EFFECT OF GROWTH RETARDANTS ON THE GROWTH, PHYSIOLOGY AND YIELD POTENTIAL IN SUNFLOWER (*Helianthus annuus* L.) GENOTYPES

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CERTIFICATE

This is to certify that the thesis entitled "**EFFECT OF GROWTH RETARDANTS ON THE GROWTH, PHYSIOLOGY AND YIELD POTENTIAL IN SUNFLOWER (*Helianthus annuus* L.) GENOTYPES**" submitted by **Mr.SHASHIDHAR S. KULKARNI**, for the degree of **MASTER OF SCIENCE (AGRICULTURE)** in **CROP PHYSIOLOGY** of the University of Agricultural Sciences, Dharwad, is a record of research work done by him during the period of his study in this University under my guidance and supervision and the thesis has not previously formed the basis of the award of any degree, diploma, associateship, fellowship or other similar titles.

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LIST OF ABBREVIATIONS

1.	AGR	Absolute growth rate
2.	CCC	Cycocel
3.	CGR	Crop growth rate
4.	DAS	Days after sowing
5.	DPC	1,1 Dimethyl piperdinium chloride (Mepiquat chloride)
6.	Fr.wt	Fresh weight
7.	H	Harvest
8.	LAD	Leaf area duration
9.	LAI	Leaf area index
10.	MH	Maleic hydrazide
11.	NAR	Net assimilation rate
12.	NS	Non-significant
13.	PPM	Parts per million
14.	RGR	Relative growth rate
15.	SLA	Specific leaf area
16.	SLW	Specific leaf weight
17.	TDM	Total dry matter
18.	TIBA	2,3,5 Tri-iodobenzoic acid

CHAPTER - I

INTRODUCTION

I INTRODUCTION

Oilseed crops play an important role in the national economy of India and rank second after food grains as a farm commodity group. The oils not only form the essential part of the human diet, but also serves as an important raw material for the agro based industries to manufacture various products.

The per capita consumption of vegetable oils in India is only 6.97 kg as against 22 kg in developed countries. The present production of vegetable oils in India is about 4.59 m tons which is in short of the total requirement of about 5.13 m t (Anon., 1990). This wide gap between demand and supply of vegetable oils is being met annually by importing edible oil worth of Rs.320 crores (Anon., 1990) thus causing a severe drain on foreign exchange. The demand for vegetable oils is going to increase steadily in the coming years, and it is estimated that India would require about 6.6 m t of edible oil by the end of this century. The need to build self sufficiency in oil front necessitates the identification of various sources for augmenting the vegetable oil supply in the country and cultivation of short duration and high yielding oilseed crops like sunflower.

Sunflower is an important oilseed crop in the world and ranks third, next only to soybean and cotton, with an area of 16.24 m ha producing 22.02 m t (Anon., 1991). In India, it is cultivated over an area of 1.05 m ha with a production of 0.40 m t (Anon., 1990). Among the important sunflower growing states in the country, Karnataka is one, where it occupies an area of more than 0.58 m ha with an annual production of 0.2 m t (Anon., 1990).

Sunflower promises a bright future during the present oil crisis and is distinctly superior to other oilseed crops due to its year long adaptability to varied soil and climatic conditions, high degree of drought tolerance and short duration. Being photoperiod insensitive, it is able to substitute season bound crops like seesamum and groundnut. Seeds contain high quality edible oil including oleic and linoleic acid. Apart from being rich source of quality edible oil, it also contains appreciable quantities of proteins, vitamins A, D and E.

Low productivity in India seems to be due to non uniform filling of seeds in the head which is a common problem in most of the sunflower genotypes and it has been estimated that seed filling occurs in only 40 to 50 per cent of the head, particularly in the peripheral region. It is expected that there may be source limitation particularly, at later stages of the crop growth, during which the leaves are affected by leaf spot causing the senescence and shedding of the leaves. Usually, the photosynthetic rate in the leaves of sunflower plant declines after development of the reproductive organs due to ageing of the leaves (Srivastava and Sairam, 1980; 1983).

The growing capitulum thus suffers a limitation on the availability of photosynthates for its developing seeds. At this stage, the demand for assimilates is largely met by the bracts proximate to the head (Srivastava *et al*., 1977).

Sunflower, though being a determinant plant, vegetative growth continues leading to an increase in the plant height and leaf area, which have been found not conductive for better seed yield (Khanna, 1972). Further, it is only top 4 to 6 fully developed leaves that play a significant role in seed filling (Srivastava *et al*., 1977). Thus, it appears that more photosynthates probably could be made available for seed filling, if the plant size is reduced.

It has also been speculated that the auxins are concentrated at the tip where, they are produced and there is no downward translocation of auxins. The application of growth retardants particularly, cycocel and TIBA are known to enhance the downward translocation and helps in the better redistribution of auxins in the plants. The application of growth retardants may enhance the chlorophyll synthesis in the leaves and may help to retain the leaf area for a longer period and improve the partitioning efficiency leading to increased productivity. There is hardly any precise and conclusive information available in this regard. Therefore, studies were initiated to establish useful effects of the application of growth retardants on sunflower genotypes with the following objectives.

1. To find out the effect of growth retardants on the pattern of growth and development in sunflower genotypes.

2. To find out the effect of growth retardants on dry matter partitioning and bio-productivity in sunflower.

3. To find out the physiological basis of yield variation in sunflower genotypes as influenced by growth retardants.

4. To find out the effect of growth retardants on seed yield, oil content and seed protein content.

CHAPTER-II

REVIEW OF LITERATURE

II REVIEW OF LITERATURE

Sunflower is one of the important oilseed crops and is being widely cultivated in India. Though, it has several advantages over other oilseed crops, poor seed setting and high per cent of hollow seeds in its capitulum, which adversely affect the production potential is a serious concern. Several reasons like, decrease in the photosynthetic activity at the time of seed filling (Srivastava and Sairam, 1983), limiting sink capacity (Prasad et al., 1977) and imbalance in the source-sink relationship due to poor translocation (Starck,1966) have been attributed to poor seed set in sunflower. It has been observed that most of the middle leaves and few top leaves start senescing when seeds at the central portion of the capitulum are developing (Srivastava and Sairam, 1983). It may be possible to regulate the mobilization of metabolites during grain filling stage by shortening the plant size and delaying the leaf senescence, there by increasing the yield. Several attempts have been made to regulate the crop growth and yield by applying growth retardants, and the discovery of a new group of growth regulators, growth retardants by Mitchell et al.(1949) gave an impetus to the research on the control of plant growth and development. Cathey (1964) defines a growth retardant as a chemical that decreases the cell division and cell elongation in the shoot apex and regulates plant height physiologically without formative effects. The effects of growth retardants vary with plant species, variety, concentration used, method of application, frequency of application and various other factors which influence the uptake and translocation of the chemicals. Plants treated with growth retardants generally have a thick and dark green leaves and delayed leaf senescence. The results of the earlier investigations on the effect of TIBA (2, 3, 5-tri-iodobenzoic acid), Maleic hydrazide (MH) (6 hydroxy-3-(2H)-Pyridzinone), chlormequat (CCC) (2 chloroethyl) trimethyl ammonium chloride) and Mepiquat chloride (DPC)(1,1 dimethyl-piperdinium chloride) on growth, yield and biochemical aspects of sunflower and other crops are reviewed here under.

2.1 GROWTH PARAMETERS

Although sunflower is a determinate crop, the vegetative growth continues even after heading to an increased plant height and leaf area, which have been found non conducive for increased seed yield (Khanna, 1972). Further, due to leaf senescence and greater distance between the source and sink, only top 4-6 fully developed leaves play a significant role in seed filling.

The effect of TIBA on growth of plants has been reported by several workers. Galston (1947) reported that TIBA suppresses the activity of endogenous auxins in avena curvature test and inhibits both internode elongation and apical dominance in soybean. Later, similar responses were reported in cotton, groundnut, pigeon pea and faba beans (Dastur and Prakash, 1954; Santelmann, 1977; Newaz and Lawes, 1980 and Deshpande, 1983).

Greer and Anderson (1965) noticed that foliar application of TIBA in soybean showed a reduction in plant height ranging from 4.5 to 22.2 per cent with different concentrations (0, 10 and 50 ppm). Similarly, application of TIBA (1 oz/acre) during early blossom period of soybean reduced the plant height by 16 per cent, increased branching, shortened the leaf petiole and produced a conical shape row profile (Burton and Curley,1966). While, TIBA applied to soybean grown at high fertility levels decreased plant height by 33 per cent due to its shorter internodes, leaf area by 20 per cent and produced thicker leaves with short and erect petioles (Hicks *et al.*, 1967). Such alterations in the leaf and plant morphology allowed better utilisation of sunlight. Similar results were reported by Wax and Pendleton (1968) and Bauer *et al.* (1969).

Kapp and Cowley (1969) reported that the plant height was reduced from 47.7 cm in control to 41.2 cm in the plants treated with TIBA. While in flax, TIBA applied at seven weeks after planting reduced the height from 60.4 cm in control to 57.9 cm in treated plants (Vetter *et al.*, 1970). Clapp (1973) reported a reduction in plant height by 13.3 per cent from two years experiment on soybean with TIBA applied either at four or six trifoliate growth stage. The maximum reduction in the plant height was within the range of 10-15 per cent when TIBA was applied one month prior to bloom in sorghum and a further decrease in plant height reduced the yield (Motley, 1985). On the other hand, Santelmann (1977) reported that in groundnut none of the six growth regulators applied at various concentrations and different crop growth stages increased seed yield, but SADH 1.1 or 2.2 kg/ha) or TIBA (0.6 kg/ha) reduced the plant height.

TIBA, despite reducing the plant height, was also responsible for increase in the total dry weight of the soybean plants (Barthakur, 1980). Similarly, faba beans were reported to have higher dry matter with short stature in response to TIBA (15-60 mg/l) applied at 15 days after bud stage (El-Sawily et al., 1985). In a field trial of soybean, Zappi and Salas (1990) observed that the foliar application of TIBA (50 g/ha) at the begining of flowering resulted in greater reduction of dry matter.

TIBA has been used in the investigation of floral development in certain plants. Zimmerman and Hitchcock (1942) found that the axillary buds of tomato plants were induced to grow flower cluster instead of the normal leaf shoots when treated with TIBA. While, Galston (1947) showed that vegetative soybean plants were not induced to flower by TIBA; however, photo-induced plants set more flowers when treated with TIBA. Anderson et al. (1965) reported that pre-flowering treatments with TIBA delayed maturity whereas, treatment at flowering or after flowering hastened maturity.

The growth inhibiting property of maleic hydrazide (MH) was reported by Schoene and Hoffman (1949) for the first time and later several workers have reported the similar action of MH in suppression of apical dominance in different crops run as Jasmine, Chrysanthemum and china aster. Moore (1950) has summarised the effects of MH on plant growth as: a temporary suspension of stem elongation from terminal bud and adjacent tissue, alternation in the expansion of lateral bud and the terminal bud, localised accumulation of anthocyanins, narrowing of leaves and leaf chlorosis, suppression of nodule formation in bush beans and induction of temporary male sterility.

Rakova and Minor (1970) reported that the treatment with MH resulted in retarded vegetative growth of pea plants. The lower concentrations of MH (0.1-1mg/1) accelerated the growth of plant, whereas, higher concentrations (10 to 20 mg/1) retarded the growth and reduced the dry matter accumulation. Similarly, Patel and Srivastava (1971) observed the reduction in plant height of peas especially at higher concentration of MH (400 ppm) when sprayed on 3-4 weeks old plants.

In a study to know the effect of different growth regulators such as GA, TIBA, MH, 2,4-D and NAA on groundnut, MH showed significant inhibition in the plant growth during both kharif and rabi seasons. Whereas, NAA, GA and 2,4-D stimulated the plant growth (Suryanarayana, 1977). Lin *et al.* (1987) also reported that MH reduced the plant height by reducing the number of nodes.

Gomande and Zode (1987) demonstrated that the foliar application of 200 ppm of MH at 30 days after sowing in sorghum decreased the plant height and increased the leaf area. Similar results were obtained when 400 ppm of MH was sprayed (Gode and Durge, 1988). Similarly, the foliar application of MH to Calendula seedlings reduced the plant height at all the concentrations used (5, 25, 50 and 100 ppm) and the maximum reduction was observed at 100 ppm (Srivastava and Bojpai ,1964).

Sen and Sen (1968) reported that the application of MH at 1000 ppm recorded a significant reduction in plant height and nodal length of chrysanthemum and petunia. Later, