	*
LSD	0.31	0.37
CV	9.09	7.60

Table 14: Effect of treatments and varieties interaction on Straw yield and Biological yield of mustard

Interactions	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})
T_1xV_1	1.82d	2.45e
T_1xV_2	1.63d	2.34e
T_1xV_3	1.72d	2.46e
T_2xV_1	2.71bc	3.83d
T_2xV_2	2.57c	3.71d
T_2xV_3	2.88bc	4.06bc
T_3xV_1	2.78bc	4.08bc
T_3xV_2	3.48a	4.89a
T_3xV_3	2.93bc	4.31bc
T_4xV_1	2.97b	4.41b
T_4xV_2	2.56c	3.74b
T_4xV_3	2.78bc	3.92cd
LS	*	*
LSD	0.54	0.64
CV	3.60	7.60

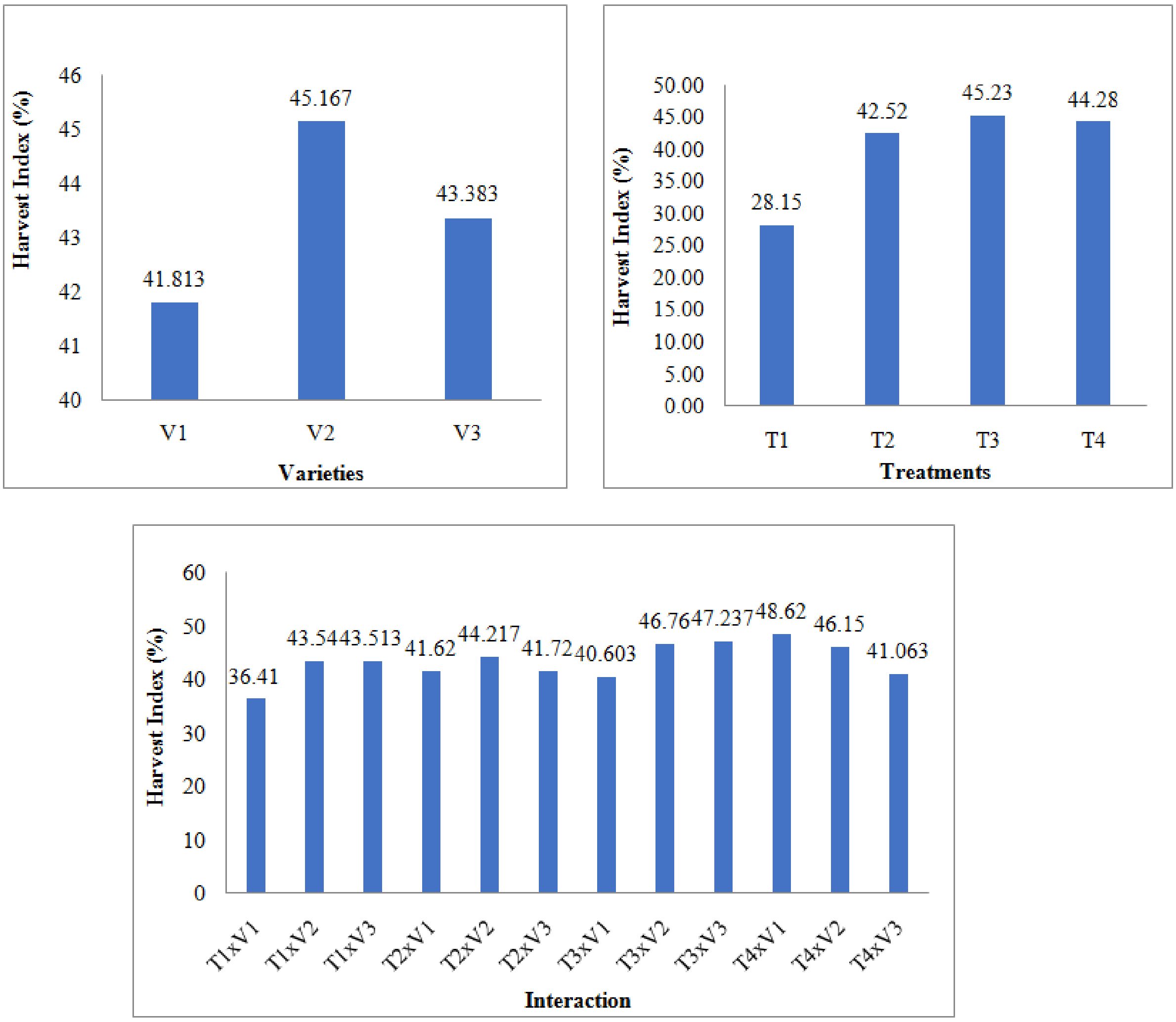
Here**,** ** = significantly different at 1% level of probability; * = significantly different at 5% level of probability and NS =Non significance, LS = Level of significance; CV = Co-efficient of variance

