# PERFORMANCE OF MEPIQUAT CHLORIDE ON GROWTH, YIELD AND OIL CONTENT OF SUNFLOWER

**TANJILA AFROSE**

**DEPARTMENT OF AGRONOMY**

**SHER-E-BANGLA AGRICULTURAL UNIVERSITY**

**DHAKA-1207**

**DECEMBER, 2021**

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**BY**

**TANJILA AFROSE**

**REG. NO. 19-10199**

**Email: tanjilaafrose199@gmail.com**

**Mobile: 01723424371**

**A Thesis**

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

**MASTER OF SCIENCE**

**IN**

**AGRONOMY**

**SEMESTER: JULY-DECEMBER, 2021**

**Approved by:**

| | |
|---|---|
| **Prof. Dr. A.K.M. Ruhul Amin** | **Prof. Dr. Tuhin Suvra Roy** |
| **Supervisor** | **Co-Supervisor** |

**Prof. Dr. Md. Abdullahil Baque**

**Chairman**

**Examination Committee**

**DEPARTMENT OF AGRONOMY**

**Sher-e-Bangla Agricultural University**

**Sher-e-Bangla Nagar, Dhaka-1207**

*CERTIFICATE*

*This is to certify that thesis entitled, "**PERFORMANCE OF MEPIQUAT CHLORIDE ON GROWTH, YIELD AND OIL CONTENT OF SUNFLOWER**" submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfilment of the requirements for the degree of **MASTER OF SCIENCE (MS) in AGRONOMY**, embodies the result of a piece of bona-fide research work carried out by **TANJILA AFROSE,** Registration no.**19-10199** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

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

**Date:**

**Place: Dhaka, Bangladesh**

**Prof. Dr. A.K.M. Ruhul Amin**

Department of Agronomy

Sher-e-Bangla Agricultural University

Dhaka-1207

***Dedicated to***

***My***

***Beloved Parents***

# *ACKNOWLEDGEMENTS*

*All praises are done to the Almighty Allah, the great, the gracious, merciful and supreme ruler of the universe who enables her to complete this present piece of work for the degree of Master of Science (M.S.) in the Department of Agronomy.*

*The author would like to express her deepest sense of gratitude, respect to her research supervisor,* ***Prof. Dr. A.K.M. Ruhul Amin****, Department of Agronomy, Sher-e-Bangla Agricultural University, for his kind and scholastic guidance, untiring effort, valuable suggestions, inspiration, extending generous help and encouragement during the research work and guidance in preparation of manuscript of the thesis.*

*The author sincerely expresses her deepest respect and boundless gratitude to her co-supervisor,* ***Prof. Dr. Tuhin Suvra Roy,*** *Department of Agronomy, for his helpful suggestion and valuable advice during the preparation of this manuscript.*

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

*The author would like to express her deepest respect and boundless gratitude to all respected teachers of the Dept. of Agronomy, Sher-e-Bangla Agricultural University, for their valuable teaching, sympathetic co-operation and inspirations throughout the course of this study and suggestions and encouragement to research work. The author thanks to the departmental and farm staff members for their active help during the experimental work.*

*The author is really indebted to her beloved friends for their great support, help and encouragement and also special thanks to all other friends for their support and encouragement to complete this study.*

*At last but not the least, the author feels indebtedness to her beloved parents, brother and sister whose sacrifice, inspiration, encouragement and continuous blessing paved the way to her higher education and reach at this stage. May Allah bless us all.*

***The Author***

# PERFORMANCE OF MEPIQUAT CHLORIDE ON GROWTH, YIELD AND OIL CONTENT OF SUNFLOWER

## ABSTRACT

A field experiment was conducted at research field of Sher-e-Bangla Agricultural University, Dhaka during the period from November 2020 to March 2021 in Rabi season to study the performance of mepiquat chloride on growth, yield and oil content of sunflower. The experiment consisted of two factors, and followed split-plot design with three replications. Factor A: Sunflower varieties- (2) *viz:* $V_1$= BARI Surjumukhi-2, $V_2$ = Mayabi Hybrid (China variety) and Factor B: Mepiquat chloride application level- (5) *viz:* $M_0$ = Control, $M_1$ = 12.5 ml ha$^{-1}$, $M_2$ = 25.0 ml ha$^{-1}$, $M_3$ = 37.5 ml ha$^{-1}$ and $M_4$ = 50.0 ml ha$^{-1}$. Experimental results revealed that different varieties and mepiquat chloride application significantly influenced the seed yield and yield contributing characteristics of sunflower. In case of different sunflower varieties the lowest seed yield (2.15 t ha$^{-1}$) was obtained from $V_1$ treatment (BARI Surjumukhi-2). Whereas cultivating Mayabi Hybrid ($V_2$) variety gave the highest head diameter (16.69 cm), seeds head$^{-1}$ (611.93), seed yield (2.36 t ha$^{-1}$), biological yield (7.97 t ha$^{-1}$) and harvest index (29.52 %) while BARI Surjumukhi-2 ($V_1$) cultivar dominated in 1000-seeds weight (60.91 g) and oil content percentage (38.56 %). Among the 5 doses of mepiquat chloride, the highest two doses ($M_3$ and $M_4$) produced the highest seed yield (2.55 and 2.62 t ha$^{-1}$, respectively) and shortest plant. These two treatments also showed highest stem diameter, dry weight plant$^{-1}$, SPAD value, head diameter, seeds head$^{-1}$ and 1000-seed weight. However, lower doses of mepiquat chloride ($M_1$, $M_2$ and $M_3$) treatment showed highest oil content (in percentage). Regarding interaction, $V_2M_3$ and $V_2M_4$ were maximum seed yielder (2.72 and 2.74 t ha$^{-1}$, respectively) and produced shorter plants than other interactions which was attributed to higher head diameter, seeds head$^{-1}$ and 1000-seed weight in these interaction treatments. These two interactions also showed higher growth and yield attribute parameters. On the other hand, $V_1M_1$ and $V_1M_2$ interactions gave maximum oil content. Considering all, it may be concluded that Mayabi Hybrid ($V_2$) and mepiquat chloride dose 37.5 ml ha$^{-1}$ ($M_3$) and their interaction seems promising for reducing plant height and increasing seed yield but for oil content (%), BARI Surjumukhi-2 ($V_1$), lower mepiquat chloride dose and their interaction was found best for sunflower.

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## ABBREVIATIONS

| Abbreviations | Full word |
|---|---|
| Agr. | Agriculture |
| AEZ | Agro-Ecological Zone |
| BBS | Bangladesh Bureau of Statistics |
| Biol. | Biology |
| Biotechnol. | Biotechnology |
| Bot. | Botany |
| Cv. | Cultivar |
| DW | Dry weight |
| Eds. | Editors |
| Entomol. | Entomology |
| Environ. | Environments |
| FAO | Food and Agriculture Organization |
| FW | Fresh weight |
| Intl. | International |
| J. | Journal |
| LSD | Least Significant Difference |
| L | Liter |
| Sci. | Science |
| Sl. | Serial |
| SRDI | Soil Resource Development Institute |
| Technol. | Technology |
| TSP | Triple super phosphate |

# CHAPTER I

# INTRODUCTION

Sunflower (*Helianthus annus* L.) is an oilseed crop belongs to family Asteraceae originated from temperate region of North America. It has been domesticated as an oil crop in Russia in the early 18th century. Among the oilseed crops sunflower ranked 4th for edible oil production in the world (Pilorge, 2020) after soybean, palm and rapeseed. However, as an oilseed crop, sunflower has been introduced and began to cultivate in Bangladesh since 1975 on a small scale (Habib *et al*., 2017). Compared to other oilseed crop, sunflower possesses several advantages. As for example, short duration (90-110 days) and high yield potential with higher % of edible oil, having tolerance to drought and salt (Habib *et al*., 2021) with wider adaptability to different soil and climatic conditions (Debaeke *et al*., 2017). Sunflower was grown on about 1599.27 ha in Bangladesh from which about 2006.20 metric ton are produced in the year 2021, with the average regional yield of 1.07 t $ha^{-1}$(BBS, 2021). However, the country grain yield is far less than the attainable yield (2.5 to 3.5 t $ha^{-1}$) under good management conditions at farmers field (MOANR, 2017). Low yield of sunflower is attributed to several production constraints which include shortage of improved varieties, poor crop management practices, moisture stresses, low soil fertility, diseases and insect pests (Begna, 2020). Therefore, the country's edible oil production can be increased by cultivating improved sunflower varieties along with proper agronomic management practices.

Commercial cultivation of sunflower in Bangladesh started with the composite varieties namely BARI Surjamukhi-2 and Kironi. These varieties were developed by ORC (Oilseed Research Center), BARI, Gazipur. Lodging tendency due to tallness and lower yield are the major constrains for the expansion of these varieties to the farmer's field. Farmer prefer hybrid sunflower variety as hybrids are stable, self fertile, high yielding as well as uniform at maturity (Habib *et al*., 2021). However, in Bangladesh there is no local high yielding sunflower hybrid variety for cultivation. The imported hybrid seeds are expensive which increase the production cost and most of the farmers cannot afford to obtain hybrid seeds every year. Besides, sometimes imported seeds do not give desired oil yield due to acclimatization in local climatic condition (Hossain, 2020). Hence, development of local synthetic or hybrid variety with high achenes yield, lodging resistance and uniform maturity is the burning issue of the day.

Plant growth regulators (Triiodobenzoic Acid, Cycocel and Mepiquat chloride chloride), both promoters and inhibitors, are chemicals designed to manipulate plant growth and development (Arteca, 2014). These regulators have been applied for specific purposes, e.g., to control plant height, to eliminate excessive vegetative growth, and to enhance flowering (Koutroubas and Damalas, 2020). One of their main effects, particularly of the so-called growth retardants, is to limit stem growth (i.e., to shorten internode length). These substances usually do not affect flower development, although increased application rates or late applications can affect flower size and delay flowering. Growth retardants inhibit the production of gibberellic acid, which is involved in cellular elongation (Bisht *et al*., 2018). Consequently, cell elongation is reduced due to the lack of gibberellins, and plants do not grow as tall. Therefore, plants become more compact, with deep green foliage and prolonged postharvest life (Litvin *et al*., 2016). Nevertheless, applying plant growth regulators at incorrect rates or time can produce stunted plants that are of poor market suitability. This is often apparent for products that are effective at very low concentrations, such as paclobutrazol.

The substance mepiquat chloride (MPC) was introduced to the market as a plant growth regulator at the end of 1970s to limit excessive plant growth in cotton (Abbas *et al*., 2022). The mechanism of action of this growth regulator is related to the suppression of gibberellic acid, a growth stimulant that induces cell elongation in plants. In cotton, suppression of gibberellic acid decreases cell elongation as well as the vertical and horizontal elongation of stems and branches (Shan *et al*., 2021). It should be noted that MPC inhibits cell expansion, but does not affect cell division. This growth regulator is not thought to be readily translocated through the plant. The overall effect of MPC on plant growth and development depends on growing conditions soon after application. Favorable growth conditions, such as optimal temperature and availability of soil moisture, typically increase the likelihood of realizing positive plant responses and benefits (Koutroubas and Damalas, 2020).

There is little information on the possibility of using MPC in sunflower. Nevertheless, it is often necessary to treat sunflower plants with a fungicide after flowering or apply a desiccant before harvest as a usual practice to achieve an economical and stable yield as well as to maintain oil quality. Given that the confection sunflower height may often reach 250 cm between flowering and harvest, these operations cannot be performed without some damage of the stand (Spitzer *et al*., 2011). Research pertaining to use of MPC for regulating plant height in sunflower is scarce, particularly under field conditions. Previous research showed that application of MPC at a rate of 25 g $ha^{-1}$ provided a height reduction by 11.7% at maturity without any impact on achene and oil yields (Koutroubas *et al*., 2014). Mepiquat chloride application at the rate of 60 g a.i. $ha^{-1}$ in the early growth stage ($V_4$) of non-oilseed sunflower was the most effective on plant characteristics, and could be used as a means of reducing plant height in non-oilseed sunflower production (Polat *et al*., 2017). Moreover control of plant height in sunflower is of great practical importance because it can provide lodging resistance to the plants and also facilitate mechanical harvest (Debaeke *et al*., 2017).

Therefore, keeping this information in view, the present study was undertaken with following objectives:

i. To find out the performance of inbreed and hybrid sunflower varieties in respect of growth, yield and oil content,

ii. To observe the different application levels of mepiquat chloride on growth and yield of sunflower, and

iii. To evaluate the interaction effect of variety and mepiquat chloride levels on growth, yield and oil content of sunflower.

# CHAPTER-II

# REVIEW OF LITERATURE

Sunflower is the third oilseed produced in the world, the fourth vegetable oil and third oilseed meal among protein feed sources. The objective of this "review of Literature" chapter is to give a review of the significant works that have been performed in the past and it gives basic information for conducting and considering the outcome of the present research. An attempt was made to collect and study the related information available in the country as well as abroad regarding the "Performance of mepiquat chloride on growth, yield and oil content of sunflower" for conducting the current research work was discussed under the headings below:

## 2.1 Effect of variety

Awoke and Anteneh (2022) found significant different among varieties on grain yield traits of sunflower. The highest (2824.1 kg ha$^{-1}$) and (2797.6 kg ha$^{-1}$) grain yield were recorded from Red-Black and OISA variety, respectively among tested treatments. The highest yielder variety Red-Black showed by 0.95 % (2797.6 kg ha$^{-1}$) and 35 % (2092.1 kg ha$^{-1}$) yield increment as compared to variety Oissa and Local, respectively.

AL-Abody *et al*. (2021) carried out a field experiment during the Spring 2020 season at Al-Huwair area, north of Basra Governorate, to evaluate the effect of sprinkling three levels of humic acid (0, 3, 6 and 9 ml L$^{-1}$) on the growth and yield of three sunflower cultivars; namely Zahrat al Iraq, Aqmar, and Flamme. The Aqmar cultivars provided the highest mean of plant height, stem diameter, leaf area, head diameter, number of seeds head$^{-1}$, 1000-seed weight, seed yield, and percentage of oil.

Abd *et al*. (2019) carried out a field experiment at Sora-Imdaina during the seasons of 2017 to study the response of four Sunflower genotypes (Shomos, Aqmar, Tarsan 1018 and Lilo) to different planting dates (1st, 15th and 30th of March 2017) included growth, yield, yield components and quality. Results showed that genotypes were significantly different in growth, yield and quality characters. The genotype of Shomos was superior in all the growth characters and recorded the highest head diameter, number of seeds in disc (1225 seed disc$^{-1}$), 1000-seed weight (63.01 g), yield of seed (3766 kg ha$^{-1}$), and harvest index comparable to other genotypes of sunflower.

Bjaili *et al*. (2019) conducted an experiment in 2017 and 2018 cropping seasons at the Agricultural Research Station of King Abdulaziz University at Hada Al-Sham, to study the responses of 3 sunflower cultivars (Egyptian cv. Sakha -53, Argentina cv. Argentina -11 and Turkish cv. May Hybrid ) to nitrogen fertilizer rates (100, 200 and 300 kg N $ha^{-1}$) and defoliation levels (0, 2 and 4 leaves $plant^{-1}$). The results showed significant effects of N, defoliation and cultivars and their interactions on all studied parameters. The Egyptian variety Sakha 53 produced the highest percentage of seed oil followed by May Hybrid and Argentina-11. The Turkish May Hybrid showed the highest protein content followed by Sakha 53 and Argentina-11. The Egyptian cultivar Sakha 53 suggested to cultivate under arid land climate with high rate of Nitrogen fertilizer and defoliation 2-4 leaves from plant bottom at flowering stage.

Das *et al.* (2019) reported that height of a plant is determined by genetical character and under a given set of environment different variety will acquire their height according to their genetical makeup.

Demir (2019) was conducted an experiment in 2012 and 2013 at the Research Farm of Ahi Evran University located in Kirşehir, Turkey to determine effects of sowing date on yield and agronomic characteristics of sunflower hybrid cultivars in rainfed conditions. Five sowing dates 10 days apart set on 10th April, 20th April, 1st May, 10th May and 20th May and 6 hybrid sunflower cultivars (LG-5580, SanayMr, SanbroMr, Sirena, Tarsan and Transol) were used. Experimental result showed that SanbroMr cultivar in the first year and Transol cultivar in the second year reached the higher yields with best yield components.

Hossain *et al*. (2018) conducted a research work with three sunflower genotypes to evaluate their performance in saline and non-saline soil after harvesting of T. Aman rice. Three genotypes significantly influenced almost all the growth and yield parameters in both non-saline and saline field. Genotype Hysun-33 showed maximum germination percentage in non-saline soil but minimum in saline soil. Whereas, KUSL-1 performed the best in saline soil but worst in non-saline condition. Hysun-33 produced maximum leaf at flowering in both conditions but minimum leaf by BARI Sunflower-2 in saline soil and by KU-SL-1 in non-saline soil. In both non-saline and saline soils, plant height at flowering, head diameter, total seed $head^{-1}$ and filled seed $head^{-1}$ were maximum for the genotype Hysun-33 and that of minimum for the genotype BARI Sunflower-2. Genotype KU-SL-1 showed maximum value for 1000-seeds weight followed by Hysun-33 in both saline and non-saline soils. In case of seed yield head$^{-1}$, Hysun-33 performed best in saline soils but worst in non-saline soil. In non-saline soil, KU-SL-1 produced maximum seed yield head$^{-1}$.

Santhosh *et al.* (2017) were carried out an experiment to study the physiological and yield variability in sunflower lines at college farm, College of Agriculture, PJTSAU, Hyderabad during late rabi2013-14. The material composed of four sunflower hybrids (GMU-337, GMU-437, EC-602063 and DRSF-113). Water stress imposed from 30-65 DAS resulted in decreased SCMR values, stomatal conductance, fluorescence, and photosynthetic rate. The analysis of variance revealed the presence of sufficient variability for physiological attributes. The genotype DRSF-113 showed maximum values for SPAD chlorophyll meter readings (31.5), stomatal conductance (193.5 mmol ($H_2O$) $m^{-2}s^{-1}$), photosynthetic rate (25.5 μ moles $CO_2$ $m^{-2}s^{-1}$), fluorescence (Fv/ Fm) (0.565) and yield (1488 kg $ha^{-1}$). The results also shown that the yield positively correlated with leaf greenness (SPAD chlorophyll meter readings) and fluorescence (Fv/ Fm). Based on the results, out of the four genotypes studied DRSF-113 and EC-602063 can be concluded as tolerant for moisture stress than genotypes GMU-337 and GMU-437.

Hussain *et al.* (2016) reported that the cultivars showed wide differences in their agronomic characteristics and seed yield, depending on their genotypes and environmental conditions.

Wable (2016) conducted a field experiment titled “Response of sunflower hybrids *(Helianthus annus* L.) to different fertilizer level in rabi season at Oilseed Research Station, Latur. The experimental field was leveled and well drained. The experiment was laid out in a FRBD design with twenty one treatment combinations, which includes three fertilizer levels 50% RDF (Fi), I00% RDF (F2), 150% RDF (F3) in main plots and seven hybrids LSFH-176 (Hi). KBSH-72 (H2), KBSH-71 (H3), DRSH-1 (HO. KBSH-44(H5), LSFH-171 (He) and RSFH-130 (H7), as sub-plot treatments. Experimental result revealed that seed yield and yield attributes namely head diameter, filled seed, test weight were remarkably higher in the hybrid KBSH-44 (H5) as compared to hybrids DRSH-1 (EU). RSFH-130 (H7). KBSH-72 (H2). LSFH-176 (Hi), KBSH-71 (H3). and LSFH-171 (He). Pronounced and significant increase in seed yield (1036 kg ha$^{-1}$) and stalk yield (3650 kg ha$^{-1}$) were observed in hybrid KBSH-44 (H5) reflecting its superiority over LSFH-171 (He). The improvement in seed yield of hybrids KBSH-44 (Hs) was 12.25, 13.22, 18.14, 22.97, 28.18 and 28.66 per cent higher over DRSH-1 (H*). RSFH-130 (H7).KBSH-72 (H2), LSFH-176 (Hi), KBSH-71 (H3), and LSFH-171 (Kg), respectively. Seed setting percentage (93.59 %) and harvest index (17.19 %) were considerably higher in hybrid KBSH-44 (Hs)than DRSH-1 **(H*),** RSFH- 130 (Hy). KBSH-72 (H2). LSFH-176 (Hi), KBSH-71 (H3). and LSFH-171 (He). The oil content (34.70 %) and oil yield (359.7 kg ha$^{-1}$) were higher in hybrid KBSH-44 (Hs) as compared to rest of the hybrids.

Tyeb *et al.* (2013) reported that the variation in plant height due to the effect of varietal differences. The variation of plant height is probably due to the genetic makeup of the cultivars.

Nasim *et al.* (2012) experimented on three sunflower hybrids and reported that hybrids have their own distinctive characteristics and yield potential. They observed significant difference for head diameter trait among sunflower hybrids.

Alahdadi *et al*. (2011) conducted field experiment at Tehran, Iran; to investigate the effect of water stress on seed yield with for sunflower hybrids namely Azargol, Alstar, Hysun-33 and Hysun-25 and revealed that Alstar hybrid exhibited the high characteristics, except for seed oil and protein contents. The results also indicated that, under normal irrigation maximum seed yield was obtained by Azargol (3498 kg ha$^{-1}$) Alstar (2121 kg ha$^{-1}$), respectively.

Lawal *et al*. (2011) reported that the head diameter of sunflower varies depending on the genetic characteristics of the cultivars. The significant difference in the head diameter could be attributed to the availability of the cultivars to hold adequate moisture, which helps roots to absorb sufficient amount of nutrients for plant growth and development.

Safavi (2011) studied the genetic variability of some morphological traits in sunflower and described that sunflower genotypes were significantly differed for genotypic and phenotypic traits and the range of variability was quite appreciable for almost all the characters studied among different genotypes.

Uddin *et al.* (2011) reported that the harvest index differed significantly among the varieties due to its genetic variability. Abdel- Motagally and Osman (2010) reported that sunflower cultivars significantly differed in plant height and these differences may be due to varietal behavior.

Karaaslan *et al.* (2010) conducted the trial on determination of potential sunflower cultivars for the irrigated conditions of Diyarbakir and concluded that cultivar adaptation is important for regions in terms of obtaining maximum yield. They also found significant difference among hybrids for achene yield potential among various hybrids.

Binodh *et al*. (2009) conducted field trial to investigate nine high yielding sunflower hybrids along with three check hybrids for seed yield plant$^{-1}$, oil content and oil yield in rabi 2005 at Coimbatore, India and revealed that the hybrids *viz.*, CSFH- 6008, CSFH-6037, CSFH-6039, CSFH-6045 and CSFH-6058 were stable over environment for seed yield and oil yield. Among these hybrids CSFH-6045, was found superior.

Gudade *et al.* (2009) conducted experiment at Akola and observed that sunflower variety GAUSUF-12 was at par with LSF-1-28 and DRSF-118 and significantly superior ova: DRSF -119, SS-2038 and DRSF-108 in oil content and oil yield.

Anwar-ul-Haq *et al.* (2006) evaluated the sunflower hybrids for yield and yield components in central Punjab and reported that all the sunflower hybrids showed significant positive effect for head diameter. This is because of the fact that breeder’s always select medium size heads as these usually produce medium size achenes that contain more oil as compared to large size achenes.

Bakht *et al.* (2006) studied the performance of various hybrids of sunflower in Peshawar Valley and reported that sunflower production is greatly affected by choice of hybrid, they also worked on performance of various sunflower hybrids and found a significant difference in yield and yield components of various hybrids.

Ali *et al.* (2004) studied the quantitative and qualitative traits of sunflower in response to planting dates and nitrogen application and reported that sunflower cultivars significantly differed in plant height and dry matter weight and this difference may be due to varietal behavior.

Pal (2004) carried out field experiment at Pantnagar to evaluate ten sunflower cultivars for nutrient uptake and seed quality in spring season of 1999 and concluded that the highest head diameter was noticed in No-3301 (21.23 cm) followed by MSFH-08 (21.13 cm), whereas 1000-seed weight was found greatest in MSFH-8 followed by NSFH-999, MSFH-51, No-3301 and No-6460. MSFH-08 recorded higher seed weight plant$^{-1}$ which did not differ with NSFH-999 and No- 3301.

Parameshwarappa and Lamani (2004) carried out the field trial at ARS, Baihongal (Karnataka) to asses fourteen sunflower hybrids in late kharif2001 and 2002 and found that among the hybrids NSFH-51, recorded the higher average seed yield of 2338 kg ha$^{-1}$ followed by MSFH-17 (2292 kg ha$^{-1}$), RSFH-213 (2280 kg ha$^{-1}$) and KBSH-1 (2217 kg ha$^{-1}$). Hybrids MSFH-17 and KBSH-1 recorded 24.4 and 23.2 per cent higher seed yield over check DSH-1 and Morden. Sana *et al.* (2003) reported that, the final plant height reflected the growth behaviour of a crop.

Sable (2003) conducted field experiment to study the response of sunflower cultivars (MSFH-1, MSFH-8,SS-56 and Morden) in rabiseason 1995-96 at Pune and found that more 1000-seed weight (35.19 g) and seed yield (18.52 g plant$^{-1}$) and higher dry matter (123.4 g plant$^{-1}$) were observed in MSFH-8.

Ali *et al.* (2000) studied the response of sunflower hybrids to various levels of nitrogen and phosphorus and reported that sunflower hybrids exhibited differential genotypic response to different nitrogen levels by increasing seed yields combined with achene oil yields.

## 2.2 Effect of mepiquat chloride application

Abbas *et al.* (2022) carried out an investigation to know the effect of mepiquat chloride (MC) and N application on yield and yield components of transgenic cotton variety 'BT-FSH-326'. Two N rates (0, 198 kg ha$^{-1}$) and five MC rates (0, 30, 60, 90 and 120 g ha$^{-1}$) were included in the study. Results revealed that MC and N application improved boll weight, number of bolls plant$^{-1}$, and seed cotton and lint yields. The highest seed cotton and lint yields (3595 kg ha$^{-1}$ and 1701 kg ha$^{-1}$, respectively) were observed under foliar application of 198 kg ha$^{-1}$ N and 120 g ha$^{-1}$ MC. Fiber length, fiber strength, micronaire and uniformity were significantly improved with foliar application of MC and N. In conclusion, foliar application of MC and N could be helpful in improving yield and fiber quality of cotton.

Murtza *et al.* (2022) reported that a late application of MC (at 70 DAS) caused a significant reduction in the time to flowering (8 %), with a simultaneous increase in the number of opened bolls (60 %), boll weight (32 %), ginning out turn (8 %) and lint yield (27 %) as compared to MC application at 50 DAS. In terms of lint quality, cotton planted on beds had better fiber uniformity (8 %) compared to that on the flat field, while MC applied at 70 DAS produced better fiber fineness by 27 % in comparison to MC applied earlier. Overall, cotton planting on beds and MC application at 70 DAS may help improve cotton yield and fiber quality and may help in the mechanical picking of cotton.

Amoanimaa-Dede *et al.* (2022) reported that plant growth regulators (PGRS) are known to improve physiological efficiency including photosynthetic ability of plants and offer significant role in soybean realizing higher crop yields. The experiment conducted at Brazil among the most important major yield attributing traits viz; number of flowers per plant, number of pods plant$^{-1}$, pod length, pod width, pod weight, 1000-seed weight, seed yield, biological yield and harvest index were influenced by the foliar application of plant growth retardants.

Koutroubas and Damalas (2020) were conducted field experiments over two years in northern Greece to study the influence of MPC at rates of 37.5 plus 37.5 g ha$^{-1}$(named double application) and 37.5 plus 37.5 plus 37.5 g ha$^{-1}$ (named triple application) on sunflower growth and yield. MPC provided a height reduction of 9.5 % (25 cm) with the double application and a height reduction of 14.4 % (49.2 cm) with the triple application at maturity. The number of nodes was also reduced, indicating shorter plants, whereas stem width did not show a consistent response. Moreover, MPC resulted in increased crop growth rate with the triple application scheme.

Raut *et al.* (2019) reported that mepiquat chloride hampers gibberellic acid biosynthesis by stopping the conversion of geranyl diphosphate to entkaurene, which ultimately reduces cell division and enlargement.

Chandrashekara *et al*. (2018) reported an increase in chlorophyll content in maize plants sprayed with 20 ppm of mepiquat chloride at 30 and 45 DAS.

Jaidka *et al*. (2018) conducted an experiment to know the influence of detopping and mepiquat chloride on the morpho-physiological and yield attributes of soybean and reported that application of mepiquat chloride significantly decreased LAI, abscission of reproductive parts, increased total dry matter accumulation plant$^{-1}$, pods plant$^{-1}$, seeds pod$^{-1}$,1000-seed weight and seed yield over control.

Secondo and Reddy (2018) conducted a field experiment to reduce the plant height by foliar application of plant growth retardants viz., paclobutrazol (PBZ), mepiquat chloride (MPC) and chloromequat chloride (CCC) to improve the sink strength. Application of growth retardants at 39 days after sowing reduced the plant height immediately after the application. However, the plant height recovered by the time of crop maturity. Application of mepiquat chloride twice (39and 52 days after sowing) resulted in increased seed yield (49.8 g plant$^{-1}$) over the control (35.2 g plant$^{-1}$) and even over the cycocel or paclobutrazol treatment. The increased seed yield (41.5 %) with mepiquat chloride was due to increased sink strength parameters such as increased seed number (820 seeds thalamus$^{-1}$), test weight (6.01 g 100 seeds) and HI (0.35) over unsprayed control plants.

Suzuki *et al*. (2018) reported that the concentration of 10 L ha$^{-1}$ of mepiquat chloride was the most effective dose in reducing the height of a red-yellow 'Florenza' sunflower showing a height 43.2 cm smaller than the one from the control treatment.

Paikra *et al.* (2017) reported from the investigation entitled ''Effect of Cyclanilide + Mepiquat Chloride on growth and productivity of Soybean [*Glycine max* (L.) Merrill]''. That the soybean variety JS-9752 tested under different plant growth regulator management. The result revealed that application of Cyclanilide 22 + Mepiquat chloridee 88 SC @ 100 ml ha$^{-1}$ recorded the significantly highest plant height, number of branches plant$^{-1}$, number of leaves plant$^{-1}$, Leaf area index, seed yield (kg ha$^{-1}$) straw yield (kg ha$^{-1}$) biological yield (kg ha$^{-1}$), seed index (100-seeds weight) and harvest index as compare to other treatment.

Polat *et al*. (2017) reported that in comparison with the control treatment, the MC application of @ 60 g a.i. ha$^{-1}$ decreased plant height by 5.38% and increased stem diameter, head diameter, seed filling percentage, ratio of dehulled hulled seed$^{-1}$ weight, 1000-achene weight, and seed yield by 14.01%, 3.78 %, 1.61 %, 4.20 %, 5.94 %, and 5.26 %, respectively. Similarly, the applications of MC at different growth stages also significantly affected seed yield and other characteristics such as plant height, stem diameter, and head diameter. The application of MC at the early growth stage ($V_4$) was more effective compared to the later growth stages ($R_1$, $R_2$, and $R_3$). The results of this study suggest that the mepiquat chloride application rate of 60 g a.i. $ha^{-1}$ in the early growth stage ($V_4$) was more effective on the plant characteristics and that MC application could be effectively used as a means of reducing plant height and the risk of lodging in non-oilseed sunflower production.

Singh *et al.* (2017) found that highest seed cotton yield (2.97 q $ha^{-1}$) was recorded with application of mepiquat chloride at 1500 ml $ha^{-1}$ primarily due to improved boll weight (3.92g) and bolls $plant^{-1}$ (53.2).

Da Costa *et al*. (2016) reported that the sunflower seed treatment with paclobutrazol showed a decrease in plant height at flowering. The plant height was reduced from 1.88 m in control to 1.71 m in paclobutrazol (150 ml $ha^{-1}$) without affecting the seed yield. The plant height was 1.77 m at 50 ml $ha^{-1}$. These results indicated that even seed treatment with growth retardants will reduce the plant height at flowering and the effect of growth retardant was continued with till the crop maturity with no reduction in seed yield. Ernst *et al*. (2016) reported that the application of PGRs has contributed to an increase of sunflower seed yield mainly through increased seed weight.

Kaul *et al*. (2016) studied the effect of 3 different chemicals i.e. MC @ 300 ppm, 2, 3, 5-triiodo benzoic acid (TIBA) @ 100 ppm and maleic hydrazide (MH) @ 250 ppm at 80 days after sowing (DAS) on growth and development of Bt cotton as affected by detopping and plant growth regulation. Among all treatments, application of MC @ 300 ppm at 80 DAS reduced plant height significantly in comparison to de-topping and control.

Liu *et al.* (2016) showed that application of plant growth regulators such as mepiquat chloride (400 mg $L^{-1}$), chlormequat chloride (800 mg $L^{-1}$) and paclobutrazol (75 mg $L^{-1}$) have improved the head diameter, seed weight $head^{-1}$, 1000-seed weight, kernel weight and yield of sunflower.

Niu *et al.* (2016) reported that application of mepiquat chloride (MC) decreases plant height, number of nodes on main stem, internodal distance, leaf expansion and increases light use efficiency and crop productivity. It improves leaf $CO_2$ exchange rate, transpiration, stomatal conductance, chlorophyll contents and $CO_2$ fixation. It also improves nutrients uptake and assimilation towards reproductive parts by enhancing cotton lateral root growth and sink volume. The MC-treated plants uptake more N compared to non-treated ones.

Sethy *et al*. (2016) reported that application of growth retardant (maleic hydrazide) twice at 30 and 45 DAS at the concentration of 500 ppm or more resulted in reduction in plant height in ornamental sunflower.

Sandhu *et al*. (2015) studied the effect of growth regulation on yield attributes and growth of summer moongbean (*Vigna radiata*) at Ludhiana, Punjab. Experiment compromised of mepiquat chloride at the doses 200, 250 and 300 ppm applied at 35 and 45 DAS and one treatment of detopping. Grain yield was significantly higher with the mepiquat chloride @ 250 ppm (10.50 q $ha^{-1}$) which was 33.34 per cent higher than control (6.70 q $ha^{-1}$). Dry matter accumulation was also significantly higher with the mepiquat chloride @ 250 ppm.

Koutroubas *et al*. (2014) demonstrated that MPC applied at 25 g ai $ha^{-1}$ provided a height reduction of 11.7% in sunflower plants, whereas MPC applied at 25 plus 25 g ai $ha^{-1}$ had detrimental effects on achene yield.

Sawan (2014) research on cotton showed that MPC (mepiquat chloride) promoted seed yield, probably due to increased redirection of assimilates towards reproductive development. The increased capacity of early buds and boll retention in cotton plants with application of MPC was linked to high nutrient availability, probably due to increased partitioning of assimilates from vegetative parts to reproductive organs, resulting in high crop yield. This response may be due the relationship between source and sink, i.e., the reduction of elongation caused by MPC decreases the demand of assimilates for growth, which are used in higher proportion by the plant reproductive organs.

Ramesh *et al*. (2013) observed that the application of brassinosteroid at 25 ppm, mepiquat chloride 5 % and chlormequat chloride applied at 187.5g a.i $ha^{-1}$, 162.5g a.i $ha^{-1}$ and 137.5g a.i $ha^{-1}$ resulted in higher seed yield, compared to control and water spray.

Ramesh and Ramprasad (2013) noted significantly increased in the seed protein content with the application of NAA (20 ppm), Brassinosteroid (25 ppm), mepiquat chloride (5 %), ammonium sulphate (5 %) and chlormequat chloride at different concentration, as compared to control and water spray.

Ali *et al*. (2012) found that foliar spraying with mepiquat chloride significantly increased yield of cotton as compared with untreated treatment. Sharma and Sardana (2012) observed that Chl a, Chl b and total chlorophyll enhanced with the mapiquat chloride application @ 125 ppm in peanut.

Kim *et al.* (2011) carried out an experiment to investigate the possible effects of mepiquat chloride (TE) and trinexapac-ethyl (MC) on oil composition, seed yield and endogenous gibberellins content of flax cultivar. Foliar application of plant growth retardants mepiquat chloride (0.897, 1.794 and 2.691 kg a.i. $ha^{-1}$) and trinexapac-ethyl (0.756, 1.512 and 2.668 kg a.i. $ha^{-1}$) had significantly increased seeds ripening rate and seed yield. In contrast, plant height was decreased by foliar application of MC and TE. The application of MC significantly increased seed oil yield (730 kg $ha^{-1}$ by 27.0%) compared to the control. Seed and oil yield, and unsaturated fatty acids (oleic acid, linoleic acid and linolenic acid) were increased by foliar application of MC.

Spitzer *et al.* (2011) reported that the plant height of sunflower was reduced by 63 cm with application of chlormequat chloride plus ethephon and by 35 cm with only the application of ethephon.

Kashid *et al*. (2010) reported decrease in plant height with mepiquat chloride and cycocel treated plants. However, maleic hydrazide (100, 200 and 300 ppm), TIBA (25, 50and 75 ppm) and cycocel (500 ppm) remained ineffective and were at par with the control. Cycocel and mepiquat chloride are anti-gibberellin dwarfing agents, and foliar spray of these may induce deficiency of gibberellin in the plant and reduce the growth by blocking and conversion of geranyl pyrophosphate to coponyl pyrophosphate which is the first step of gibberellins synthesis. Maximum reduction in plant height was observed in mepiquat chloride treatments than any of other chemicals.

Bogiani and Rosolem (2009) stated that mepiquat chloride plant growth regulator applied at 0, 7.5, 15 and 22.5 g $ha^{-1}$ of the active ingredient reduced the growth of cotton plants, and this effect was intensified by increasing the dosage.

Reddy *et al.* (2009) found that the application of growth retardants and nipping at 35 DAS increased the chlorophyll content and the seed protein content did not differ significantly, though there was increase in its content MC @ 500 ppm, 1000 @ ppm, lihocin @ 500 ppm and nipping at 1 week after tendril formation significantly increased chlorophyll content and NRA at later stages which in turn increased the yield.

Kashid (2008) showed that the application of mepiquat chloride (2000 ppm, 1500 ppm, and 1000 ppm) showed a profound effect on the stem dry weight of sunflower. However, maximum stem dry weight was recorded with the application of mepiquat chloride at the rate of 2000 ppm followed by 1500 ppm, 1000 ppm, and cycocel (1500 ppm) and they were significantly higher over control (26.79 g plant$^{-1}$).

Anitha *et al*. (2007) reported that the beneficial effect of MC and another PGRs on plants may be related to increased photosynthesis activity due to increased leaf area, dry substance ratio, net assimilation ratio, and leaf chlorophyll concentration by increasing photosynthesis activity in sunflower. They also reported that in sunflower MC (Mepiquat Chloride) application increased the ratio of dehulled hulled seed$^{-1}$ weight by 11.1% compared to control plots.

Sawan *et al*. (2007) studied the effect of foliar application of mepiquat chloride (300 ppm), cycocel (300 ppm), alar (daminozide 300 ppm) and zinc (50 ppm) at 75 DAS, 80 DAS and 95 DAS and; reported that the mepiquat chloride and cycocel recorded the highest increase in seed yield of cotton.

Elkoca and Kantar (2006) conducted an experiment on response of pea (*Pisum sativum* L.) to mepiquat chloride under varying doses (25 g a.i ha$^{-1}$, 50 ga.i ha$^{-1}$, 75 g a.i ha$^{-1}$ and 100 g a.i ha$^{-1}$) and growth stages (late vegetative, early blooming, and early pod filling), and reported that the application of MPC showed significant decrease in plant height by 5.3 %, 7.2 %, and 6.4 % respectively compared to the control. These applications increased the stem diameter by 7.5 %, 12.7 %, 12.3 % and 15.7 % respectively when compared to untreated control.

Kumar *et al.* (2006) reported that application of growth retardants enhance the chlorophyll content of leaves which helps to increase the functional life of the source for a longer period leading to improved partitioning efficiency and increased productivity.

Arora *et al.* (2005) studied the effect of mepiquat chloride (MC) and gibberllic acid (GA) on yield and yield attributes of soybean at Ludhiana. Foliar application of plant growth regulators MC @ 100 and 200 μg $ml^{-1}$ and GA @ 10 and 20 μg $ml^{-1}$ was done at pre flowering (50 DAS) stage and they found that soybean sprayed with higher concentration of MC gave the highest seed yield than other treatments and control. Foliar application of MC resulted in higher number of flowers $plant^{-1}$, pods $plant^{-1}$ and seeds $pod^{-1}$.

Hanchinamath (2005) reported that in cluster bean with the application of mepiquat chloride (1000 ppm) increased 1000-seed weight, pods per plant and subsequent increase in seed yield. Kirankumar *et al.* (2005) reported that the mepiquat chloride (50 ppm) showed significantly higher SLW (Specific leaf weight) and NAR (Net assimilation rate) as compared to the control. Nurettin and Tanko (2005) reported an increase in seed yield of sunflower due to application of growth promoter by 15.3 % as compared to the control.

Nagashima *et al*. (2005) reported that cotton seeds treated with MPC resulted in plants with a smaller number of flower buds. The application of MPC increased both the rate of flowering and the number of flowers per meter of cotton row, but did not impact the ability of flowers to survive to maturity.

An investigation by Tan and Temel (2005) on common vetch (*Vicia sativa*) results on the yield attributes showed significantly higher number of pods $plant^{-1}$ in mepiquat chloride application @ 75 g a.i $ha^{-1}$ followed by mepiquat chloride application @ 50 g a.i $ha^{-1}$. Mepiquat chloride @ 75 g a.i $ha^{-1}$ registered significantly higher seeds $pod^{-1}$ as compared to control but was statistically at par with MC application @ 100 g a.i $ha^{-1}$. All the levels of mepiquat chloride resulted in significantly higher seed weight per plant and harvest index in comparison with control. 1000-seed weight was found highest in treatment including application of MC @ 25g a.i $ha^{-1}$ which was statistically at par with MC @ 50 g a.i $ha^{-1}$. Significantly higher seed yield was realized by MC application @ 75 g a.i $ha^{-1}$which was at par with mepiquat chloride @ 50g a.i $ha^{-1}$.

Koutroubas *et al*. (2004) reported that the mepiquat chloride and paclobutrazol reduced the plant height at maturity in sunflower. The height reduction was very pronounced, ranging from 9.5 to 11.7 % as compared to the untreated control due to the reduction in internode length. However, use of these two growth retardants was accompanied by a decrease in achene yield by 26 and 29 % respectively. Using chlormequat chloride at a rate of 3 kg $ha^{-1}$ brought a decrease in achene yield. However, they reported that the application of paclobutrazol at (12.5g a.i $ha^{-1}$) or mepiquat chloride at (25g a.i $ha^{-1}$) and cycocel at (1.5 kg $ha^{-1}$) did not decrease significantly the internode length and stem diameter.

Prakash *et al.* (2003) recorded that the application of mepiquat chloride at 120 ppm decreased the plant height and increased number of branches and leaves in pigeon pea. Parmar *et al.* (2003) have demonstrated in their field studies that application of mepiquat chloride decreased partitioning of photo assimilates to the main stem branches but increased the mobilization of assimilates into the reproductive sinks.

Solaimalai *et al.* (2001) reported that plant growth regulators are known to enhance the source-sink relationship and stimulate the translocation of photo-assimilates thereby helping in effective flower formation, fruit and seed development and ultimately enhance productivity of the crops. Growth regulators can improve the physiological efficiency including photosynthetic ability and can enhance the effective partitioning of accumulates from source and sink in the field crops.

Ghourab *et al*. (2000) carried out a study to know the the response of cotton plant cv. Giza 80 to the application of mepiquat chloride (0, 100, 150, 200, and 250 $cm^3fed^{-1}$), sprayed once at the start of flowering. The results revealed that the application of mepiquat chloride showed significant increase in phenol contents in leaves and oil content in seeds comparable to control treatment.

# CHAPTER-III

# MATERIALS AND METHODS

A field experiment entitled "Performance of mepiquat chloride on growth, yield and oil content of sunflower" was conducted during the Rabi season of 2020-2021. The details of materials used and techniques adopted during the course of investigation are described below.

## 3.1 Experimental period

The experiment was conducted during the period from November 2020 to March 2021 in Rabi season.

## 3.2 Description of the experimental site

### 3.2.1 Geographical location

The experiment was conducted in the Agronomy field of Sher-e-Bangla Agricultural University (SAU). The experimental site is geographically situated at 23°77′ N latitude and 90°33′ E longitude at an altitude of 8.6 meter above sea level (Anon., 2004).

### 3.2.2 Agro-Ecological Zone

The experimental site belongs to the Agro-ecological zone (AEZ) of "The Modhupur Tract", AEZ-28 (Anon., 1988 a). This was a region of complex relief and soils developed over the Modhupur clay, where floodplain sediments buried the dissected edges of the Modhupur Tract leaving small hillocks of red soils as 'islands' surrounded by floodplain (Anon., 1988 b). For better understanding about the experimental site has been shown in the Map of AEZ of Bangladesh in Appendix-I.

### 3.2.3 Soil

The soil of the experimental field belongs to the General soil type, Shallow Red Brown Terrace Soils under Tejgaon soil series. Soil pH ranges from 5.4-5.6 (Anon., 1989). The land was above flood level and sufficient sunshine was available during the experimental period. Soil samples from 0-15 cm depths were collected from the Sher-e-Bangla Agricultural University (SAU) Farm, field. The soil analyses were done at Soil Resource and Development Institute (SRDI), Dhaka. The morphological and physicochemical properties of the soil are presented in Appendix-II.

### 3.2.4 Climate and weather

The climate of the experimental site was subtropical, characterized by the winter season from November to February and the pre-monsoon period or hot season from March to April and the monsoon period from May to October (Edris *et al.*, 1979). Meteorological data related to the temperature, relative humidity and rainfall during the experiment period of was collected from Bangladesh Meteorological Department (Climate division), Sher-e-Bangla Nagar, Dhaka and has been presented in Appendix-III.

## 3.3 Planting materials

BARI Surjumukhi-2 and Mayabi Hybrid were used as planting materials for this experiment. The important characteristics of BARI Surjumukhi-2 and Mayabi Hybrid of sunflower variety were mentioned below:

**BARI Surjumukhi-2**

BARI Surjamukhi-2 was developed by the Bangladesh Agriculture Research Institute (BARI) in Gazipur, Bangladesh. It was released in 2004 after being developed through open pollination and selection methods. Plant height 125-140 cm, radium 2.0-2.4 cm, ripen inflorescence of head radium 15-18 cm, seed color black, number of seed/head 350-450. It is cultivated both the rabi and kharif seasons crop and duration in rabi season 95-100 days and kharf season 85-90 days required for harvesting. Rabi season yield is 2.0-2.3 t $ha^{-1}$, while kharif season yield is 1.5-1.8 t $ha^{-1}$. Oil $seed^{-1}$ content 42-44%.

**Mayabi Hybrid (China variety)**

Mayabi Hybrid is imported from China. Plant height 170-180 cm, radium 2.0-2.8 cm, ripen inflorescence of head radium 20-22 cm, seed color black, number of seed/head 500-700. It is cultivated both the rabi and kharif seasons crop and duration in Rabi season 95-110 days and kharif season 85-100 days required for harvesting. Rabi season yield is 2.0-3.0 t $ha^{-1}$, while kharif season yield is 2-2.5 t $ha^{-1}$. Oil $seed^{-1}$ content 42-43 %.

### 3.4 Experimental treatment

There were two factors in the experiment namely different varieties of sunflower and different rate of Mepiquat chloride application as mentioned below:

**Factor A:** Sunflower varieties- 2

$V_1$= BARI Surjumukhi-2

$V_2$ = Mayabi Hybrid

**Factor B:** Mepiquat chloride application level– 5

$M_0$= Control (Without Mepiquat chloride)

$M_1$= 12.5 ml $ha^{-1}$

$M_2$= 25.0 ml $ha^{-1}$

$M_3$= 37.5 ml $ha^{-1}$, and

$M_4$= 50.0 ml $ha^{-1}$

### 3.5 Salient features of the plant growth retardants used in this experiment

| Scientific name and chemical formula | Common names | Physiological effects and uses |
|---|---|---|
| Mepiquat Chloride<br>$C_7H_{16}ClN$ | Pix Plus, Pix Ultra, Pentia, Ponnax, Mepex, Mepex Ginout, and Mepichlor | Mepiquat chloride is an anti gibberellin that inhibits cell expansion but not cell division. It inhibits the cyclization of geranylgeranyl pyrophosphate to copallyl pyrophosphate and to ent-kaurene in the gibberellin biosynthesis pathway. |

### 3.6 Layout of the field experiment

The field experiment was laid out in split-plot design with three replications. The two varieties were assigned in the main plot and five levels of mepiquat chloride application were assigned in the sub-plot within each replication. Plan of experimental layout is shown in Appendix IV.

### 3.7 Land preparation

The experimental field was ploughed once with tractor drawn disc plough after the harvest of previous crop. The rotavator which was passed to break down the clods and to prepare a fine seed bed. After that the land was demarcated into plots of required size and laid as per the design and leveled within each plot. Farm yard manure (FYM) was applied in advance before sowing as to get complete decomposition.

### 3.8 Fertilizer application

The recommended dose of fertilizers (60:35:80:30:3:6 kg $ha^{-1}$of N, P, K,S, Zn and B) were applied in the form of Urea, TSP, MP, Gypsum, Zinc sulphate and Boric acid. The first half (50 per cent) of nitrogen was applied along with full dose of others fertilizers at the time of sowing and the second dose (50 per cent) of nitrogen was applied at 30 days after sowing (Haq *et al*., 2020).

### 3.9 Sowing of seeds and spacing

The sunflower varieties of BARI Surjumukhi-2 and Mayabi Hybrid were used for sowing in Rabi season in present investigation. Sowing was done by dibbling two seeds at each hill to a depth of 3 cm by maintaining 60 cm inter-row and 30 cm intra-row distance.

### 3.10 Sowing time and sowing method

Sowing of seed was done manually by line sowing on 25th November, 2020 using a seed rate of 8-10 kg $ha^{-1}$. Sowing of seeds in each plot was done by maintaining the spacing at 60 cm × 30 cm with depth of 3-4 cm and two to three seeds were dibbled at each place and then seeds were covered with fine soil.

### 3.11 Application of growth retardants

Different levels of mepiquat chloride was applied according at par treatment requirement mention in section 3.4.

### 3.12 Irrigation

The light irrigation was applied immediately after sowing on 15th November, 2020 to ensure the better germination. After seed sowing an irrigation was given on 5th day and later at intervals of 10 days according to soil and climatic conditions, seeding, flowering and seed development stage (ie) two weeks before and after flowering.

### 3.13 Plant protection measures

Seeds were treated with a fungicide (Metalaxyl, at 1.5 ml $L^{-1}$) before sowing and a pre-emergent herbicide lasso (Sinochem, at 1.5 ml $L^{-1}$) was sprayed in the field on two days after sowing to control weeds. Manual weeding was carried out twice at 21 days after plant emergence and 40 days after sowing. However, 30 days after sowing insecticide lambda-cylothrin (Karate, at 1.5 $mlL^{-1}$) was applied due to minor prevalence of caterpillar species.

### 3.14 Harvesting

The crop was harvested when the foliage and heads of the sunflower plants turned yellowish brown to brown in colour and started to fall down. The area excluding one border row from each side and 30 cm at both ends of the rows were harvested to eliminate the border effect. The harvested produced of each plot was brought to the threshing flour from the field. The harvested produce of each plot was tied into bundles and tagged with luggage label for demarcation. The plot wise produce was allowed for sun drying for 10 days.

### 3.15 Threshing and winnowing

After sun drying, the threshing was done by manually for each plot separately. The produce of each plot was weighed plot-wise by using spring balance. The threshed material of each plot contained seeds and chaffy materials. The chaffs were removed and clean seeds of each plot were separated by winnowing manually. The weight of clean seeds obtained from each plot was recorded plot wise with the help of digital electric balance.

### 3.16 Recording of data

Five plants were selected randomly from each treatment and tagged at 25 days after sowing and used for recording data of various morphological characters and yield attributes. The following data were recorded during the experiment.

i. Plant height (cm)
ii. Stem diameter (mm)
iii. Dry weight plant$^{-1}$ (g)
iv. SPAD value
v. Head diameter (cm)
vi. Number of seeds head$^{-1}$
vii. 1000-seed weight (g)
viii. Seed yield (t ha$^{-1}$)
ix. Stover yield (t ha$^{-1}$)

x. Biological yield (t $ha^{-1}$)
xi. Harvest index (%)
xii. Oil content (%)

**3.17 Detailed procedures of recording data**

**i. Plant height**

The plant height of selected 5 plants was recorded at 25, 45, 65 and 85 days after sowing (DAS) and at harvest, respectively. The height was measured from the base to the tip of the stem using measuring scale and averaged them and expressed in centimeter (cm).

**ii. Stem diameter**

Stem diameter was measured from main stem of five plants and then averaged. This was taken at 25, 45, 65 days after sowing (DAS) and at harvest, respectively. Stem diameter was measured with the help of digital slide caliper.

**iii. Dry weight $plant^{-1}$**

Five plants at 25, 50 and 75 different days after sowing (DAS) were collected from each plot and dried at 70° C for 48 hours. The dried samples were then weighed and averaged.

**iv. SPAD value**

SPAD value was measured by using chlorophyll meter (SPAD 502 plus, made in Japan). Five plants per plot were selected randomly and SPAD values at 25, 40, 55 and 70 DAS were recorded from the fully matured leaves counted from the top of the plants, the youngest fully expanded leaf.

**v. Head diameter (cm)**

From the five randomly selected plants of each plot, the diameter of head was measured by slide caliper and average was calculated.

**vi. Number of seeds $head^{-1}$**

From the five randomly selected plants of each plot, the number of seeds $head^{-1}$ were recorded and average was calculated.

**vii. Weight of 1000-seed**

One thousand cleaned, dried seeds were counted from each harvested sample and weighed by using a digital electric balance and weight was expressed in gram (g).

**viii. Seed yield**

The seed yield per plot was recorded after winnowing with the help of balance from the harvested area. Finally, seed yield of each plot was converted in to seed yield per hectare by multiplying it with appropriate conversion factor.

**ix. Stover yield**

The stover yield per plot was determined by subtracting seed yield (economical yield) of each plot from biological yield (bundle weight) of the same plot. This was later on converted into stover yield per hectare by multiplying with the same conversion factor which was used in case of seed yield per hectare.

**x. Biological yield**

Seed yield and stover yield together were regarded as biological yield. The biological yield was calculated with the following formula:

Biological yield = Seed yield + Stover yield.

**xi. Harvest index**

It is defined as the ratio of economic yield to biological yield and expressed in percentage. The formula is as follow:

$$\text{Harvest Index (\%)} = \frac{\text{Grain yield}}{\text{Biological yield}} \times 100$$

**xii. Oil content**

To determine oil content in seeds of each variety was taken into ‘Sunflower cup’ which is used to feed these seeds to the instrument called NIR SPECTRA ANALYSER (Near Infra-Red Region). The principle involved is - Light emitted by tungsten halogen lamp interact with sample and reflected light collected in gold coated integrating sphere and measured by lead sulfide detector. The resulting analog signal is amplified and digitalized by analog board.

### 3.18 Data analysis technique

The collected data were compiled and analyzed statistically using the analysis of variance (ANOVA) technique with the help of a computer package program name Statistix 10 data analysis software and the mean differences were adjusted by Least Significant Difference (LSD) test at 5% level of probability (Gomez and Gomez, 1984).

# CHAPTER IV

# RESULTS AND DISCUSSION

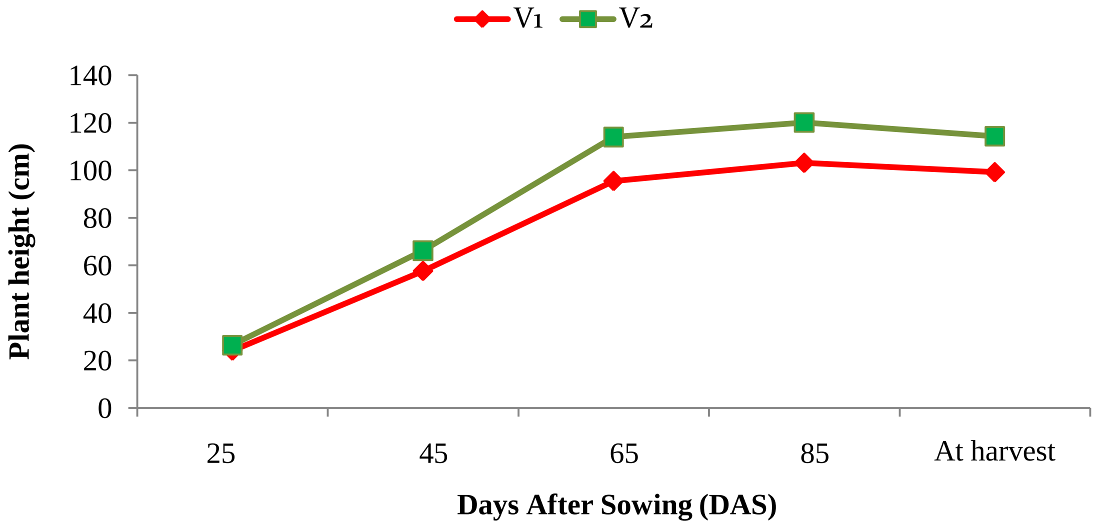
Results obtained from the present study have been presented and discussed in this chapter with a view to study the performance of mepiquat chloride on growth, yield and oil content of sunflower. The results have been discussed and possible interpretations are given under the following headings.

## 4.1 Plant growth parameters

### 4.1.1 Plant height

**Effect of variety**

Plant height is an essential character of the vegetative stage of the crop plant and indirectly impacts on yield of crop plants. Different variety significantly influenced on plant height of sunflower at different days after sowing (DAS). It was seen that height increased gradually with the age of the crop up to 85 DAS. The plant height reached the highest value at 85 DAS after that it reduced naturally (Figure 1). Experimental result revealed that the higher plant height (26.43, 66.17, 113.91, 120.02 and 114.24 cm at 25, 45, 65, 85 DAS and at harvest, respectively) was observed in $V_2$ (Mayabi Hybrid) variety. Whereas, the lower plant height (24.03, 57.62, 95.51, 103.15 and 99.21 cm at 25, 45, 65, 85 DAS and at harvest, respectively) was observed in $V_1$ (BARI Surjumukhi-2) variety. The variation in plant height due to the effect of varietal differences. The variation of plant height is probably due to the genetic make-up of the varieties. Das *et al.* (2019) reported that height of a plant is determined by genetical character and under a given set of environment and different variety will acquire their height according to their genetical makeup. Tyeb *et al.* (2013) also reported that the variation in plant height due to the effect of varietal differences and it may be due to the genetic makeup of the cultivars.

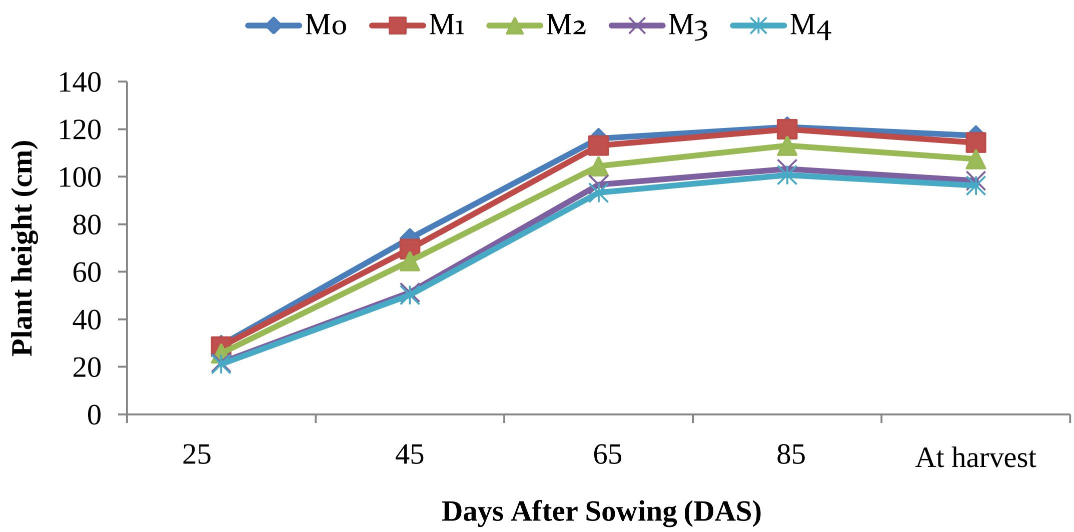



Here, $V_1$= BARI Surjumukhi-2 and $V_2$ = Mayabi Hybrid

**Figure 1. Effect of variety on plant height at different days after sowing (DAS) of sunflower ($LSD_{(0.05)}$ =1.25, 3.07, 1.81, 1.13 and 6.82at 25, 45, 65, 85 DAS and at harvest, respectively)**

**Effect of mepiquat chloride**

Significant variance in sunflower plant height was observed as a result of various doses of mepiquat chloride application at different days after sowing (Figure 2). Experimental result showed that the tallest plant (29.12, 74.03, 116.15, 120.96 and 117.26 cm at 25, 45, 65, 85 DAS and at harvest, respectively) was observed in $M_0$ (Control) treatment which was statistically similar with $M_1$ treatment at different DAS. While The $M_4$ (Mepiquat chloride application @ 50.0 ml $ha^{-1}$) treatment had the lowest plant height (21.07, 50.14, 93.26, 100.72 and 96.29 cm at 25, 45, 65, 85 DAS and at harvest, respectively) which was statistically similar with $M_3$ treatment at different DAS. The mechanism of reduction in plant height due to application of growth retardants appears to be due to slowing down of cell division and reduction in cell expansion. It has been suggested that, mepiquat chloride is anti-gibberellin dwarfing agents, leading to a deficiency of gibberellin in the plant and reduce the growth by blocking the conversion of geranyl pyrophosphate to copalyl pyrophosphate which is the first step of gibberellin synthesis. Raut *et al.* (2019) reported that mepiquat chloride hampers gibberellic acid biosynthesis by stopping the conversion of geranylgeranyl diphosphate to entkaurene, which ultimately reduces cell division and enlargement. The result obtained from the present study was similar with the findings of Sethy *et al*. (2016) who reported that application of growth retardant (maleic hydrazide) twice at 30 and 45 DAS at the concentration of 500 ppm or more resulted in reduction in plant height in ornamental sunflower.




Here, $M_0$= Control (Without mepiquat chloride), $M_1$= 12.5 ml $ha^{-1}$ mepiquat chloride, $M_2$= 25.0 ml $ha^{-1}$ mepiquat chloride, $M_3$= 37.5 ml $ha^{-1}$ mepiquat chloride and $M_4$= 50.0 ml $ha^{-1}$ mepiquat chloride

**Figure 2. Effect of mepiquat chloride on plant height at different days after sowing (DAS) of sunflower ($LSD_{(0.05)}$ = 0.94, 3.37, 6.37, 6.31 and 7.53at 25, 45, 65, 85 DAS and at harvest, respectively)**

**Interaction effect of variety and mepiquat chloride**

Variety and mepiquat chloride application had shown significant effect on sunflower plant height at different days after sowing (Table 1). The results of the experiment showed that the $V_2M_0$ interaction treatment gave the highest plant height (29.81, 78.49, 127.31, 129.83 and 124.35 cm at 25, 45, 65, 85 DAS and at harvest, respectively) which was statistically similar with $V_2M_1$ interaction treatment. While $V_1M_4$ interaction treatment showed the lowest plant height (19.25, 48.56, 85.01, 91.60 and 88.43 cm at 25, 45, 65, 85 DAS and at harvest, respectively) which was statistically similar to $V_1M_3$ interaction treatment at different DAS.

**Table 1. Interaction effect of variety and mepiquat chloride on plant height at different days after sowing (DAS) of sunflower**

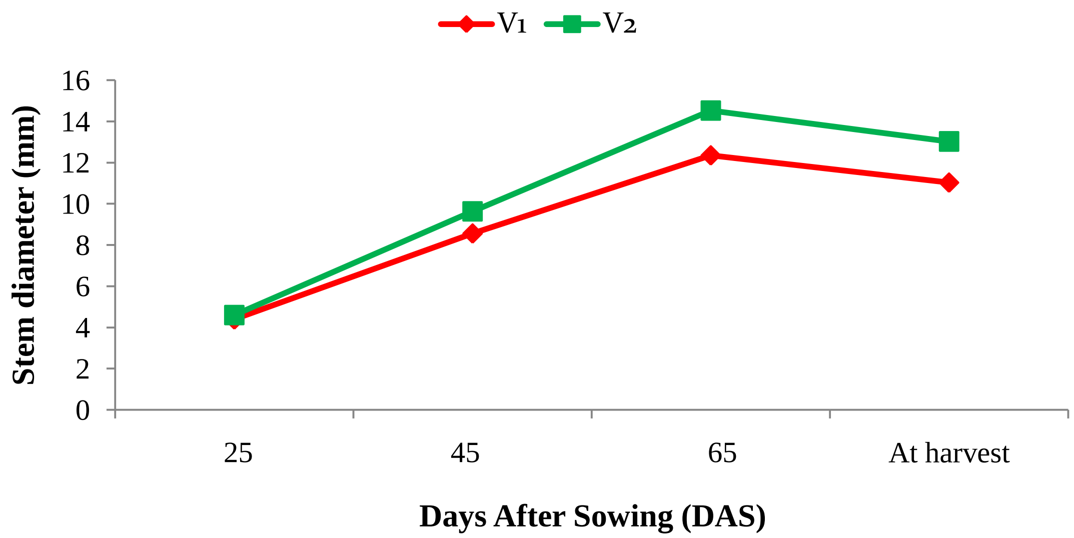
| Treatment combinations | Plant height (cm) at | | | | |
|---|---|---|---|---|---|
| | 25 DAS | 45 DAS | 65 DAS | 85 DAS | Harvest |
| $V_1M_0$ | 28.43 bc | 69.58 b | 104.98 bc | 112.09 c | 110.16 bc |
| $V_1M_1$ | 27.70 cd | 62.14 c | 102.12 cd | 111.89 c | 106.30 c |
| $V_1M_2$ | 24.45 e | 58.69 c | 95.61 de | 105.50 c | 100.55 cd |
| $V_1M_3$ | 20.33 g | 49.14 d | 89.82 ef | 94.69 d | 90.60 de |
| $V_1 M_4$ | 19.25 g | 48.56 d | 85.01 f | 91.60 d | 88.43 e |
| $V_2M_0$ | 29.81 a | 78.49 a | 127.31 a | 129.83 a | 124.35 a |
| $V_2M_1$ | 29.38 ab | 76.96 a | 124.06 a | 128.03 ab | 122.43 ab |
| $V_2M_2$ | 26.87 d | 70.27 b | 113.22 b | 120.57 b | 114.22 a-c |
| $V_2 M_3$ | 23.21 ef | 53.43 d | 103.47 cd | 111.84 c | 106.03 c |
| $V_2M_4$ | 22.89 f | 51.71 d | 101.51 cd | 109.84 c | 104.15 cd |
| $LSD_{(0.05)}$ | **1.27** | **5.00** | **8.44** | **8.16** | **14.01** |
| CV (%) | **5.07** | **4.45** | **4.96** | **4.62** | **5.77** |

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5% level of significance.
Here, $V_1$= BARI Surjumukhi-2, $V_2$ = Mayabi Hybrid, Here, $M_0$= Control (Without mepiquat chloride), $M_1$= 12.5 ml $ha^{-1}$ mepiquat chloride, $M_2$= 25.0 ml $ha^{-1}$ mepiquat chloride, $M_3$= 37.5 ml $ha^{-1}$ mepiquat chloride and $M_4$= 50.0 ml $ha^{-1}$ mepiquat chloride

### 4.1.2 Stem diameter

### Effect of variety

Depending on the variety sunflower stem diameter varied significantly at different days after sowing (DAS). According to the experimental results, the $V_2$ (Mayabi Hybrid) variety had the higher stem diameter 4.60, 9.63, 14.53 and 13.03 mm at 25, 45, 65 DAS and at harvest, respectively. While the $V_1$ (BARI Surjumukhi-2) variety, had the lower stem diameter 4.39, 8.56, 12.35 and 11.03 mm at 25, 45, 65 DAS and at harvest, respectively (Figure 3).The reason of difference in stem diameter $plant^{-1}$ is the genetic makeup of the variety, which is primarily influenced by heredity.

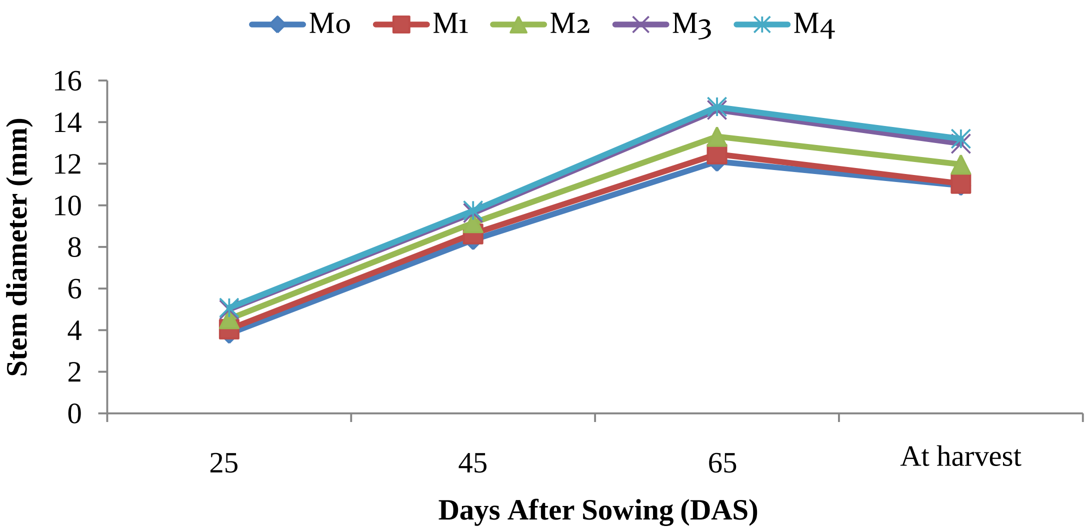



Here, $V_1$= BARI Surjumukhi-2 and $V_2$ = Mayabi Hybrid

**Figure 3. Effect of variety on stem diameter at different days after sowing (DAS) of sunflower ($LSD_{(0.05)}$ = 0.20, 0.15 and 1.49 at 25, 45 and 65 DAS, respectively)**

**Effect of mepiquat chloride**

Different doses of mepiquat chloride application at various days after sowing had shown significant effect in respect of stem diameter of sunflower (Figure 4). According to the experimental results, the $M_4$ (Mepiquat chloride application @ 50.0 ml $ha^{-1}$) treatment had the highest stem diameter (5.08, 9.75, 14.73 and 13.20 mm at 25, 45, 65, 85 DAS and at harvest, respectively) which was statistically similar with $M_3$ treatment at different DAS. While the lowest stem diameter (3.83, 8.34, 12.11 and 10.95 mm at 25, 45, 65 DAS and at harvest, respectively) was found in $M_0$ (Control) treatment which was statistically similar with the $M_1$ treatment at various DAS. The stem diameter of sunflower depends on the accumulation and partitioning of photo assimilates in reproductive parts of the plant. Increasing stem diameter of sunflower could be due to relatively higher biomass, better partitioning of photo assimilates towards reproductive structures, higher values of yield components. Polat *et al*. (2017) also found similar result which supported the present finding and reported that in comparison with the control treatment, the MC application of @ 60 g a.i. $ha^{-1}$ decreased plant height by 5.38 % and increased stem diameter by 14.01 % respectively. The applications of MC at different growth stages also significantly affected seed yield and other characteristics such as plant height, stem diameter, and head diameter. The application of MC at the early growth stage was more effective compared to the later growth stages.




Here, $M_0$= Control (Without mepiquat chloride), $M_1$= 12.5 ml $ha^{-1}$ mepiquat chloride, $M_2$= 25.0 ml $ha^{-1}$ mepiquat chloride, $M_3$= 37.5 ml $ha^{-1}$ mepiquat chloride and $M_4$= 50.0 ml $ha^{-1}$ mepiquat chloride

**Figure 4. Effect of mepiquat chloride on stem diameter at different days after sowing (DAS) of sunflower ($LSD_{(0.05)}$= 0.16, 0.50 and 0.77 at 25, 45 and 65 DAS, respectively)**

**Interaction effect of variety and mepiquat chloride**

At various days after sowing, the treatment of variety and mepiquat chloride had shown significant effect on the stem diameter of sunflower (Table 2). The experimental findings revealed that the $V_2M_4$ interaction treatment showed the maximum stem diameter (5.18, 10.37, 15.87 and 14.02 mm at 25, 45, 65 DAS and at harvest, respectively) which was statistically similar with $V_2M_3$ interaction treatment at various DAS. The $V_1M_4$ and $V_1M_3$ interactions at 25 DAS had the highest and similar stem diameter with $V_2M_4$ interaction. The lowest stem diameter (3.73, 7.78, 10.92 and 9.87 mm at 25, 45, 65 DAS and at harvest, respectively) was found in $V_1M_0$ interaction treatment which was statistically similar with  (3.92, 8.18, 11.39 and 9.95 at 25, 45, 65 DAS and at harvest, respectively).

**Table 2. Interaction effect of variety and mepiquat chloride on stem diameter at different days after sowing (DAS) of sunflower**

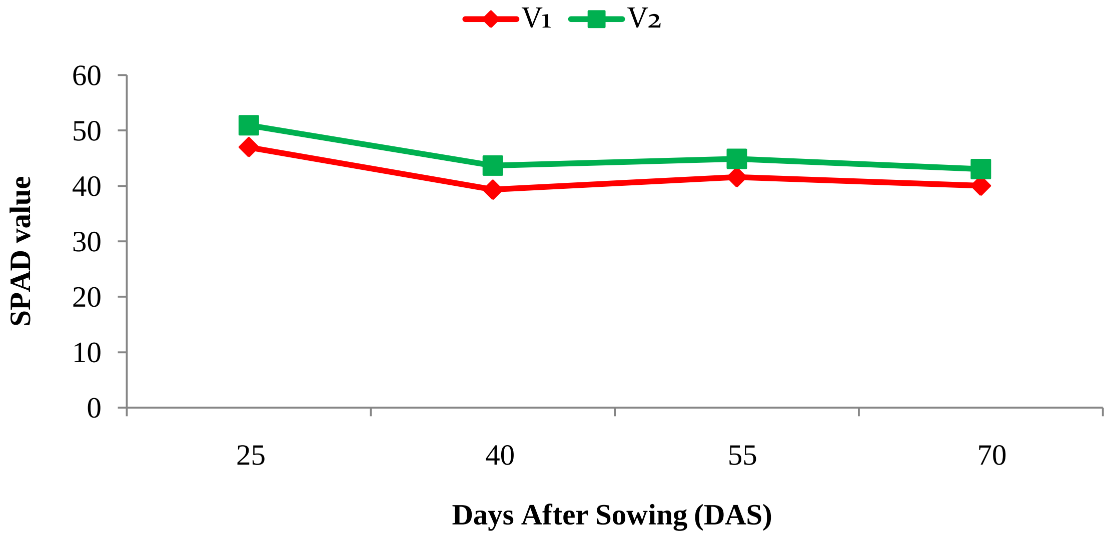
| Treatment combinations | Stem diameter (mm) at | | | |
|---|---|---|---|---|
| | 25 DAS | 45 DAS | 65 DAS | Harvest |
| $V_1M_0$ | 3.73 f | 7.78 f | 10.92 e | 9.87 d |
| $V_1M_1$ | 3.92 ef | 8.18 ef | 11.39 de | 9.95 d |
| $V_1M_2$ | 4.43 cd | 8.68 de | 12.40 cd | 10.99 c |
| $V_1M_3$ | 4.88 ab | 9.06 cd | 13.43 bc | 11.94 bc |
| $V_1 M_4$ | 4.97 ab | 9.12 cd | 13.59 b | 12.38 b |
| $V_2M_0$ | 3.93 ef | 8.89 d | 13.30 bc | 12.03 b |
| $V_2M_1$ | 4.15 de | 9.05 cd | 13.53 bc | 12.15 b |
| $V_2M_2$ | 4.65 bc | 9.63 bc | 14.22 b | 12.95 b |
| $V_2 M_3$ | 5.09 a | 10.20 ab | 15.73 a | 13.98 a |
| $V_2M_4$ | 5.18 a | 10.37 a | 15.87 a | 14.02 a |
| **$LSD_{(0.05)}$** | **0.33** | **0.75** | **1.67** | **1.01** |
| **CV (%)** | **4.08** | **4.57** | **4.71** | **5.92** |

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5% level of significance.
Here, $V_1$= BARI Surjumukhi-2, $V_2$ = Mayabi Hybrid, Here, $M_0$= Control (Without mepiquat chloride), $M_1$= 12.5 ml $ha^{-1}$mepiquat chloride, $M_2$= 25.0 ml $ha^{-1}$ mepiquat chloride, $M_3$= 37.5 ml $ha^{-1}$ mepiquat chloride and $M_4$= 50.0 ml $ha^{-1}$ mepiquat chloride

### 4.1.3 SPAD value

#### Effect of variety

SPAD value determine the chlorophyll content in leaf. In this experiment sunflower SPAD value varied significantly at various days after sowing due to effect of different varieties cultivation (Figure 5). Experimental result revealed that, the $V_2$ (Mayabi Hybrid) variety had the highest SPAD value (50.94, 43.67, 44.89 43.04 at 25, 40, 55 and 70 DAS, respectively). While the $V_1$ (BARI Surjumukhi-2) variety had the lowest SPAD value (46.99, 39.32, 41.58 and 40.04 at 25, 40, 55 and 70 DAS, respectively). Santhosh *et al.* (2017) reported that SPAD value significantly varied among different genotype and the genotype DRSF-113 showed maximum values for SPAD chlorophyll meter readings (31.5) comparable to other sunflower varieties.

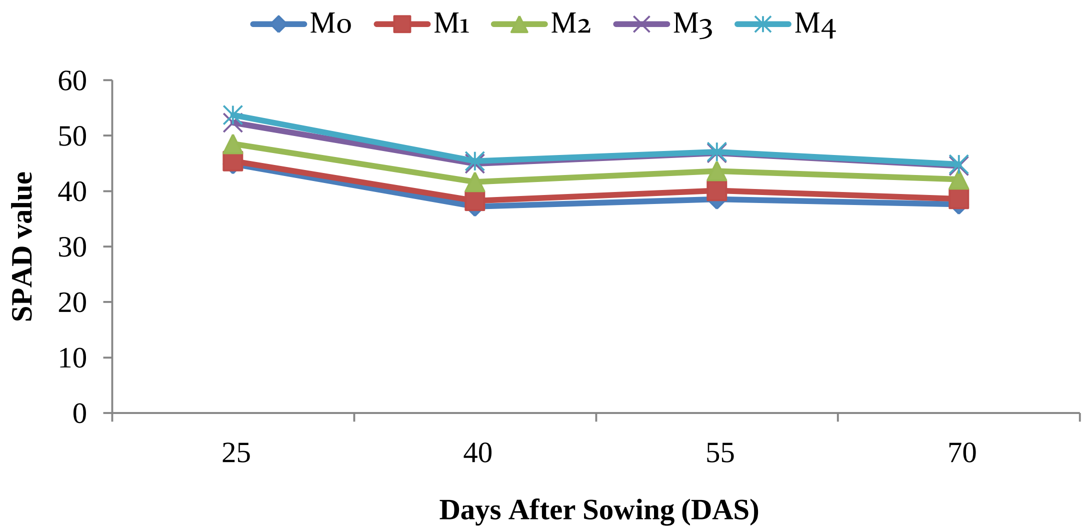



Here, $V_1$= BARI Surjumukhi-2 and $V_2$ = Mayabi Hybrid

**Figure 5. Effect of variety on SPAD value at different days after sowing (DAS) of sunflower ($LSD_{(0.05)}$= 1.98, 1.49, 2.48 and 2.93at 25, 40, 55 and 70 DAS, respectively)**

**Effect of mepiquat chloride**

Mepiquat chloride application at different days after sowing had shown significant effect on the SPAD value of sunflower (Figure 6). Experimental result showed that the $M_4$ treatment (Mepiquat chloride application @ 50.0 ml $ha^{-1}$) exhibited the highest SPAD value (53.73, 45.38, 47.08, 44.83 at 25, 40, 55 and 70 DAS, respectively) which was statistically similar with $M_3$ treatment at various DAS. While the lowest SPAD value (44.88, 37.23, 38.53 and 37.61 at 25, 40, 55 and 70 DAS, respectively) was found in $M_0$ (Control) treatment which was statistically equivalent with the $M_1$ treatment at different DAS. The result obtained from the present study was similar with the findings of Chandrashekara *et al*. (2018) who reported that an increase in chlorophyll content in maize plants sprayed with 20 ppm of mepiquat chloride chloride at 30 and 45 DAS. Sharma and Sardana (2012) also reported that Chl a, Chl b and total chlorophyll enhanced with the mapiquat chloride application @ 125 ppm in peanut.




Here, $M_0$= Control (Without mepiquat chloride), $M_1$= 12.5 ml ha$^{-1}$ mepiquat chloride, $M_2$= 25.0 ml ha$^{-1}$ mepiquat chloride, $M_3$= 37.5 ml ha$^{-1}$ mepiquat chloride and $M_4$= 50.0 ml ha$^{-1}$ mepiquat chloride

**Figure 6. Effect of mepiquat chloride on SPAD value at different days after sowing (DAS) of sunflower (LSD$_{(0.05)}$= 1.87, 2.25, 1.73 and 2.33 at 25, 40, 55 and 70 DAS, respectively)**

**Interaction effect of variety and mepiquat chloride**

The interaction treatment of variety and mepiquat chloride had shown significant effect on the SPAD value of sunflower at different days after sowing (Table 3). The results of the experiment showed that the $V_2M_4$ interaction treatment showed the highest SPAD value (55.88, 47.13, 48.93 and 46.25 at 25, 40, 55 and 70 DAS, respectively) which was statistically similar with $V_2M_3$ interaction treatment at different DAS. At 70 DAS, the interaction treatments $V_2M_2$ and $V_1M_3$ showed statistically similar SPAD value with $V_2M_4$ interaction treatment. While the lowest SPAD value (43.33, 34.99, 37.72 and 36.12 at 25, 40, 55 and 70 DAS, respectively) was discovered in the $V_1M_0$ interaction treatment, which was statistically similar with $V_1M_1$ interaction at different DAS.

**Table 3. Interaction effect of variety and mepiquat chloride on SPAD value at different days after sowing (DAS) of sunflower**

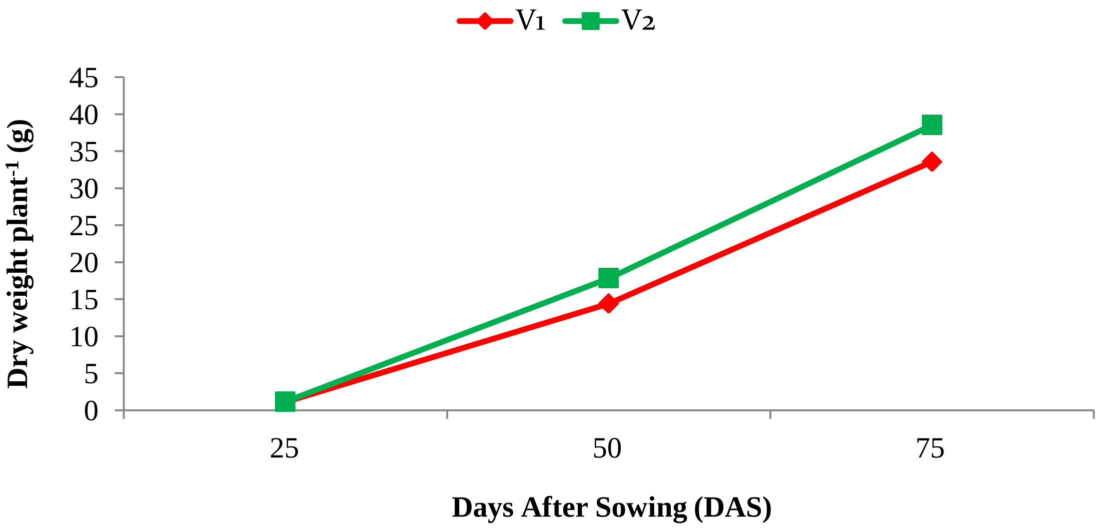
| Treatment combinations | SPAD value at | | | |
|---|---|---|---|---|
| | 25 DAS | 40 DAS | 55 DAS | 70 DAS |
| $V_1M_0$ | 43.33 f | 34.99 e | 37.72 f | 36.12 f |
| $V_1M_1$ | 43.75 ef | 35.63 e | 38.30 f | 37.09 ef |
| $V_1M_2$ | 46.59 d | 39.43 d | 41.72 de | 40.51 b-d |
| $V_1M_3$ | 49.72 bc | 42.94 c | 44.92 bc | 43.07 a-c |
| $V_1 M_4$ | 51.57 b | 43.62 c | 45.23 b | 43.41 a-c |
| $V_2M_0$ | 46.42 de | 39.47 d | 39.33 ef | 39.10 d-f |
| $V_2M_1$ | 47.02 cd | 40.88 cd | 41.84 cd | 40.15 c-e |
| $V_2M_2$ | 50.42 b | 43.93 bc | 45.58 b | 43.72 ab |
| $V_2 M_3$ | 54.97 a | 46.92 ab | 48.79 a | 45.98 a |
| $V_2M_4$ | 55.88 a | 47.13 a | 48.93 a | 46.25 a |
| **$LSD_{(0.05)}$** | **2.95** | **3.13** | **3.12** | **3.93** |
| **CV (%)** | **5.13** | **4.44** | **5.27** | **4.59** |

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5% level of significance.
Here, $V_1$= BARI Surjumukhi-2, $V_2$ = Mayabi Hybrid, Here, $M_0$= Control (Without mepiquat chloride), $M_1$= 12.5 ml ha$^{-1}$ mepiquat chloride, $M_2$= 25.0 ml ha$^{-1}$ mepiquat chloride, $M_3$= 37.5 ml ha$^{-1}$ mepiquat chloride and $M_4$= 50.0 ml ha$^{-1}$ mepiquat chloride

### 4.1.4 Dry weight plant$^{-1}$

#### Effect of variety

The result of the experiment shown that different varieties had shown significant effect on the dry weight plant$^{-1}$ of sunflower at different days after sowing (Figure 7). The result revealed that the dry weight plant$^{-1}$ showed an increasing trend with increases growth stage and its continued upto 75 DAS. According to the experimental result, the higher dry weight plant$^{-1}$ (1.14, 17.84 and 38.53 g at 25, 50 and 75 DAS, respectively) was found in $V_2$ (Mayabi Hybrid) variety. Whereas the lower dry weight plant$^{-1}$ (1.10, 14.40 and 33.56 g at 25, 50 and 75 DAS, respectively) was found in $V_1$ (BARI Surjumukhi-2) variety. The reason of varying dry weight plant$^{-1}$ between different varieties is because each variety has a unique growth stage and makes use of resources from its environment differently. Ali *et al.* (2004) reported that sunflower cultivars significantly differed in dry weight plant$^{-1}$ and this difference may be due to their varietal behavior.

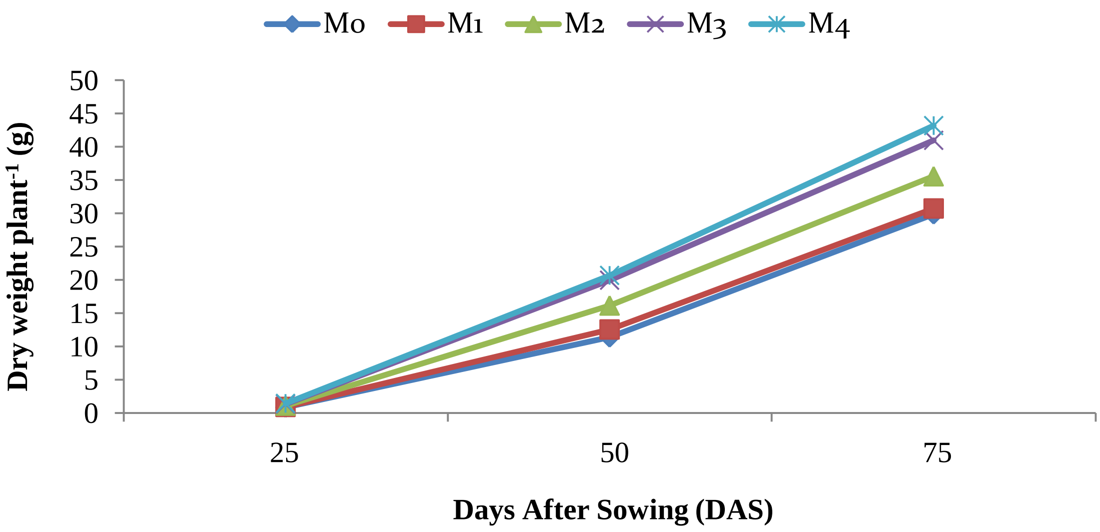



Here, $V_1$= BARI Surjumukhi-2 and $V_2$ = Mayabi Hybrid

**Figure 7. Effect of variety on dry weight plant$^{-1}$at different days after sowing (DAS) of sunflower ($LSD_{(0.05)}$= 0.02, 2.20 and 2.28 at 25, 50 and 75 DAS, respectively)**

**Effect of mepiquat chloride**

Application of mepiquat chloride on had shown significant effect on dry weight plant$^{-1}$ of sunflower at various days after sowing (Figure 8). The results showed that, the $M_4$ treatment (Mepiquat chloride application @ 50.0 ml ha$^{-1}$) had the highest dry weight plant$^{-1}$ (1.44, 20.65 and 43.16 g at 25, 50 and 75 DAS, respectively) which was statistically similar with the $M_3$ treatment at 50 DAS. However, the $M_0$ (Control) treatment, was found to produce the lowest dry weight plant$^{-1}$ (0.83, 11.36 and 29.85 g at 25, 50 and 75 DAS, respectively) which was statistically similar with the $M_1$ treatment at 55 and 75 DAS. The result obtained from the present study was similar with the findings of Jaidka *et al*. (2018) who reported that application of mepiquat chloride significantly increased total dry matter accumulation plant$^{-1}$ over control. Kashid (2008) also reported that the application of mepiquat chloride showed a profound effect on the stem dry weight of sunflower.




Here, $M_0$= Control (Without mepiquat chloride), $M_1$= 12.5 ml $ha^{-1}$ mepiquat chloride, $M_2$= 25.0 ml $ha^{-1}$ mepiquat chloride, $M_3$= 37.5 ml $ha^{-1}$ mepiquat chloride and $M_4$= 50.0 ml $ha^{-1}$ mepiquat chloride

**Figure 8. Effect of mepiquat chloride on dry weight plant$^{-1}$at different days after sowing (DAS) of sunflower ($LSD_{(0.05)}$= 0.06, 1.51 and 1.86 at 25, 50 and 75 DAS, respectively)**

**Interaction effect of variety and mepiquat chloride**

The dry weight plant$^{-1}$ of sunflowers at various days after sowing had significantly influenced as a result of the variety and mepiquat chloride interaction treatment (Table 4). The experimental findings revealed that the $V_2M_4$ interaction treatment had the highest dry weight plant$^{-1}$ (1.42, 22.04 and 45.84 g at 25, 50 and 75 DAS, respectively) which was statistically similar with $V_1M_4$ interaction treatment at 25 DAS and with $V_2M_3$ interaction treatment at 50 and 75 DAS. While the $V_1M_0$ interaction treatment had the lowest dry weight plant$^{-1}$ (0.78, 9.25 and 27.22 g at 25, 50 and 75 DAS, respectively) which was statistically similar with $V_1M_1$ interaction treatment at different DAS.

**Table 4. Interaction effect of variety and mepiquat chloride on dry weight plant$^{-1}$ at different days after sowing (DAS) of sunflower**

| Treatment Combinations | Dry weight plant$^{-1}$ (g) at | | |
|---|---|---|---|
| | **25 DAS** | **50 DAS** | **75 DAS** |
| **$V_1M_0$** | 0.78 e | 9.25 f | 27.22 e |
| **$V_1M_1$** | 0.87 de | 10.21 f | 28.14 e |
| **$V_1M_2$** | 1.08 c | 14.87 de | 33.41 d |
| **$V_1M_3$** | 1.33 b | 18.43 c | 38.57 c |
| **$V_1 M_4$** | 1.46 a | 19.25 bc | 40.48 bc |
| **$V_2M_0$** | 0.87 de | 13.46 e | 32.48 d |
| **$V_2M_1$** | 0.94 d | 14.87 e | 33.26 d |
| **$V_2M_2$** | 1.13 c | 17.42 cd | 37.71 c |
| **$V_2 M_3$** | 1.33 b | 21.43 ab | 43.35 ab |
| **$V_2M_4$** | 1.42 ab | 22.04 a | 45.84 a |
| **$LSD_{(0.05)}$** | **0.09** | **2.75** | **3.10** |
| **CV (%)** | **4.88** | **7.68** | **5.22** |

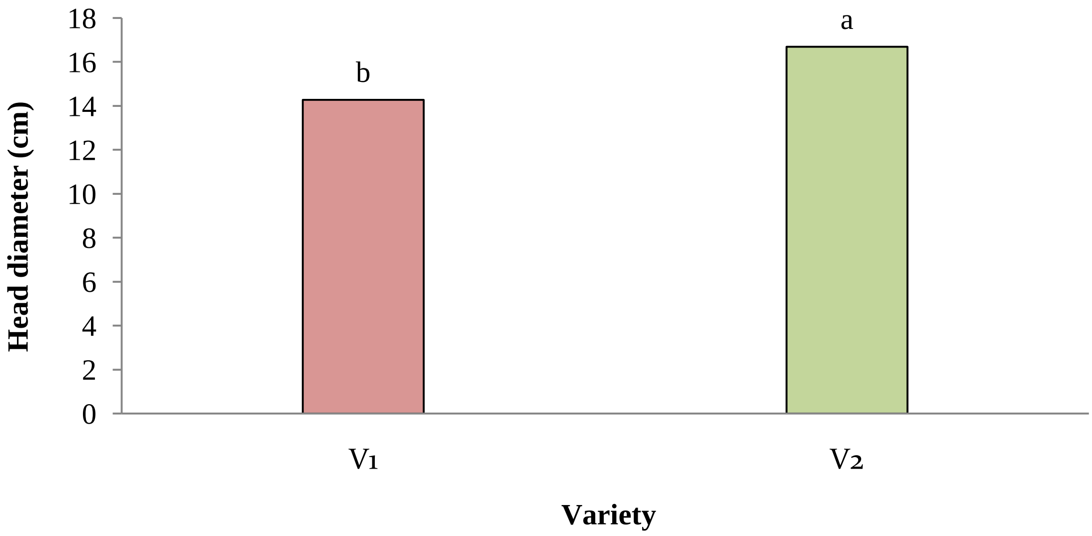
In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5% level of significance.
Here, $V_1$= BARI Surjumukhi-2, $V_2$ = Mayabi Hybrid, Here, $M_0$= Control (Without mepiquat chloride), $M_1$= 12.5 ml ha$^{-1}$ mepiquat chloride, $M_2$= 25.0 ml ha$^{-1}$ mepiquat chloride, $M_3$= 37.5 ml ha$^{-1}$ mepiquat chloride and $M_4$= 50.0 ml ha$^{-1}$ mepiquat chloride

## 4.2 Yield contributing characters

### 4.2.1 Head diameter

**Effect of variety**

The head diameter of sunflower was significantly influenced by different varieties (Figure 9). Experimental result revealed that the higher head diameter (16.69 cm) was found in $V_2$ (Mayabi Hybrid) variety. Whereas the lower head diameter (14.28 cm) was found in $V_1$ (BARI Surjumukhi-2) variety. Different sunflower varieties had different head diameter was due to the genetic makeup of the variety and maximum head diameter was obtained from high yielding varieties comparable to low yielding sunflower varieties. The result obtained from the present study was similar with the findings of Nasim *et al.* (2012) who reported that hybrids have their own distinctive characteristics and yield potential. They observed significant difference for head diameter trait among sunflower hybrids. Lawal *et al*. (2011) also reported that the head diameter of sunflower varies depending on the genetic characteristics of the cultivars. The significant difference in the head diameter could be attributed to the availability of the cultivars to hold adequate moisture, which helps roots to absorb sufficient amount of nutrients for plant growth and development.

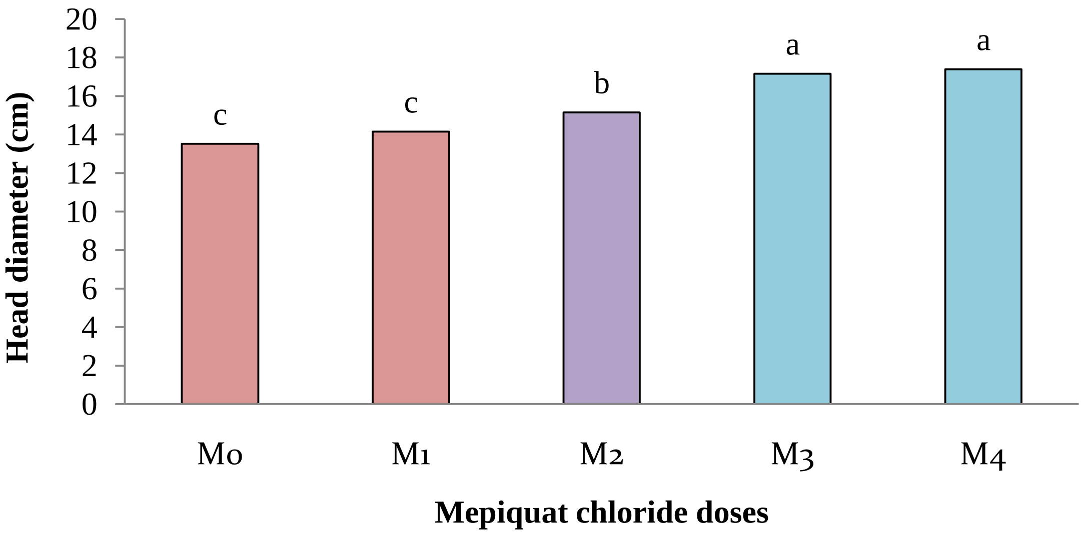



In the bar graph having dissimilar letter(s) differ significantly at 0.05 level of probability.
Here, $V_1$= BARI Surjumukhi-2 and $V_2$ = Mayabi Hybrid

**Figure 9. Effect of variety on head diameter of sunflower ($LSD_{(0.05)}$= 1.49)**

**Effect of mepiquat chloride**

The different doses of mepiquat chloride application had a significant effect on the head diameter of sunflower (Figure 10). According to the experimental results, the highest head diameter (17.40 cm) was observed in the $M_4$ (Mepiquat chloride application @ 50.0 ml $ha^{-1}$) treatment which was statistically similar with $M_3$ (17.17 cm) treatment. However, the $M_0$ (Control) treatment had the lowest head diameter (13.53 cm) which was similar with $M_1$ (14.16 cm) treatment. The growth retardants are capable of redistribution of dry matter in the plant there by bringing about improvement in yield contributing characteristics and yield. The result obtained from the present study was similar with the findings of Polat *et al*. (2017) who reported that in comparison with the control treatment, the MC (Mepiquat Chloride) application of @ 60 g a.i. $ha^{-1}$ decreased plant height by 5.38 % and increased head diameter 3.78 %. Liu *et al.* (2016) also reported that application of plant growth regulators such as mepiquat chloride (400 mg $L^{-1}$), chlormequat chloride (800 mg $L^{-1}$) and paclobutrazol (75 mg $L^{-1}$) have improved the head diameter of sunflower.




In the bar graph having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability.
Here, $M_0$= Control (Without mepiquat chloride), $M_1$= 12.5 ml $ha^{-1}$ mepiquat chloride, $M_2$= 25.0 ml $ha^{-1}$ mepiquat chloride, $M_3$= 37.5 ml $ha^{-1}$ mepiquat chloride and $M_4$= 50.0 ml $ha^{-1}$ mepiquat chloride

**Figure 10. Effect of mepiquat chloride on head diameter of sunflower ($LSD_{(0.05)}$= 0.77)**

**Interaction effect of variety and mepiquat chloride**

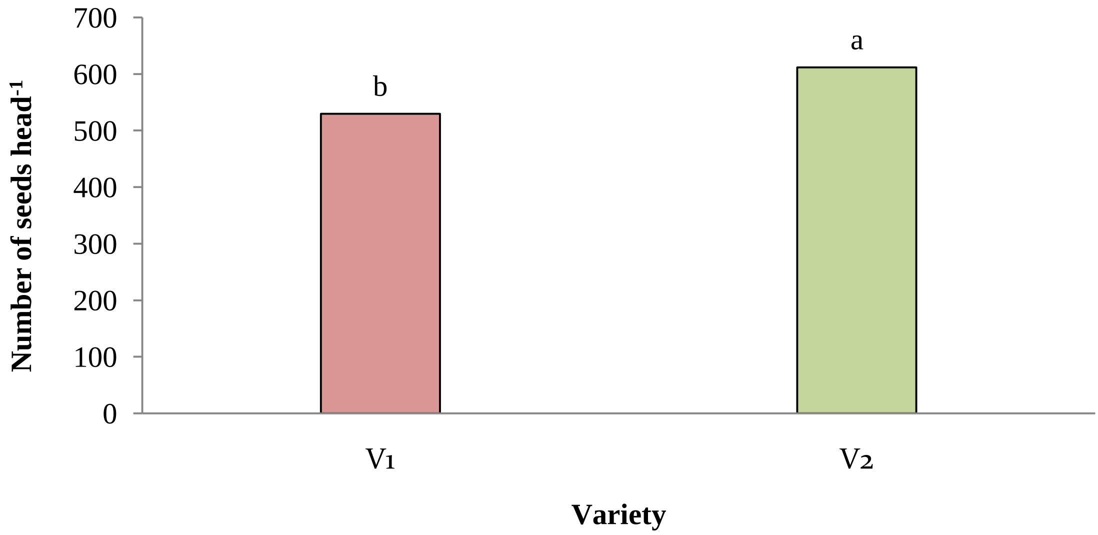
Sunflower head diameter was significantly influenced by the interaction effect of variety and mepiquat chloride doses (Table 5). Experimental result revealed that the highest head diameter (18.78 cm) was observed in $V_2M_4$ interaction treatment which was statistically similar with $V_2M_3$ (18.60 cm) interaction treatment. While the lowest head diameter (12.55 cm) was observed in $V_1M_0$ interaction treatment which was statistically similar with $V_1M_1$ (13.04 cm) interaction treatment.

### 4.2.2 Number of seeds head$^{-1}$

**Effect of variety**

The number of seeds head$^{-1}$of sunflower varied significantly depending on the variety (Figure 11).The experimental findings revealed that the $V_2$ (Mayabi Hybrid) variety had the higher number of seeds head$^{-1}$ (611.93). On the other hand the $V_1$ (BARI Surjumukhi-2) variety had the lower highest number of seeds head$^{-1}$ (529.61).The differences of number of seeds head$^{-1}$ was due to the genetic makeup of the varieties.

Abd *et al*. (2019) reported that different genotypes were significantly different in growth, yield and quality characters. Similar result observed by Hossain *et al*. (2018) who reported that, variations in terms of number of seeds head$^{-1}$ among all the varieties due to reason of difference in the genetic makeup of the variety, which is primarily influenced by heredity.

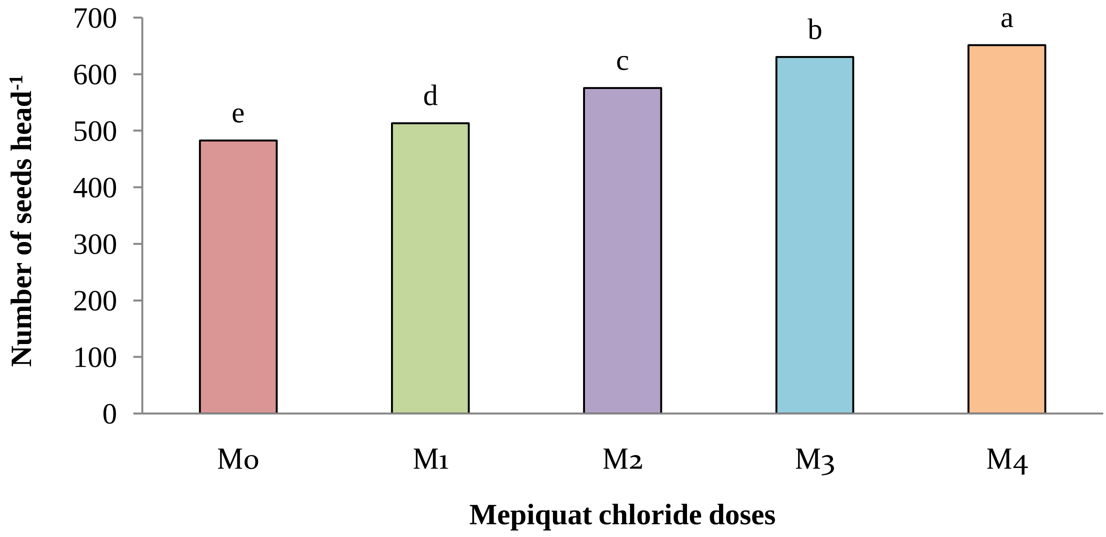



In the bar graph having similar dissimilar letter(s) differ significantly at 0.05 level of probability.
Here, $V_1$= BARI Surjumukhi-2 and $V_2$ = Mayabi Hybrid

**Figure 11. Effect of variety on number of seeds head$^{-1}$of sunflower (LSD$_{(0.05)}$= 9.93)**

**Effect of mepiquat chloride**

The number of seeds head$^{-1}$ of the sunflower was significantly affected by the various mepiquat chloride application doses (Figure 12). The results showed that the $M_4$ treatment (Mepiquat chloride application @ 50.0 ml ha$^{-1}$) had the highest number of seeds head$^{-1}$ (651.41). While the $M_0$ (Control) treatment had the lowest seeds head$^{-1}$ (482.92). It can be informed from the result that the number of seeds head$^{-1}$ of the sunflower varied with increased the application of growth retardants. This might be due to an inhibition of vegetative growth and thus making availability of food reserves for developing seeds which was evident from significantly increased number of seeds head$^{-1}$. The result obtained from the present study was similar with the findings of Jaidka *et al*. (2018) who reported that application of mepiquat chloride chloride significantly increased total dry matter accumulation plant$^{-1}$, seeds pod$^{-1}$ and seed yield of sunflower over control.




In the bar graph having dissimilar letter(s) differ significantly at 0.05 level of probability.
Here, $M_0$= Control (Without mepiquat chloride), $M_1$= 12.5 ml ha$^{-1}$mepiquat chloride, $M_2$= 25.0 ml ha$^{-1}$mepiquat chloride, $M_3$= 37.5 ml ha$^{-1}$ and$M_4$= 50.0 ml ha$^{-1}$mepiquat chloride

**Figure 12. Effect of mepiquat chloride on number of seeds head$^{-1}$of sunflower (LSD$_{(0.05)}$= 17.30)**

**Interaction effect of variety and mepiquat chloride**

Different varieties along with mepiquat chloride application had shown significant effect on the number of seeds head$^{-1}$ of sunflower (Table 5). The experimental results showed that the $V_2M_4$ interaction treatment had the highest number of seeds head$^{-1}$ (699.67). While the $V_1M_0$ interaction treatment showed the lowest number of seeds head$^{-1}$ (439.17).

**4.2.3 1000-seed weight**

**Effect of variety**

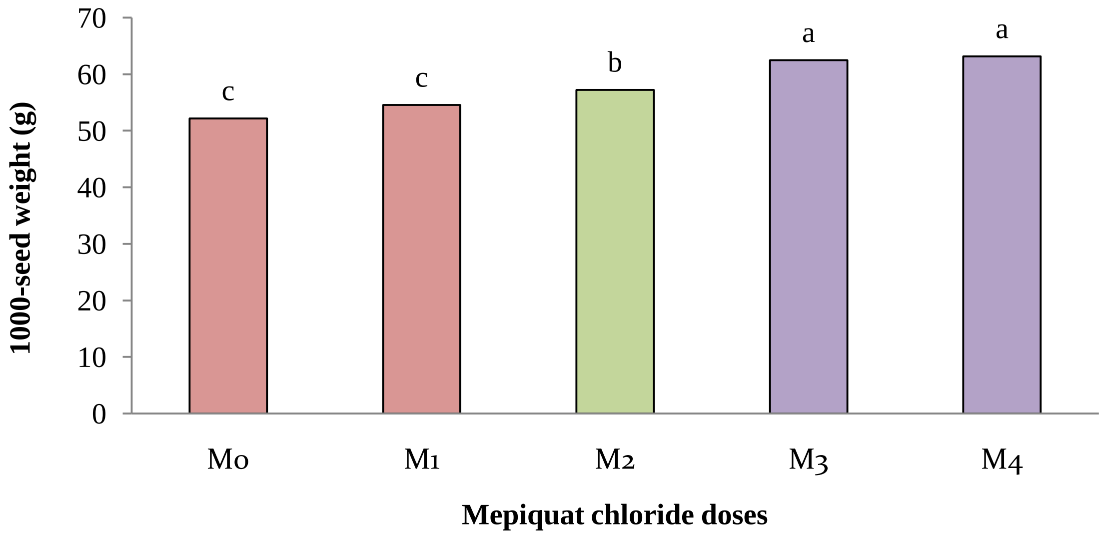
The 1000-seed weight of sunflower was significantly affected by different varieties (Figure 13). The results of the experiment showed that the $V_1$ (BARI Surjumukhi-2) variety had higher 1000-seed weight of sunflower (60.91 g). While the $V_2$ (Mayabi Hybrid) variety, had the lower 1000-seed weight of sunflower (54.98 g). The differences in 1000-seed weight among the various sunflower varieties could be attributed to the traits of the sunflower varieties and their genetic makeup. Similar result observed by AL-Abody *et al*. (2021) who reported that among different varieties the Aqmar variety provided the highest mean 1000-seed weight, seed yield, and percentage of oil. Bakht *et al.* (2006) also reported significant differences in yield and yield components of various hybrids.


In the bar graph having dissimilar letter(s) differ significantly at 0.05 level of probability.
Here, $V_1$= BARI Surjumukhi-2 and $V_2$ = Mayabi Hybrid

**Figure 13. Effect of variety on 1000-seed weight of sunflower ($LSD_{(0.05)}$= 5.51)**

**Effect of mepiquat chloride**

The different doses of mepiquat chloride application had shown significant effect on the 1000-seed weight of sunflower (Figure 14). The finding revealed that the $M_4$ treatment (Mepiquat chloride application @ 50.0 ml $ha^{-1}$) had the highest 1000-seed weight of sunflower (63.18 g) which was statistically similar to the $M_3$ (62.49 g) treatment. While the $M_0$ (Control) treatment, which was closer to the $M_1$ (54.59 g) treatment, had the lowest 1000-seed weight (52.21 g). Mepiquat chloride application promoted better translocation of photosynthates by shortening the plant size. The efficiency of translocation depends on the distance between the source and sink and it is inversely related i.e. shorter the distance, better will be the translocation and vice versa thus various doses of mepiquat chloride greatly influence on 1000-seed weight of sunflower. Hanchinamath (2005) reported that in cluster bean with the application of mepiquat chloride (1000 ppm) increased 1000-seed weight.




In the bar graph having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability.
Here, $M_0$= Control (Without mepiquat chloride), $M_1$= 12.5 ml $ha^{-1}$ mepiquat chloride, $M_2$= 25.0 ml $ha^{-1}$ mepiquat chloride, $M_3$= 37.5 ml $ha^{-1}$ mepiquat chloride and $M_4$= 50.0 ml $ha^{-1}$ mepiquat chloride

**Figure 14. Effect of mepiquat chloride on 1000-seed weight of sunflower ($LSD_{(0.05)}$= 2.63)**

## Interaction effect of variety and mepiquat chloride

The 1000-seed weight of sunflower varied significantly depending on the different interactions of variety and mepiquat chloride (Table 5). According to the experimental findings, the highest 1000-seed weight (66.02 g) was found in $V_1M_4$ interaction treatment which was statistically similar with the $V_1M_3$ (65.11 g) interaction treatment. While the lowest 1000-seed weight was indicated by the $V_2M_0$ interaction treatment (49.19 g) which was statistically similar with the $V_2M_1$ (51.33 g) interaction treatment.

**Table 5.Interaction effect of variety and mepiquat chloride on head diameter, number of seeds head$^{-1}$ and 1000-seed weight of sunflower**

| Treatment combinations | Head diameter (cm) | Seeds head$^{-1}$ (no.) | 1000-seed weight (g) |
|---|---|---|---|
| $V_1M_0$ | 12.55 f | 439.17 g | 55.23 c |
| $V_1M_1$ | 13.04 ef | 472.00 f | 57.85 bc |
| $V_1M_2$ | 14.05 de | 535.67 de | 60.33 b |
| $V_1M_3$ | 15.73 bc | 598.08 c | 65.11 a |
| $V_1 M_4$ | 16.02 bc | 603.15 c | 66.02 a |
| $V_2M_0$ | 14.51 c-e | 526.67 e | 49.19 e |
| $V_2M_1$ | 15.28 b-d | 555.00 d | 51.33 de |
| $V_2M_2$ | 16.27 b | 615.67 c | 54.17 cd |
| $V_2 M_3$ | 18.60 a | 662.66 b | 59.86 b |
| $V_2M_4$ | 18.78 a | 699.67 a | 60.33 b |
| **$LSD_{(0.05)}$** | **1.67** | **23.53** | **3.72** |
| **CV (%)** | **4.08** | **5.48** | **5.72** |

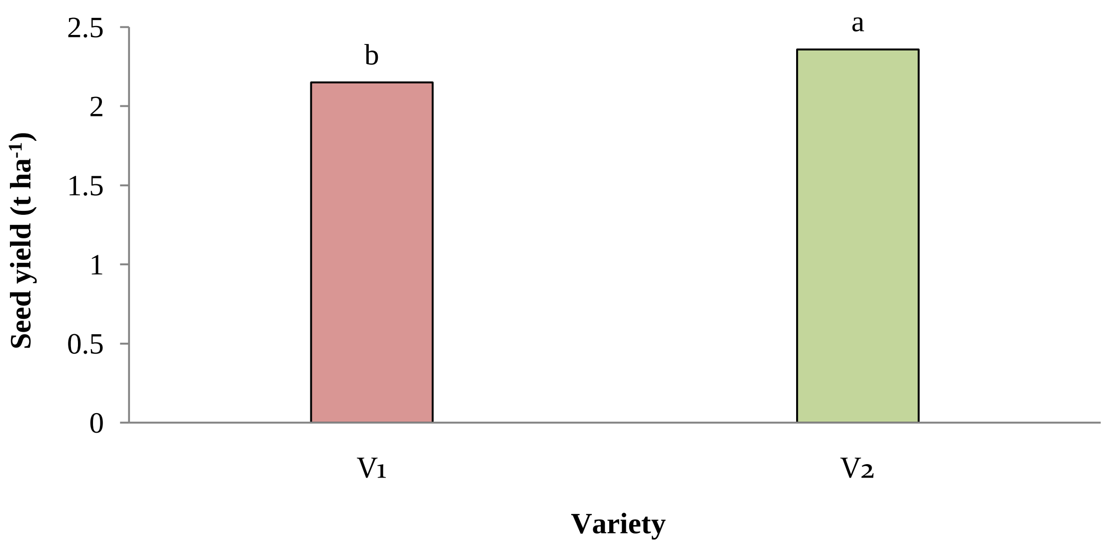
In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5% level of significance.
Here, $V_1$= BARI Surjumukhi-2, $V_2$ = Mayabi Hybrid, Here, $M_0$= Control (Without mepiquat chloride), $M_1$= 12.5 ml ha$^{-1}$ mepiquat chloride, $M_2$= 25.0 ml ha$^{-1}$ mepiquat chloride, $M_3$= 37.5 ml ha$^{-1}$ mepiquat chloride and $M_4$= 50.0 ml ha$^{-1}$ mepiquat chloride

## 4.3 Yield characters

### 4.3.1 Seed yield

#### Effect of variety

Sunflower seed yield was significantly influenced by different varieties (Figure 15). In this experiment result revealed that the $V_2$ (Mayabi Hybrid) variety recorded the higher seed yield of sunflower (2.36 t ha$^{-1}$). While $V_1$ (BARI Surjumukhi-2) variety had the lower seed yield (2.15 t ha$^{-1}$). Different sunflower varieties had different genetic makeup which affects the growth and yield among varieties. The result obtained from the present study was similar with the findings of Hussain *et al.* (2016) who reported that the cultivars showed wide differences in their agronomic characteristics and seed yield, depending on their genotypes and environmental conditions. Bakht *et al.* (2006) also reported that sunflower production is greatly affected by choice of hybrid, and there yield and yield components.

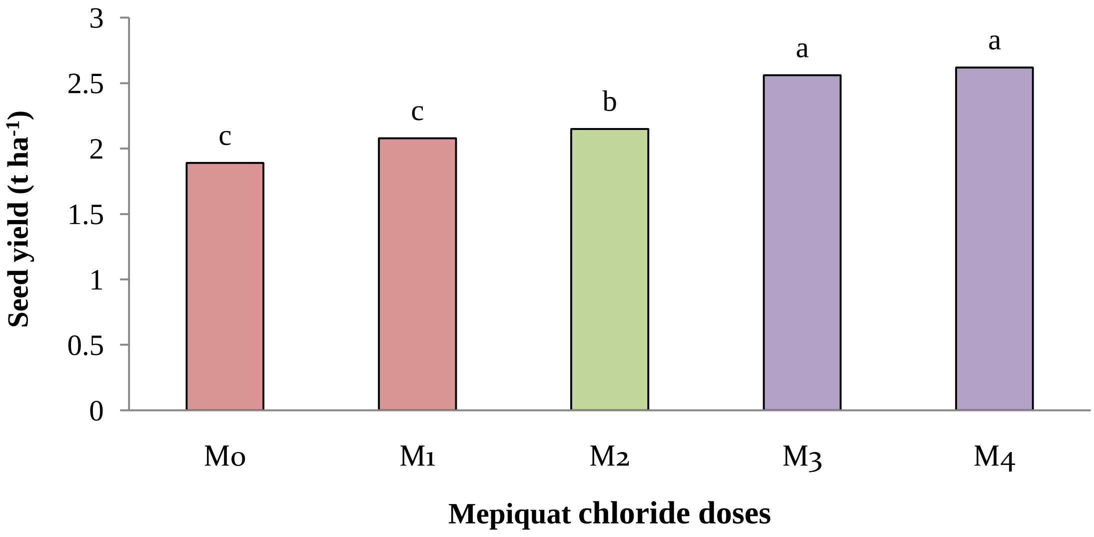



In the bar graph having dissimilar letter(s) differ significantly at 0.05 level of probability.
Here, $V_1$= BARI Surjumukhi-2 and $V_2$ = Mayabi Hybrid

**Figure 15. Effect of variety on seed yield of sunflower ($LSD_{(0.05)}$= 0.17)**

**Effect of mepiquat chloride**

The seed yield of sunflower was significantly affected by the varied doses of mepiquat chloride application (Figure 16). The results showed that the $M_4$ treatment (Mepiquat chloride application @ 50.0 ml $ha^{-1}$) had the highest seed yield of sunflower (2.62 t $ha^{-1}$), which was statistically similar to the $M_3$ treatment (2.56 t $ha^{-1}$). The lowest seed yield of sunflower (1.89 t $ha^{-1}$) was found in the $M_0$ (Control) treatment. The seed yield depends on the accumulation and partitioning of photo assimilates in reproductive parts of the plant. Higher seed yield might be due attributed to corresponding increase in head weight, total number of seeds, number of filled seeds, seed filling per cent, and 1000-seed weight. Amoanimaa-Dede *et al.* (2022) reported that plant growth regulators (PGRS) are known to improve physiological efficiency including photosynthetic ability of plants and offer significant role in soybean realizing higher crop yields. Ali *et al*. (2012) reported that foliar spraying with mepiquat chloride significantly increased yield of cotton as compared with untreated treatment.




In the bar graph having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability.
Here, $M_0$= Control (Without mepiquat chloride), $M_1$= 12.5 ml $ha^{-1}$ mepiquat chloride, $M_2$= 25.0 ml $ha^{-1}$ mepiquat chloride, $M_3$= 37.5 ml $ha^{-1}$ mepiquat chloride and$M_4$= 50.0 ml $ha^{-1}$ mepiquat chloride

**Figure 16. Effect of mepiquat chloride on seed yield of sunflower ($LSD_{(0.05)}$= 0.11)**

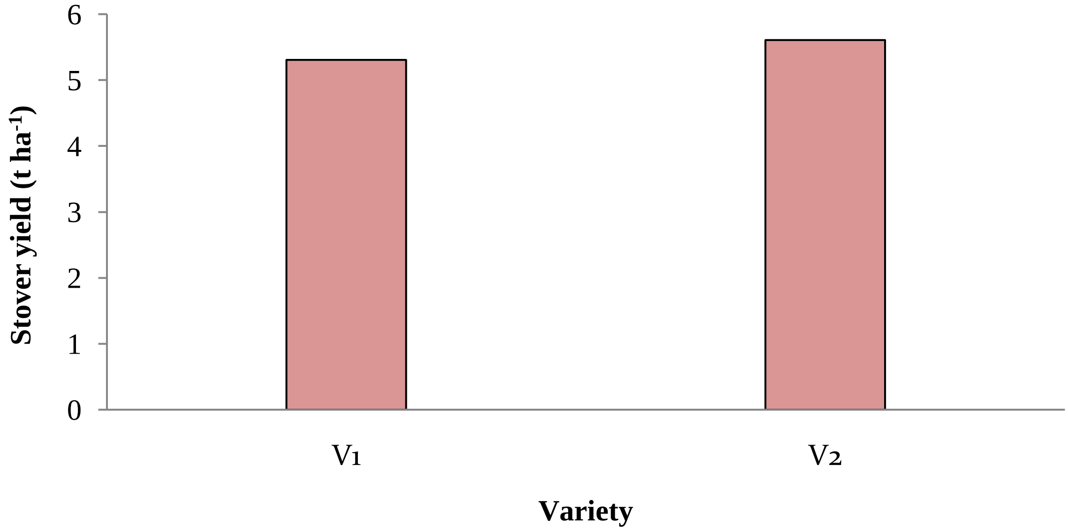
### Interaction effect of variety and mepiquat chloride

Depending on the interaction of variety and mepiquat chloride application, sunflower seed yield varied significantly (Table 6). According to the experimental results, the $V_2M_4$ interaction treatment (2.74 t $ha^{-1}$), which was statistically similar to the $V_2M_3$ (2.72 t $ha^{-1}$) interaction treatment recorded the highest seed yield. While the $V_1M_0$ interaction treatment indicated the lowest seed yield seed (1.75 t $ha^{-1}$).

### 4.3.2 Stover yield

### Effect of variety

The stover yield was not significantly influenced by different sunflower varieties (Figure 17). The results indicated that the $V_2$ variety had the numerically higher stover yield (5.61 t $ha^{-1}$) while $V_1$variety had the lower stover yield (5.31 t $ha^{-1}$).

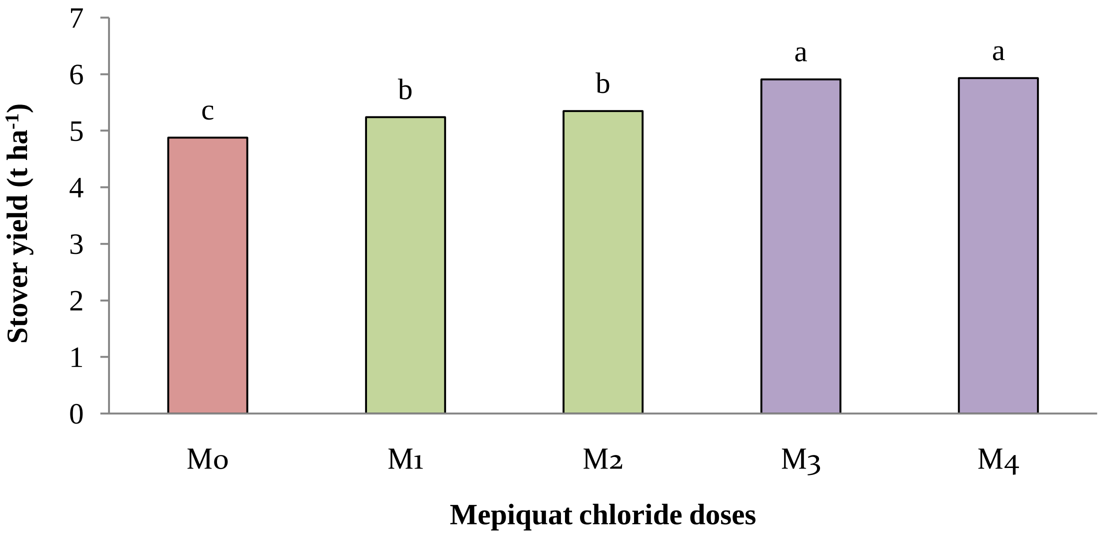



Here, $V_1$= BARI Surjumukhi-2 and $V_2$ = Mayabi Hybrid

**Figure 17. Effect of variety on stover yield of sunflower (LSD$_{(0.05)}$= NS)**

**Effect of mepiquat chloride**

The different doses of mepiquat chloride application had shown significant effect on the stover yield of sunflower (Figure 18). The experiment's findings showed that the $M_4$ (Mepiquat chloride application @ 50.0 ml ha$^{-1}$) treatment recorded the highest stover yield (5.93 t ha$^{-1}$) which was statistically similar with $M_3$ (5.91 t ha$^{-1}$) treatment. The lowest stover yield was achieved with the $M_0$ treatment (4.88 t ha$^{-1}$). The increased stover yield could be attributed to the higher dry matter production with mepiquat chloride application and it’s accumulation in reproductive parts. Sandhu *et al*. (2015) reported that dry matter accumulation was significantly higher with the mepiquat chloride @ 250 ppm application which influences growth and yield of the plant.




In the bar graph having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability.
Here, $M_0$= Control (Without mepiquat chloride), $M_1$= 12.5 ml ha$^{-1}$ mepiquat chloride, $M_2$= 25.0 ml ha$^{-1}$ mepiquat chloride, $M_3$= 37.5 ml ha$^{-1}$ mepiquat chloride and $M_4$= 50.0 ml ha$^{-1}$ mepiquat chloride

**Figure 18. Effect of mepiquat chloride on stover yield of sunflower ($LSD_{(0.05)}$=0.17)**

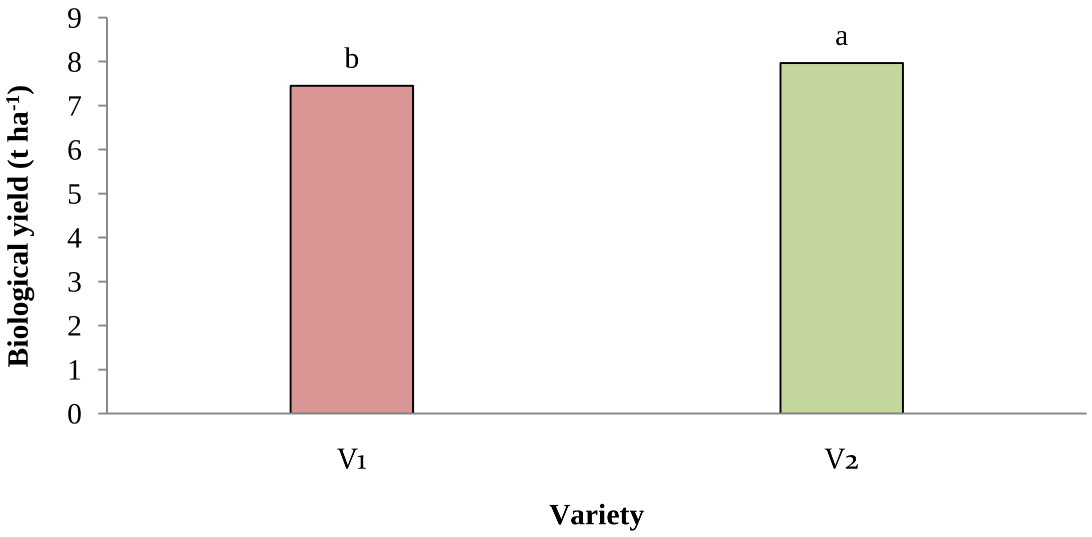
### Interaction effect of variety and mepiquat chloride

The stover yield of sunflower varied significantly according on the interaction effect of cultivar and mepiquat chloride application (Table 6). The highest stover yield (6.10 t ha$^{-1}$) was found in $V_2M_4$ interaction treatment which was statistically similar to the $V_2M_3$ (6.09 t ha$^{-1}$) interaction treatment. Whereas the lowest stover yield (4.68 t ha$^{-1}$) was revealed by the $V_1M_0$ interaction treatment.

### 4.3.3 Biological yield

### Effect of variety

Different varieties had significant effect on the biological yield of sunflower (Figure 19). The result revealed that the $V_2$ (Mayabi Hybrid) variety recorded the highest biological yield (7.97 t ha$^{-1}$), while the least biological yield was found in $V_1$ (BARI Surjumukhi-2) variety (7.45 t ha$^{-1}$). The variation of biological yield by different varieties might be due to the contribution of cumulative favourable effects of the crop characteristics viz., seed and stover yield of the crop. Demir (2019) also found similar result which supported the present finding and reported that variation in biological yield differ among sunflower cultivars.

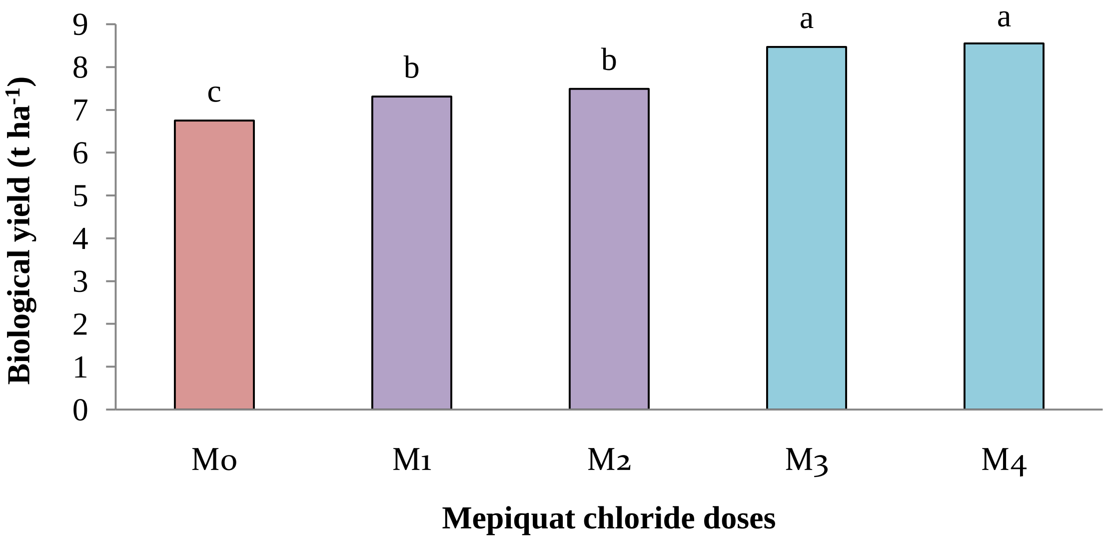



In the bar graph having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability.
Here, $V_1$= BARI Surjumukhi-2 and $V_2$ = Mayabi Hybrid

**Figure 19. Effect of variety on biological yield of sunflower ($LSD_{(0.05)}$= 0.48)**

### Effect of mepiquat chloride

The biological yield of sunflower was significantly affected by the various doses of mepiquat chloride application (Figure 20). The results of the experiment demonstrated that the highest biological yield (8.55 t $ha^{-1}$) was obtained by the $M_4$ (Mepiquat chloride application @ 50.0 ml $ha^{-1}$) treatment, which was statistically similar with the $M_3$ (8.47 t $ha^{-1}$) treatment. While the $M_0$ (Control) treatment resulted in the lowest biological yield (6.75 t $ha^{-1}$).The substantial increase in biological yield due to application of higher levels of mepiquat chloride might be due to favourable effect of mepiquat chloride on growth attributes like increased dry matter accumulation per plant and its subsequent translocation towards sink. Paikra *et al.* (2017) also found similar result which supported the present finding and reported that the application of Cyclanilide 22 + Mepiquat Chloride 88 SC @ 100 ml $ha^{-1}$ recorded the significantly highest biological yield compared to other treatments.




In the bar graph having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability.
Here, $M_0$= Control (Without mepiquat chloride), $M_1$= 12.5 ml ha$^{-1}$mepiquat chloride, $M_2$= 25.0 ml ha$^{-1}$ mepiquat chloride, $M_3$= 37.5 ml ha$^{-1}$ mepiquat chloride and $M_4$= 50.0 ml ha$^{-1}$ mepiquat chloride

**Figure 20. Effect of mepiquat chloride on biological yield of sunflower (LSD$_{(0.05)}$= 0.38)**

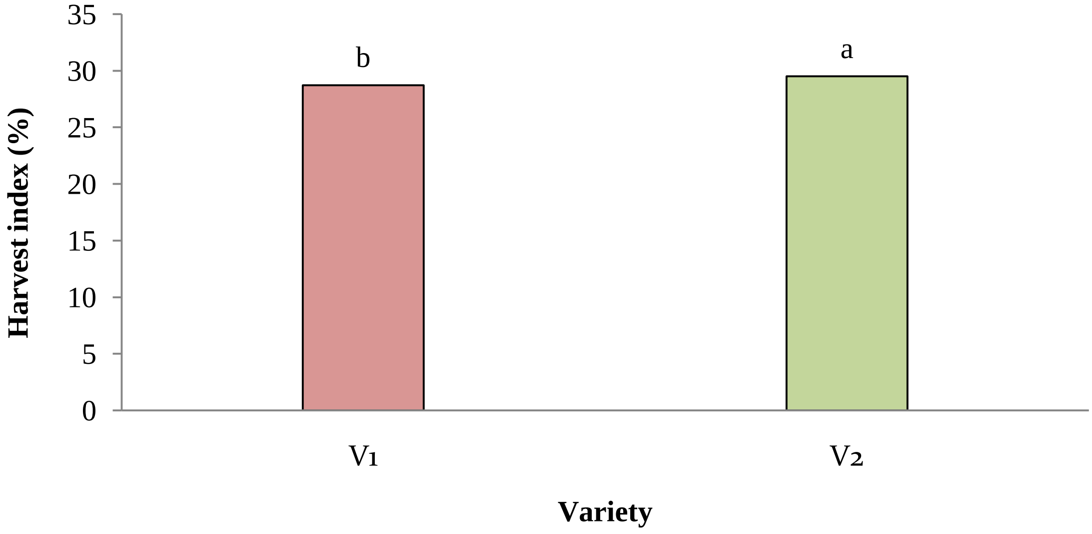
### Interaction effect of variety and mepiquat chloride

Interaction of different varieties with mepiquat chloride doses had shown significant effect on the biological yield of sunflower (Table 6). The $V_2M_4$ interaction treatment had the highest biological yield (8.84 t ha$^{-1}$), which was statistically similar to the $V_2M_3$ (8.81 t ha$^{-1}$) and $V_1M_4$ (8.25 t ha$^{-1}$) interaction treatment. Whereas the $V_1M_0$ interaction treatment recorded the lowest biological yield (6.43 t ha$^{-1}$) which was statistically similar to the $V_2M_0$ (7.07 t ha$^{-1}$) interaction treatment.

## 4.3.4 Harvest index

### Effect of variety

Sunflower varieties significantly influenced on harvest index of sunflower (Figure 21). The results of the investigation showed that the $V_2$ (Mayabi Hybrid) variety recorded the higher harvest index (29.52 %). While $V_1$ (BARI Surjumukhi-2) variety had the lower harvest index (28.74 %). Due to genetic diversity, the harvest index varied greatly between varieties. Uddin *et al.* (2011) reported that the harvest index differed significantly among the varieties due to its genetic variability.

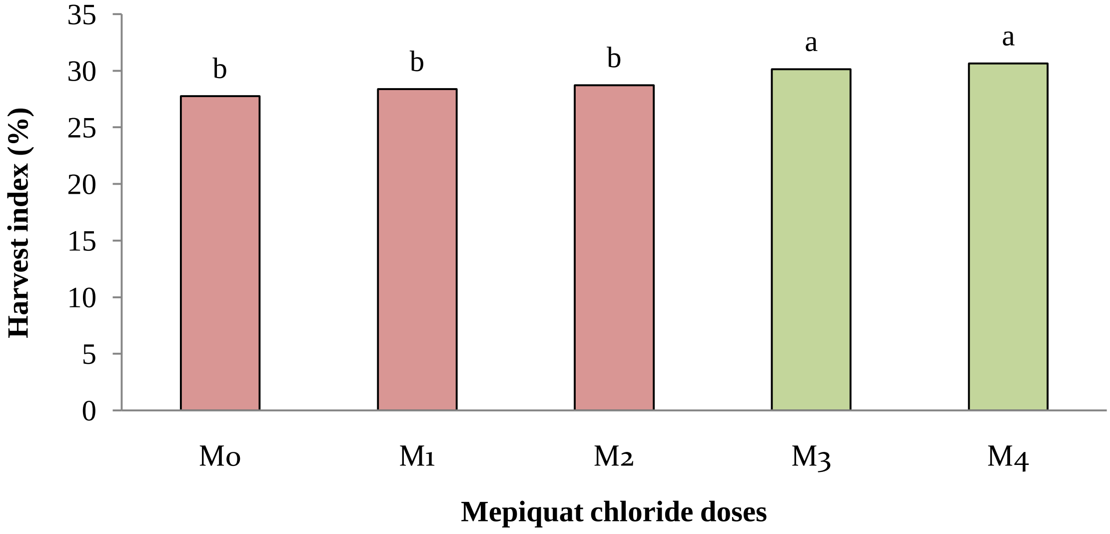



In the bar graph having dissimilar letter(s) differ significantly at 0.05 level of probability.
Here, $V_1$= BARI Surjumukhi-2 and $V_2$ = Mayabi Hybrid

**Figure 21. Effect of variety on harvest index of sunflower (LSD$_{(0.05)}$= 0.50)**

**Effect of mepiquat chloride**

The different doses of mepiquat chloride application had significant effect on the harvest index of sunflower (Figure 22). The experiment's findings showed that the $M_4$ (Mepiquat chloride application @ 50.0 ml ha$^{-1}$) treatment had the highest harvest index (30.65 %), which was statistically similar to the $M_3$ (30.15 %) treatment. The $M_0$ (Control) treatment recorded the lowest harvest index (27.76 %) which was statistically similar to the $M_1$ (28.38 %) and $M_2$ (28.72 %) treatments. The higher harvest index could be attributed to the higher dry matter production and it's accumulation in reproductive parts, higher number of filled seeds, head diameter, least number of unfilled seeds, high seed filling percentage, 1000-seed weight and seed yield plant$^{-1}$. Amoanimaa-Dede *et al.* (2022) reported that harvest index was influenced by the foliar application of plant growth retardants. Tan and Temel (2005) also reported that all the levels of mepiquat chloride resulted in significantly higher seed weight per plant and harvest index in comparison with control.




In the bar graph having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability.
Here, $M_0$= Control (Without mepiquat chloride), $M_1$= 12.5 ml $ha^{-1}$ mepiquat chloride, $M_2$= 25.0 ml $ha^{-1}$ mepiquat chloride, $M_3$= 37.5 ml $ha^{-1}$ mepiquat chloride and $M_4$= 50.0 ml $ha^{-1}$ mepiquat chloride

**Figure 22. Effect of mepiquat chloride on harvest index of sunflower (LSD$_{(0.05)}$= 0.1.28)**

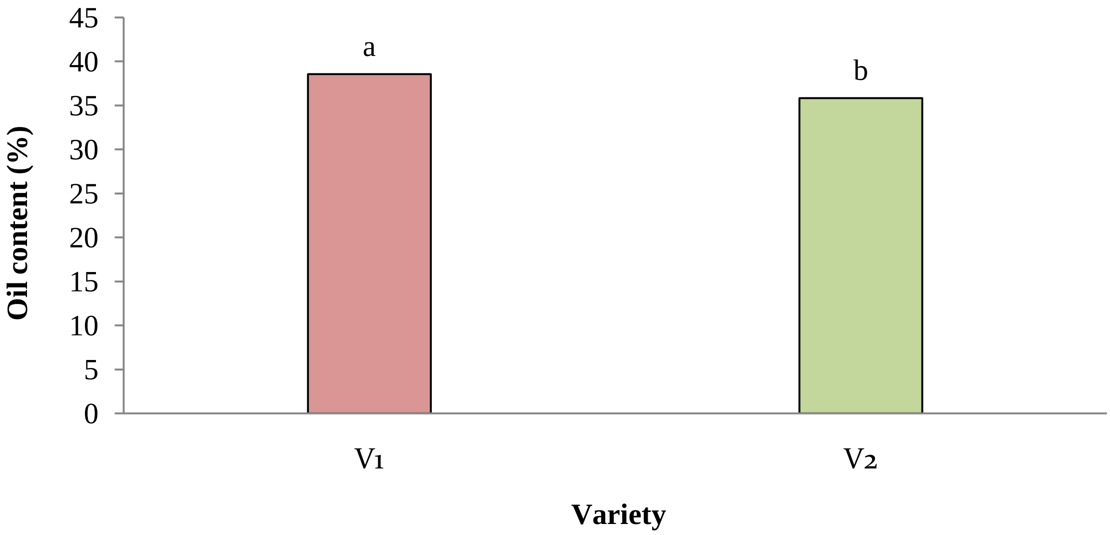
**Interaction effect of variety and mepiquat chloride**

The harvest index of sunflower was significantly influenced by different variety and mepiquat chloride application (Table 6). The maximum harvest index (31.00 %) was recorded by the $V_2M_4$ interaction treatment, which was statistically similar to the $V_2M_3$ (30.87 %) and $V_1M_4$ (30.30 %) interaction treatments. The lowest harvest index (27.22 %) was recorded by the $V_1M_0$ interaction treatment, which was statistically similar to the $V_1M_1$ (28.25 %), $V_1M_2$ (28.49 %), $V_2M_0$ (28.29 %) and $V_2M_1$ (28.51 %) interaction treatments.

### 4.3.5 Oil content

**Effect of variety**

Sunflower varieties had significant effect on oil content of sunflower (Figure 23). The results of the investigation showed that the $V_1$ (BARI Surjumukhi-2) variety recorded the higher oil content (38.56 %). While $V_2$ (Mayabi Hybrid) variety had the lower oil content (35.84 %). Similar result observed by AL-Abody *et al*. (2021) who reported that among different varieties the Aqmar variety provided the highest mean 1000-seed weight, seed yield, and percentage of oil. Wable (2016) also reported that the oil content varied among varieties and the oil content (34.70 %) and oil yield (359.7 kg $ha^{-1}$) were higher in hybrid KBSH-44 (Hs) as compared to rest of the hybrids.

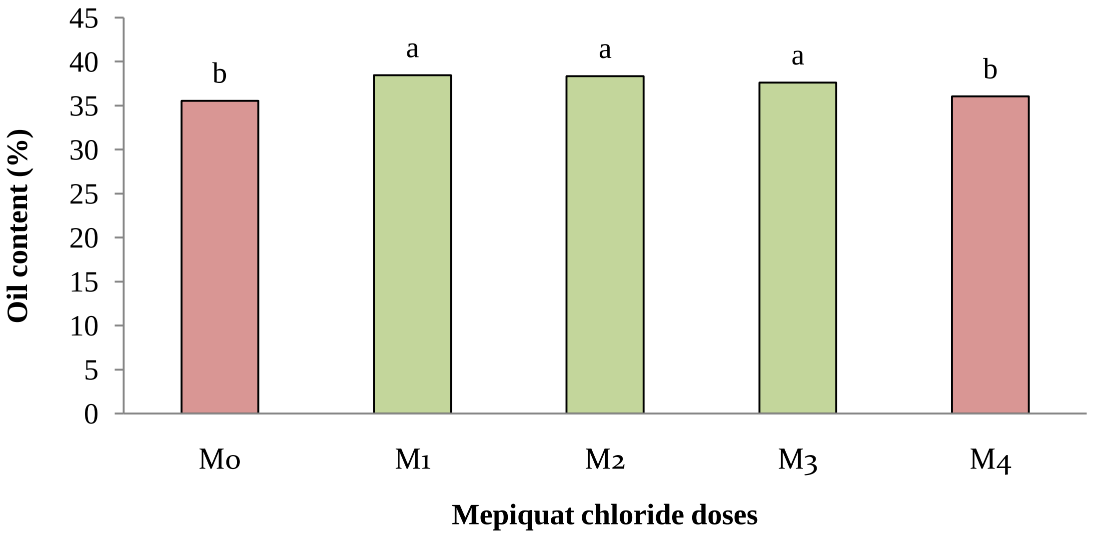



In the bar graph having dissimilar letter(s) differ significantly at 0.05 level of probability.
Here, $V_1$= BARI Surjumukhi-2 and $V_2$ = Mayabi Hybrid

**Figure 23. Effect of variety on oil content of sunflower ($LSD_{(0.05)}$= 1.25)**

**Effect of mepiquat chloride**

The oil content of sunflower was significantly affected by the various doses of mepiquat chloride application (Figure 24). The results revealed that the $M_1$ (Mepiquat chloride application @ 12.5 ml $ha^{-1}$) treatment had the highest oil content (30.65%), which was statistically similar to the $M_2$ (38.36 %) and $M_3$ (37.62 %) treatment. While the $M_0$ (Control) treatment had the lowest oil content (35.55 %) which was statistically similar to $M_4$ (36.04 %) treatment. Kim *et al.* (2011) reported that the application of Mepiquat Chloride (MC) significantly increased seed oil yield (730 kg $ha^{-1}$ by 27.0%) compared to the control. Seed and oil yield, and unsaturated fatty acids (oleic acid, linoleic acid and linolenic acid) were increased by foliar application of MC. Similar result also found by Ghourab *et al*. (2000) who the application of mepiquat chloride showed significant increase in phenol contents in leaves and oil content in seeds comparable to control treatment.




In the bar graph having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability.
Here, $M_0$= Control (Without mepiquat chloride), $M_1$= 12.5 ml $ha^{-1}$ mepiquat chloride, $M_2$= 25.0 ml $ha^{-1}$ mepiquat chloride, $M_3$= 37.5 ml $ha^{-1}$ mepiquat chloride and $M_4$= 50.0 ml $ha^{-1}$ mepiquat chloride

**Figure 24. Effect of mepiquat chloride on harvest index of sunflower ($LSD_{(0.05)}$= 1.50)**

## Interaction effect of variety and mepiquat chloride

Sunflower varieties and mepiquat chloride application had shown significant effect on the oil content of the crop (Table 6). The $V_1M_1$ interaction treatment had the highest oil content (42.02 %), which was statistically similar to the $V_1M_2$ (41.05 %) interaction treatment. Whereas the $V_2M_0$ interaction treatment, which was statistically similar to the $V_2M_1$ (34.88 %), $V_2M_2$ (35.67 %) and $V_2M_0$ (35.47 %) interaction treatments, recorded the lowest oil content (27.22%).

**Table 6. Interaction effect of variety and mepiquat chloride on seed, stover, biological yield, harvest index and oil content of sunflower**

| Treatment combinations | Seed yield (t $ha^{-1}$) | Stover yield (t $ha^{-1}$) | Biological yield (t $ha^{-1}$) | Harvest index (%) | Oil content (%) |
|---|---|---|---|---|---|
| **$V_1M_0$** | 1.75 f | 4.68 e | 6.43 e | 27.22 d | 36.79 b-d |
| **$V_1M_1$** | 2.00 de | 5.08 cd | 7.08 d | 28.25 cd | 42.02 a |
| **$V_1M_2$** | 2.10 de | 5.29 cd | 7.39 d | 28.49 cd | 41.05 a |
| **$V_1M_3$** | 2.39 bc | 5.73 ab | 8.12 bc | 29.43 a-c | 37.49 bc |
| **$V_1$ $M_4$** | 2.50 b | 5.75 ab | 8.25 ab | 30.30 ab | 35.47 c-e |
| **$V_2M_0$** | 2.00 e | 5.07 d | 7.07 de | 28.29 cd | 34.30 e |
| **$V_2M_1$** | 2.15 de | 5.39 bc | 7.54 cd | 28.51 cd | 34.88 de |
| **$V_2M_2$** | 2.19 cd | 5.40 bc | 7.59 cd | 28.95 bc | 35.67 b-e |
| **$V_2$ $M_3$** | 2.72 a | 6.09 a | 8.81 a | 30.87 a | 37.75 b |
| **$V_2M_4$** | 2.74 a | 6.10 a | 8.84 a | 31.00 a | 36.61 b-d |
| **$LSD_{(0.05)}$** | **0.21** | **0.38** | **0.65** | **1.67** | **2.19** |
| **CV (%)** | **6.09** | **5.53** | **4.10** | **5.60** | **6.30** |

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5% level of significance.
Here, $V_1$= BARI Surjumukhi-2, $V_2$ = Mayabi Hybrid, Here, $M_0$= Control (Without mepiquat chloride), $M_1$= 12.5 ml $ha^{-1}$ mepiquat chloride, $M_2$= 25.0 ml $ha^{-1}$ mepiquat chloride, $M_3$= 37.5 ml $ha^{-1}$ mepiquat chloride and $M_4$= 50.0 ml $ha^{-1}$ mepiquat chloride

# CHAPTER V

# SUMMARY AND CONCLUSION

A field experiment was conducted at research field of Sher-e-Bangla Agricultural University, Dhaka during the period from November 2020 to March 2021 in Rabi season to study the performance of mepiquat chloride on growth, yield and oil content of sunflower. The experiment consisted of two factors, and followed split-plot design with three replications. Factor A: Sunflower varieties- (2) *viz:* $V_1$= BARI Surjumukhi-2, $V_2$ = Mayabi Hybrid (China variety) and Factor B: Mepiquat chloride application level- (5) *viz:* $M_0$= Control, $M_1$= 12.5 ml $ha^{-1}$, $M_2$= 25.0 ml $ha^{-1}$, $M_3$= 37.5 ml $ha^{-1}$ and $M_4$= 50.0 ml $ha^{-1}$. Experimental results revealed that different varieties and mepiquat chloride application significantly influenced the seed yield and yield contributing characteristics of sunflower.

In case of different varieties the higher plant height (26.43, 66.17, 113.91, 120.02 and 114.24 cm at 25, 45, 65, 85 DAS and at harvest, respectively) ,stem diameter (4.60, 9.63, 14.53 and 13.03 mm at 25, 45, 65 DAS and at harvest, respectively) ,SPAD value (50.94, 43.67, 44.89 and 43.04 at 25, 40, 55 and 70 DAS, respectively) and the higher dry weight $plant^{-1}$ (1.14, 17.84 and 38.53 g at 25, 50 and 70 DAS, respectively) were found in $V_2$ (Mayabi Hybrid) variety. While the lower plant height (24.03, 57.62, 95.51, 103.15 and 99.21 cm at 25, 45, 65, 85 and at harvest, respectively),stem diameter (4.39, 8.56, 12.35 and 11.03 mm at 25, 45, 65 DAS and at harvest, respectively), SPAD value(46.99, 39.32, 41.58 and 40.04 at 25, 40, 55 and 70 DAS, respectively) and dry weight $plant^{-1}$ (1.10, 14.40 and 33.56 g at 25, 50 and 70 DAS) were found in $V_1$ (BARI Surjumukhi-2) variety.

Plant growth parameters of sunflowers significantly influenced due to application of different dose of mepiquat chloride. The tallest plant (29.12, 74.03, 116.15, 120.96 and 117.26 cm at 25, 45, 65, 85 and at harvest, respectively) was observed in $M_0$ (Control) treatment. While The $M_4$ (Mepiquat chloride application @ 50.0 ml $ha^{-1}$) treatment had the lowest plant height (21.07, 50.14, 93.26, 100.72 and 96.29 cm at 25, 45, 65, 85 and at harvest, respectively) which was statistically similar with $M_3$ (Mepiquat chloride application @ 37.5 ml $ha^{-1}$) treatment.

The $M_4$ (Mepiquat chloride application @ 50.0 ml $ha^{-1}$) treatment had the highest stem diameter (5.08, 9.75, 14.73 and 13.20 mm at 25, 45, 65 DAS and at harvest, respectively), SPAD value (53.73, 45.38, 47.08, 44.83 at 25, 40, 55 and 70 DAS, respectively) and dry weight $plant^{-1}$ (1.44, 20.65 and 43.16 gat 25, 50 and 75 DAS, respectively). But $M_3$ (Mepiquat chloride application @ 37.5 ml $ha^{-1}$) treatment also showed statistically similar stem diameter and SPAD value with $M_4$ treatment. However, the $M_0$ (Control) treatment, was found to produce the lowest stem diameter (3.83, 8.34, 12.11 and 10.95 mm at 25, 45, 65 DAS and at harvest, respectively), SPAD value (44.88, 37.23, 38.53 and 37.61 at 25, 40, 55 and 70 DAS, respectively) and dry weight $plant^{-1}$ (0.83, 11.36 and 29.85 g at 25, 50 and 75 DAS, respectively)

In case of interactions, the tallest plant was found in $V_2M_0$ treatment combination (29.81, 78.49, 127.31, 129.83 and 124.35 cm at 25, 45, 65, 85 DAS and at harvest, respectively). While the shortest plant height was observed in $V_1M_4$ treatment combination (19.25, 48.56, 85.01, 91.60 and 88.43 cm at 25, 45, 65, 85 DAS and at harvest, respectively). However, the $V_2M_4$ treatment combination showed the maximum stem diameter (5.18, 10.37, 15.87 and 14.02 mm at 25, 45, 65 DAS and at harvest, respectively), SPAD value (55.88, 47.13, 48.93 and 46.25 at 25, 40, 55 and 70 DAS, respectively) and dry weight $plant^{-1}$ (1.42, 22.04 and 45.84 g at 25, 50 and 75 DAS, respectively) which was statistically similar with $V_2M_3$ treatment combination. While the $V_1M_0$ treatment combination had the lowest stem diameter (3.73, 7.78, 10.92 and 9.87 mm at 25, 45, 65 DAS and at harvest, respectively), SPAD value (43.33, 34.99, 37.72 and 36.12 at 25, 40, 55 and 70 DAS, respectively) and dry weight $plant^{-1}$ (0.78, 9.25 and 27.22 g at 25, 50 and 75 DAS, respectively).

In case of yield contributing characteristics and yield of sunflower, between varieties the $V_2$ (Mayabi Hybrid) variety had the higher head diameter (16.69 cm), seeds $head^{-1}$ (611.93), seed yield (2.36 t $ha^{-1}$), stover yield (5.61 t $ha^{-1}$), biological yield (7.97 t $ha^{-1}$) and harvest index (29.52 %), while the lower yield contributing characteristics and yield were found in $V_1$ (BARI Surjumukhi-2) variety.

In terms of different doses of mepiquat chloride application, the highest head diameter (17.40 cm), number of seeds $head^{-1}$ (651.41),1000-seed weight (651.41 g),seed yield (2.62 t $ha^{-1}$), stover yield (5.93 t $ha^{-1}$), biological yield (8.55 t $ha^{-1}$), harvest index (30.65 %) were found in $M_4$ (Mepiquat chloride application @ 50.0 ml $ha^{-1}$)

treatment. However the lowest yield contributing characteristics and yield of sunflower were observed in $M_0$ (control) treatment.

In case of combination, $V_2M_4$ treatment combination had the highest head diameter (18.78 cm), number of seeds head$^{-1}$ (699.67), seed yield (2.74 t ha$^{-1}$), stover yield (6.10 t ha$^{-1}$), biological yield (8.84 t ha$^{-1}$) and harvest index (31.00 %). Whereas the lowest head diameter (12.55 cm), number of seeds head$^{-1}$ (439.17), yield seed (1.75 t ha$^{-1}$), stover yield (4.68 t ha$^{-1}$), biological yield (6.43 t ha$^{-1}$) and harvest index (27.22 %) were observed by $V_1M_0$ treatment combination.

**Conclusion**

Based on the above findings, the experimental results revealed that different varieties and mepiquat chloride application significantly influenced the seed yield and yield contributing characteristics of sunflower.

However, considering all, it may be concluded that Mayabi Hybrid ($V_2$) variety and mepiquat chloride dose @ 37.5 ml ha$^{-1}$ ($M_3$) and their interaction seems promising for reducing plant height and increasing seed yield but for oil content (%), BARI Surjumukhi-2 ($V_1$), lower mepiquat chloride dose and their interaction was found best for sunflower.

**Recommendations**

Considering the results of the experiment, further studies in the following areas are suggested:

- ✓ More varieties and mepiquat chloride doses may be taken for further experiments to get more accurate result,
- ✓ More number of mepiquat chloride application time may be taken for further experiments, and
- ✓ Studies of similar nature could be carried out in different agro-ecological zones (AEZ) in different seasons of Bangladesh for the evaluation of zonal adaptability.

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**APPENDICES**

Appendix I. Map showing the experimental location under study

Appendix II. Soil characteristics of the experimental field

A. Morphological features of the experimental field

| Morphological features | Characteristics |
|---|---|
| AEZ | AEZ-28, Modhupur Tract |
| General Soil Type | Shallow Red Brown Terrace Soil |
| Land type | High land |
| Location | Sher-e-Bangla Agricultural University Agronomy research field, Dhaka |
| Soil series | Tejgaon |
| Topography | Fairly leveled |

B. The initial physical and chemical characteristics of soil of the experimental site (0-15 cm depth)

| **Physical characteristics** | |
|---|---|
| **Constituents** | **Percent** |
| Clay | 29 % |
| Sand | 26 % |
| Silt | 45 % |
| Textural class | Silty clay |
| **Chemical characteristics** | |
| **Soil characteristics** | **Value** |
| Available P (ppm) | 20.54 |
| Exchangeable K (mg/100 g soil) | 0.10 |
| Organic carbon (%) | 0.45 |
| Organic matter (%) | 0.78 |
| pH | 5.6 |
| Total nitrogen (%) | 0.03 |

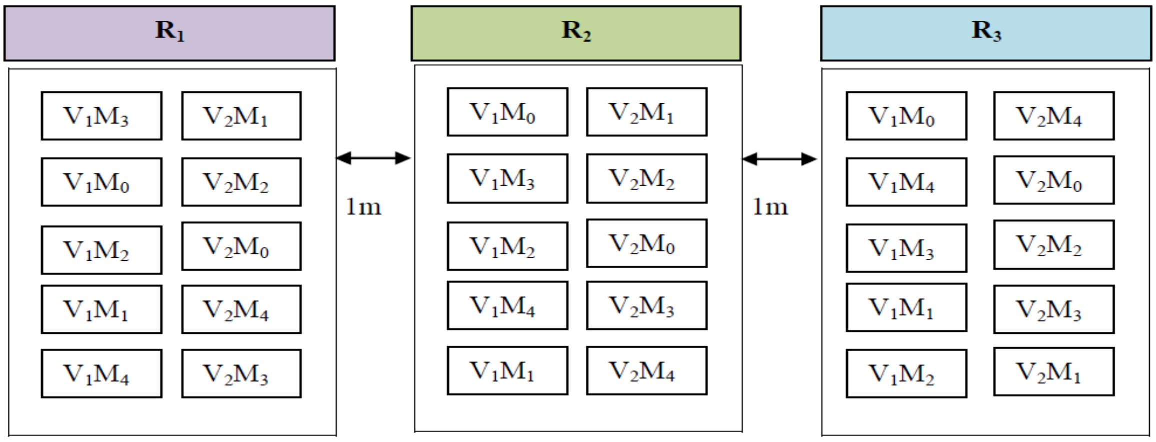
**Sourse:** Soil Resources Development Institute (SRDI), Khamarbari, Farmgate, Dhaka.

Appendix III. Monthly meteorological information during the period from November 2020 to March 2021

| Year | Month | Air temperature ($^0$C) | | Relative humidity (%) | Total rainfall (mm) |
|---|---|---|---|---|---|
| | | Maximum | Minimum | | |
| 2020 | November | 29.6 | 19.8 | 53 | 00 mm |
| | December | 28.8 | 19.1 | 47 | 00 mm |
| 2021 | January | 25.5 | 13.1 | 41 | 00 mm |
| | February | 25.9 | 14 | 34 | 7.7 mm |
| | March | 31.9 | 20.1 | 38 | 71 mm |

Source: Metrological Centre, Agargaon, Dhaka (Climate Division)


Appendix IV: Lay out of the experimental field




Here, R= Replications, $V_1$= BARI Surjumukhi-2, $V_2$ = Mayabi Hybrid, $M_0$= Control (Without mepiquat chloride), $M_1$= 12.5 ml ha$^{-1}$ mepiquat chloride, $M_2$= 25.0 ml ha$^{-1}$ mepiquat chloride, $M_3$= 37.5 ml ha$^{-1}$ mepiquat chloride and $M_4$= 50.0 ml ha$^{-1}$ mepiquat chloride

Appendix V. Analysis of variance of the data of plant height of sunflower at different DAS.

| **Sources of variation** | **DF** | Mean square of plant height at | | | | |
|---|---|---|---|---|---|---|
| | | 25 DAS | 45 DAS | 65 DAS | 85 DAS | Harvest |
| Replication (R) | 2 | 0.1000 | 3.600 | 6.40 | 1.60 | 52.90 |
| Variety (V) | 1 | 43.2000* | 548.269* | 2540.86* | 2133.97* | 1693.81* |
| Error | 2 | 0.1000 | 3.600 | 3.60 | 1.60 | 52.90 |
| Mepiquat chloride (M) | 4 | 83.3254* | 695.296* | 595.83* | 521.11* | 523.96* |
| V×M | 4 | 1.2477* | 35.974* | 20.54* | 2.43* | 1.65* |
| Error | 16 | 0.6000 | 7.600 | 27.00 | 26.60 | 37.90 |
| Total | 29 | | | | | |

* : Significant at 5% level of probability

Appendix VI. Analysis of variance of the data of stem diameter of sunflower at different DAS

| Sources of variation | DF | Mean square of stem diameter at | | | |
|---|---|---|---|---|---|
| | | 25 DAS | 45 DAS | 65 DAS | Harvest |
| Replication (R) | 2 | 0.04096 | 0.01024 | 0.9000 | 0.1000 |
| Variety (V) | 1 | 0.34347* | 8.49072* | 35.7739* | 30.0000* |
| Error | 2 | 0.03364 | 0.01024 | 0.9000 | 0.1000 |
| Mepiquat Chloride (MC) | 4 | 1.84849* | 2.28048* | 8.5648* | 6.5462* |
| V×M | 4 | 0.00020* | 0.03492* | 0.0733* | 0.0744* |
| Error | 16 | 0.01895 | 0.17274 | 0.4000 | 0.3500 |
| Total | 29 | | | | |

*: Significant at 5% level of probability

Appendix VII. Analysis of variance of the data of SPAD value of sunflower at different DAS

| Sources of variation | DF | Mean square of SPAD value at | | | |
|---|---|---|---|---|---|
| | | 25 DAS | 40 DAS | 55 DAS | 70 DAS |
| Replication (R) | 2 | 1.600 | 0.900 | 2.5000 | 3.4810 |
| Variety (V) | 1 | 117.019* | 141.528* | 82.4689* | 67.5000* |
| Error | 2 | 1.600 | 0.900 | 2.5000 | 3.4810 |
| Mepiquat Chloride (MC) | 4 | 95.757* | 83.364* | 90.3930* | 66.0544* |
| V×M | 4 | 1.138* | 0.634* | 1.3916* | 0.0307* |
| Error | 16 | 2.350 | 3.400 | 2.0000 | 3.6310 |
| Total | 29 | | | | |

*: Significant at 5% level of probability

Appendix VIII. Analysis of variance of the data of dry weight plant$^{-1}$ of sunflower at different DAS

| Sources of variation | DF | Mean square of dry weight plant$^{-1}$at | | |
|---|---|---|---|---|
| | | 25 DAS | 50 DAS | 75 DAS |
| Replication (R) | 2 | 0.00049 | 1.962 | 13.019 |
| Variety (V) | 1 | 0.00867$^{NS}$ | 88.855* | 184.810* |
| Error | 2 | 0.00049 | 1.962 | 2.107 |
| Mepiquat Chloride (MC) | 4 | 0.41995* | 105.771* | 212.944* |
| V×M | 4 | 0.00424* | 1.309* | 0.279* |
| Error | 16 | 0.00299 | 1.532 | 2.313 |
| Total | 29 | | | |

*: Significant at 5% level of probability

Appendix VIII. Analysis of variance of the data of number of head diameter, number of seed head$^{-1}$and 1000-seed weight of sunflower

| Sources of variation | DF | Mean square of | | |
|---|---|---|---|---|
| | | Head diameter | Seeds head$^{-1}$ (no) | 1000-seed weight |
| Replication (R) | 2 | 0.9000 | 360.0 | 2.401 |
| Variety (V) | 1 | 43.5608* | 50824.4* | 263.915* |
| Error | 2 | 0.9000 | 40.0 | 12.321 |
| Mepiquat Chloride (MC) | 4 | 18.2593* | 31614.7* | 138.891* |
| V×M | 4 | 0.2256* | 205.9* | 0.350* |
| Error | 16 | 0.4000 | 200.0 | 4.636 |
| Total | 29 | | | |

*: Significant at 5% level of probability

Appendix IX. Analysis of variance of the data of seed yield, stover yield, biological yield, harvest index and oil content of sunflower

| **Source** | **DF** | Mean square of | | | | |
|---|---|---|---|---|---|---|
| | | Seed yield | Stover yield | Biological yield | Harvest index | Oil content |
| Replication (R) | 2 | 0.01225 | 0.04900 | 0.10404 | 0.10000 | 0.6333 |
| Variety (V) | 1 | 0.33708* | 0.69312* | 1.99692* | 4.63347* | 55.5424* |
| Error | 2 | 0.01225 | 0.04900 | 0.09604 | 0.10000 | 0.6333 |
| Mepiquat Chloride (MC) | 4 | 0.61818* | 1.23717* | 3.59584* | 8.95803* | 10.7515* |
| V×M | 4 | 0.01308* | 0.01887* | 0.05780* | 0.33702* | 18.9243* |
| Error | 16 | 0.00850 | 0.01900 | 0.10004 | 1.10000 | 1.5083 |
| Total | 29 | | | | | |

*: Significant at 5% level of probability

## PLATES

**Plate 1. Layout of the experimental field**

**Plate 2. Young seedling of sunflower in the experimental field**

**Plate 3. Different doses of mepiquat chloride application on sunflower**


**Plate 4. Flowering of sunflower**


**Plate 5. Experimental plot with signboard**

**Plate 6. Harvesting stage of sunflower**