4.2.7 Harvest Index (%)

The results showed that different concentrations of GA_3 had significant influence on the harvest index (Fig 11). In case of variety maximum harvest index were recorded in V_2 (BARI Sarisha-17) with 45.16 % and the lowest was recorded in V_1 (BARI Sarisha-15) with 41.81 % (Fig 11).

Besides, harvest index varied significantly with the treatments. Maximum value was obtained from T_3 (50 ppm GA_3) with 45.23% and the lowest value was obtained from T_1 (control) with 28.15%. In T_2 (25 ppm GA_3) and T_4 (75 ppm GA_3) harvest index recorded 42.52% and 44.28 % respectively (Fig 11).

Significant difference was observed in interaction. Maximum harvest index was recorded from V_1T_4 (BARI Sarisha-15 with 75 ppm GA_3) 48.62 % and lowest was recorded from V_1T_1 (BARI Sarisha-15 with Control) 36.41 % shown in (Fig 11). 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 mgL^{-1} applied at 600 liters ha^{-1} at the pre- flowering stage on Indian mustard (*Brassica Juncea*) was reported to increase the harvest index (Khan, 1997).



V_1= BARI Sarisha -15 V_2= BARI Sarisha -17 V_3 = BARI Sarisha -19

T_1= Control

T_2=25 ppm gibberellic acid

T_3=50 ppm gibberellic acid

T_4=75 ppm gibberellic acid

Figure 11: Effect of gibberellic acid on harvest index of mustard

Pearson correlation among the yield contributing characters:

Correlation result showed that a strong correlation among the yield contributing traits. Plant height at 30DAS showed a position correlation with plant height at 45 DAS (0.87), siliqua plant^{-1} (0.85), leaves number plant^{-1} (0.86), fresh weight plant^{-1} (0.85), dry weight plant^{-1} (0.84), seed yield (0.72), biological yield (0.71). While negative correlation showed with only one parameter dry weight seed^{-1}(-0.034). Plant height at 45DAS showed highest positive correlation with siliqua number plant^{-1} (0.85), leaf length (0.81), biological yield (0.80), fresh weight plant^{-1} (0.85), dry weight plant^{-1} (0.86). A very low positive correlation showed with fresh weight seed^{-1} and dry weight of seed^{-1} (0.0071 and 0.03). Plant height at harvest stage showed positive with siliqua number plant^{-1} (0.84), leaves number plant^{-1} (0.83), fresh weight plant^{-1} (0.84), dry weight plant^{-1} (0.85). A very low positive correlation showed with fresh weight seed^{-1}, dry weight of seed^{-1}, and 1000-seed weight (0.13 and 0.09, 0.13).

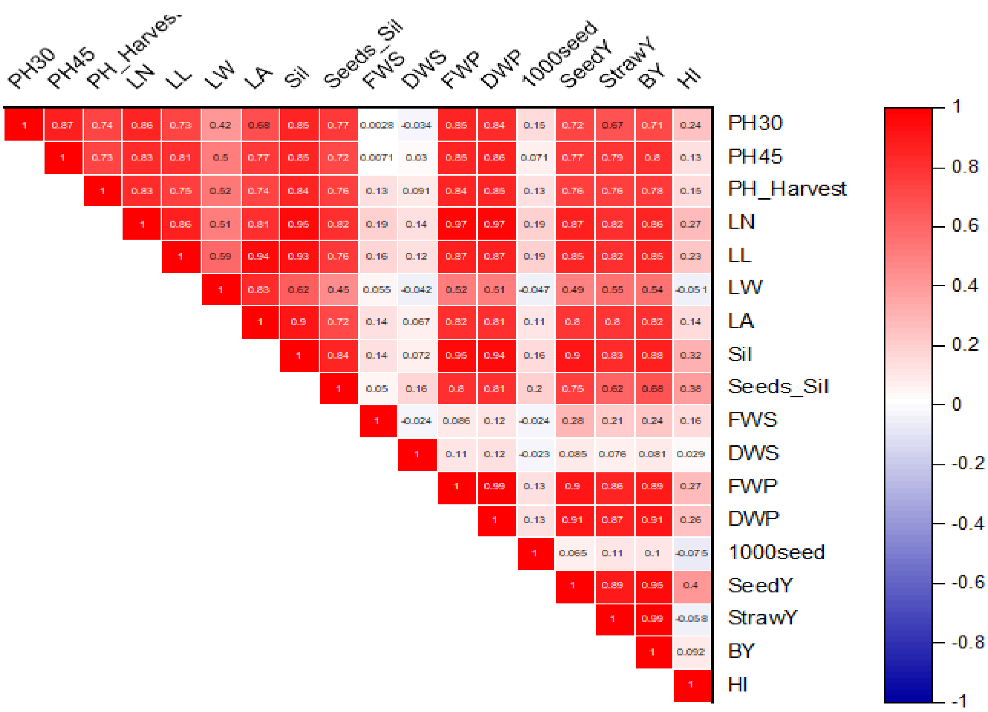


Fig 12: Pearson correlation among the yield contributing characters of mustard. Here, PH= Plant Height, LN= Leaf number, LL= Leaf length, LW= Leaf width, LA=Leaf area, Sil= Siliqua number, Seeds-Sil= Siliqua number seed$^{-1,}$ FWS =Fresh weight of seed, DWS= Dry weight of seed, FWP= Fresh weight plant$^{-1,}$ DWP= dry weight plant^{-}1, Seed Y = Seed yield, Straw Y= Straw yield, BY= Biological yield, HI=Harvest index.

Leaf number showed a positive correlation with leaf length (0.86), leaf area (0.81), seeds siliqua^{-1} (0.95), fresh weight plant^{-1} (0.97), dry weight plant^{-1} (0.97), seed yield (0.87). A very low positive correlation showed with fresh weight seed^{-1}, dry weight of seed^{-1}, and 1000 seed weight (0.19 and 0.14, and 0.19). Leaf length showed a highly positive correlation with leaf area (0.94), seeds siliqua^{-1} (0.76), fresh weight plant^{-1} (0.87), dry weight plant^{-1} (0.87), seed yield (0.85) and straw yield (0.82). A very low positive correlation showed with fresh weight seed^{-1}, dry weight of seed^{-1}, and 1000 seed weight (0.16 and 0.12, and 0.19). Leaf width showed highly positive correlation with leaf area (0.83). While showed negative correlation with dry weight of seed^{-1} (-0.042) and Harvest index (-0.051). Leaf area showed highly positive correlation with siliqua number plant^{-1} (0.90), fresh weight plant^{-1} (0.82), dry weight plant^{-1} (0.81).

Siliqua number plant^{-1} had a highly positive correlation with fresh weight plant^{-1} (0.93), dry weight plant^{-1} (0.94), seed yield (0.90), straw yield (0.83) and biological yield (0.82). Seeds siliqua^{-1} showed a highly positive correlation with fresh weight plant^{-1} (0.80), dry weight plant^{-1} (0.81).

Fresh weight plant^{-1} and dry weight plant^{-1} showed highly positive correlation with seed yield (0.90 and 0.91), straw yield (0.86 and 0.87) and biological yield (0.89 and 0.91). Seed yield showed highly positive correlation with straw yield (0.80) and biological yield (0.93). Straw yield showed highly positive correlation with biological yield (1.00). While straw yield showed negative correlation with harvest index (-0.058).

While, fresh weight seed and dry weight seed showed very poor positive correlation with the yield contributing characters. 1000-seed weight also showed very poor positive correlation with the yield contributing characters and showed negative correlation with harvest index (-0.075). Therefore, it could be concluded that plant height, leaf number, leaf length, siliqua number plant$^{-1,}$ fresh weight plant^{-1} and dry weight plant$^{-1,}$ straw yield, seed yield had a positive and strong correlation for higher yield of different mustard variety.

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-15, BARI Sarisha-17 and BARI Sarisha-19. 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 consisted of two factors namely one was variety and another one treatment. The planting material of the experiment were wheat (V_1 = BARI Sarisha-15, V_2= BARI Sarisha-17 and V_3 = BARI Sarisha-19). The treatments were, T_1 (Control), T_2 (25 ppm GA_3), T_3 (50 ppm GA_3) and T_4 (75 ppm GA_3). The experiment was laid out in a Randomized Complete Block Design (RCBD). There were 4 treatment combinations where each treatment replicated three times. The treatments were randomly distributed to the plots within a block. Thus, the number of plots was 3 × 12 = 36. The unit plot size was (4 m × 2.5 m) *i.e.*, 10 m^2. Irrigation and drainage channel were made by maintaining 50 cm width and 30 cm between the blocks and 25 cm wide and 25 cm depth between plots.

In the research field, the seeds were sown on 16 December 2022. The crop was harvested at maturity about 90 days after sowing. The growth, yield and yield components were recorded for each plot from randomly selected 15 plants. Parameters like plant height, branch number $plant^{-1}$, number of leaves $plant^{-1}$, leaf area (cm^2), number of siliqua $plant^{-1}$, fresh weight of seed $plant^{-1}$, dry weight of seed $plant^{-1}$, fresh weight $plant^{-1}$, dry weight $plant^{-1}$, thousand seed weight, grain yield, biological yield, stover yield and harvest index were influenced by GA_3. The results revealed that at 25 DAS, 50 DAS and 75 DAS as a variety, the longest plant was recorded from V_3 (BARI Sarisha-19) with (14.09cm),V_3 (BARI Sarisha-19) with (46.41 cm) and V_2 (BARI Sarisha-17) with (54.13 cm) respectively and the shortest plants were obtained from V_1(BARI Sarisha-15) (9.09 cm),V_2 (BARI Sarisha-17) (37.56 cm) and V_3 (BARI Sarisha-19) (50.61 cm) respectively. . As a treatment, the longest plant was recorded from T_3 (50 ppm GA_3) (15.15 cm), T_3 (50 ppm GA_3) (50.52 cm) and T_3(50 ppm $GA_{3)}$) (61.95 cm) respectively and the shortest plant obtained from T_1(Control) (3.92 cm, 22.71 cm and 37.59 cm) respectively. Variety treatment interaction showed the lowest plant height at V_1T_1 (BARI

Sarisha-15 with control) (3.337 cm), V_2T_1 (BARI Sarisha-17 with control) (20.86 cm) and (37.12 cm) respectively and the highest plant at V_3T_3 (BARI Sarisha-19 with 50 ppm GA_3) (19.60 cm), V_3T_4 (BARI Sarisha-19 with 75 ppm GA_3) (54.93 cm) and V_2T_2 (BARI Sarisha-17 with 25 ppm GA_3) (63.53 cm) respectively. As a variety, the results revealed that the lowest number of leaves plant^{-1} were obtained from V_1 (BARI Sarisha-15) (32.667 no.), while the highest number of leaves plant^{-1} V_2 (BARI Sarisha-17) (34.083no.) respectively. As a treatment the lowest number of leaves plant^{-1} was obtained from T_1 (Control) (13.38no.) and the highest number of leaves plant^{-1} was observed from T_4 (75 ppm GA_3) (43.44no.) respectively. As a variety treatment interaction showed the highest number of leaves plant^{-1} obtained from V_3T_4 (BARI Sarisha-19 with 75 ppm GA_3) (44.667 no.) and the lowest number of leaves plant^{-1} obtained from V_2T_1 (BARI Sarisha-17 with control) (13.33 no.) respectively. As a variety the highest leaf area plant^{-1} was obtained from V_1 (BARI Sarisha-15) (4.62 cm^2) and the lowest leaf area plant^{-1} was obtained from V_3 (BARI Sarisha-19) (3.747 cm^2). As a treatment highest leaf area plant^{-1} was obtained from T_2 (25 ppm GA_3) (5.4 cm^2) respectively and the lowest leaf area plant^{-1} was obtained from T_1 (Control) (1.288 cm^2). As a treatment and variety combination highest leaf area plant^{-1} was obtained from V_1T_2 (BARI Sarisha-15 with 25 ppm GA_3) (5.97 cm^2) and the lowest was obtained from V_3T_1 (BARI Sarisha-19 with control) (0.943 cm^2) respectively. The results of the experiment revealed that the maximum Fresh weight plant^{-1} (14.36g) was produced at V_3 (BARI Sarisha-19) and the lowest Fresh weight plant^{-1} (13.97 g) at V_2 (BARI Sarisha-17). As a treatment lowest fresh weight plant^{-1} was obtained (6.34g) at T_1 (Control) and the highest (18.87g) at T_3 (50 ppm GA_3). Finally, the interaction highest Fresh weight plant^{-1} (19.34 g) was obtained at V_2T_3 (BARI Sarisha 17 with 50 ppm GA_3) and the lowest was obtained (6.12 g) at V_2T_1 (BARI Sarisha 17 with control). As a variety, the lowest Dry weight plant^{-1} obtained (11.87g) at V_2 (BARI Sarisha-17) and highest (12.45 g) at V_1 (BARI Sarisha-15). As a treatment lowest dry weight plant^{-1} obtained (4.67g) at T_1 (Control) treatment and the highest at (16.86 g) T_3 (50 ppm GA_3). Finally, interaction showed the lowest Dry weight plant^{-1} at V_3T_1 (BARI Sarisha 19 with Control) (4.59g) and highest at V_1T_3 (BARI Sarisha 15 with 50 ppm GA_3) (17 g). Application of GA_3 had significant effect on the thousand seed weight of wheat. The highest thousand seed weight (28.66 g) was obtained from V_1 BARI Sarisha -15) and the lowest at (28.31 g) V_3 (BARI Sarisha-19). As a treatment highest (37.72 g) was obtained at T_3 (50 ppm GA_3) and while the lowest thousand seed weight (23.85 g) was obtained at T_1 (Control) and interaction showed the highest thousand seed weight (14.38g) at V_2T_2 (BARI Sarisha 17 with 25 ppm GA_3) and lowest (6.78 g) at V_2T_1 (BARI Sarisha 17 with control) and V_3T_1 (BARI Sarisha 19 with control). The results of the experiment revealed that the maximum seed fresh weight $plant^{-1}$ (21.34g) was produced at V_1 (BARI Sarisha-15) and the minimum seed fresh weight $plant^{-1}$ (20.02 g) at V_2 (BARI Sarisha-17). As a treatment lowest seed fresh weight $plant^{-1}$ was obtained at (5.64 g) at T_1 (Control) and the highest seed fresh weight $plant^{-1}$ (18.11g) at T_4 (75ppm GA_3). Finally, at interaction highest seed fresh weight $plant^{-1}$ (39.58 g) was obtained at V_2T_3 (BARI Sarisha 17 with 50 ppm GA_3) and the lowest was obtained (23.67 g) at V_1T_1 (BARI Sarisha 15 with Control). The results of the experiment revealed that the maximum Seed dry weight $plant^{-1}$ (8.17g) was produced at V_2 (BARI Sarisha 17) and the lowest Seed dry weight $plant^{-1}$ (5.58g) at V_1 (BARI Sarisha 15). As a treatment lowest Seed dry weight was obtained at (1.55g) at T_1 (Control) and the highest (7.08g) at T_4 (75 ppm GA_3). Finally, at interaction highest seed dry weight $plant^{-1}$ (13.33 g) was obtained at V_2T_3 (BARI Sarisha 17 with 50 ppm GA_3) and the lowest was obtained (5.12g) at V_1T_1 (BARI Sarisha 15 with control) and V_3T_1 (BARI Sarisha 19 with control).

The highest setting of siliqua $plant^{-1}$ (57.92) was observed at V_3 (BARI Sarisha-19) and the lowest setting of siliqua $plant^{-1}$ (57.08) was observed at V_1 (BARI Sarisha 15). In case of treatment the minimum length of siliquae $plant^{-1}$ (19.33) was found under the control treatment. The maximum length of siliquae (73.55 cm) was recorded T_3 (50 ppm GA_3). Finally at interaction highest siliquae $plant^{-1}$ was obtained in V_2T_3 (BARI Sarisha 17 with 50 ppm GA_3) (74.0 no.) and lowest was recorded in V_2T_1 (BARI Sarisha 17 with control) (18.66 no.) respectively.

The results of the experiment revealed that the maximum seed yield (1.18 t ha^{-1}) was produced at V_2 (BARI Sarisha 17) and the lowest seed yield (1.15t ha^{-1}) at V_1 (BARI Sarisha 15). As a treatment lowest seed yield was obtained at (0.69 t ha^{-1}) at T_1 (control) and the highest (1.26 t ha^{-1}) at T_3 (50 ppm GA_3). Finally, at interaction highest seed yield (1.3 t ha^{-1}) was obtained at V_2T_3 (BARI Sarisha 17 with 50 ppm GA_3) and the lowest was obtained (0.63t ha^{-1}) at V_1T_1 (BARI Sarisha 15 with control). Straw yield varied significantly with the different levels of GA_3. As a variety, the lowest straw yield obtained (2.39 t ha^1) at V_1 (BARI Sarisha 15) and highest at (2.74 t ha^{-1}) V_2 (BARI Sarisha 17). As a treatment lowest Straw yield obtained (1.72 t ha^{-1}) at T_1 (control) treatment and highest at (3.01 t ha^1) T_3 (50 ppm GA_3). Finally, interaction showed lowest straw yield at V_2T_1 (BARI Sarisha 17 with control) (1.63 t ha^{-1}) and highest at V_2T_3 (BARI Sarisha 17 with 50 ppm GA_3) (3.48 t ha^{-1}). Biological yield varied significantly with the different levels of GA_3. As a variety the lowest biological yield (11.87 t ha^{-1}) at V_2 (BARI Sarisha- 17) and highest at (12.45 t ha^{-1}) was found in V_1

(BARI Sarisha -15). As a treatment the lowest biological yield (2.42 t ha^{-1}) at T_1 (control) and highest (4.43 t ha^{-1}) at was found in T_3 (50ppm GA_3) treatment. Finally, interaction showed lowest biological yield at V_2T_1 (BARI Sarisha 17 with control) (2.34 t ha^{-1}) and highest at V_2T_3 (BARI Sarisha- 17 with 50 ppm GA_3) (4.89 t ha^{-1}). As a variety the lowest harvest index (41.81%) at V_1 (BARI Sarisha -15) and highest at (45.16 %) was found in V_2 (BARI Sarisha-17). As a treatment the lowest harvest index was obtained at (28.15 %) at T_1 (control) and the highest (45.23%) was found in T_3 (50 ppm GA_3) treatment. Finally, interaction showed the lowest harvest index at (36.41%) at V_1T_1 (BARI Sarisha 15 with control) and highest at (48.62 %) V_1T_4 (BARI Sarisha 15 with 75 ppm GA_3). From the experimental results, the highest seed yield was observed from V_2T_3 combination. Cultivation of BARI Sarisha 17 along with 50 ppm GA_3 came out very important for obtaining higher yield of mustard in the Old Himalayan Piedmont Plain (AEZ -1) soils.

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 50 ppm GA_3 had positive impact on growth and yield of mustard. The yield loss had been reduced by the application of 50 ppm GA_3. So, the application of 50 ppm GA_3 seems to have the possibility to increase the yield of mustard.

RECOMMENDATIONS

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-15, BARI Sarisha-17 and BARI Sarisha-19.
- It needs to conduct more advanced and related experiments with other varieties of mustard and also in different climate and soil condition.

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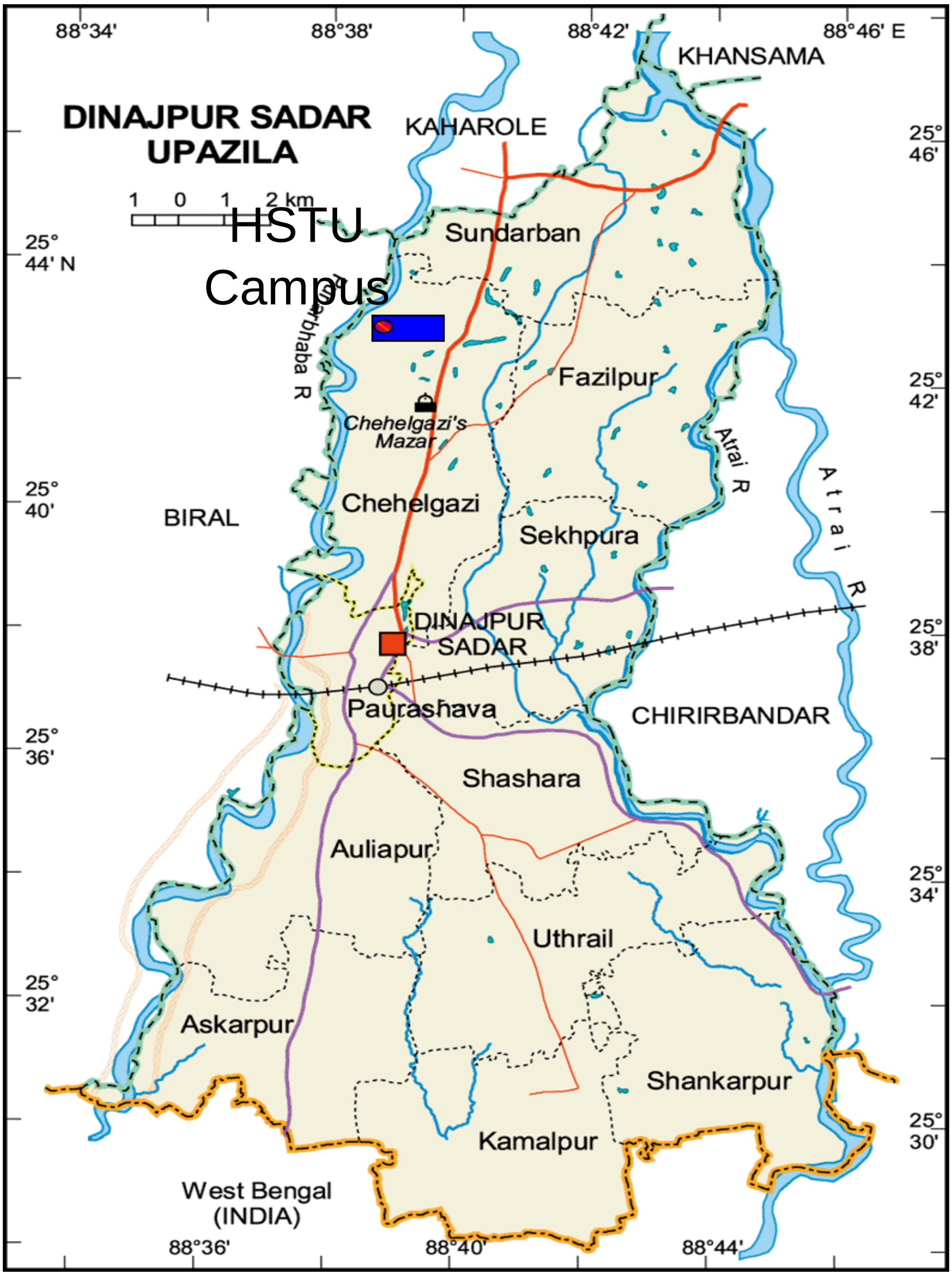
APPENDICES

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



Appendix II: Soil Physical and Chemical Properties of the experimental location

Parameters measured	units	Soil Layer between (0-40) cm
Soil textural classes	-	Sandy loam
Sand	%	47.60
Silt	%	36.00
clay	%	16.40
Organic matter	%	0.31
Organic carbon	%	0.18
Total N	%	0.007
Total P	%	14.30
Available K	$mgkg^{-1}$	0.05
Available S	$mgkg^{-1}$	18.09
Field capacity	%	10.50
CEC	Meq 100g	1.00
Ec	$mgkg^{-1}$	87.30
pH		6.12

Appendix III: Analysis of variance (mean square) of the data for plant height, leaves number plant^{-1}, leaf area and siliqua number plant^{-1} of mustard

Source of variation	df	Plant height (cm)	Leaves number plant^{-1} (no.)	Leaf area (cm^2)	Siliqua number plant^{-1} (no.)
Replication	2	75.01**	7.19*	2.37ns	2.52ns
Factor A (variety)	2	75.01^{ns}	1666.10**	2.38**	2.53ns
Factor B (Treatments)	3	242.32^{ns}	15.15**	32.84**	5952.70**
Factor A × Factor B	6	9.54*	2.49^{ns}	0.029**	3.56**
Residual	22	5.78	4.71	0.41	26.22

Appendix IV: Analysis of variance (mean square) of the data for seeds/siliqua, fresh weight of seed plant^{-1}, dry weight of seed plant^{-1}, fresh weight plant^{-1}, dry weight plant^{-1} of mustard

Source of variation	df	Seeds/siliqua (no.)	Fresh weight of seed plant^{-1} (gm)	Dry weight of seed plant^{-1} (gm)	Fresh weight plant^{-1} (gm)	Dry weight plant^{-1} (gm)
Replication	2	20.03**	557.78**	0.49**	0.48^{ns}	1.262^{ns}
Factor A (variety)	2	20.03^{ns}	557.78^{ns}	0.49^{ns}	0.49^{ns}	1.26**
Factor B (Treatment)	3	293.41**	569.87**	277.03**	277.05**	259.78**
Factor A × Factor B	6	9.99*	557.35**	1.35**	1.35**	0.63*
Residual	22	6.78	557.32	0.26	0.26	0.20

Appendix V: Analysis of variance (mean square) of the data for 1000 seed weight, seed yield, straw yield, biological yield, and harvest index of mustard

Source of variation	df	1000 seed weight (gm)	Seed yield (t/ha)	Straw yield (t/ha)	Biological yield (t/ha)	Harvest Index (%)
Replication	2	2635.80**	0.02**	0.384^{ns}	0.55^{ns}	33.78**
Factor A (variety)	2	2635.80^{ns}	0.02^{ns}	0.38**	0.55^{ns}	33.78**
Factor B (Treatment)	3	2801.68**	0.78**	3.08**	6.93**	34.45**
Factor A × Factor B	6	2623.43**	0.03*	0.08**	0.15**	36.32**
Residual	22	2627.71	0.01	0.05	0.08	20.25

Appendix VI: Some photo graphs of my research work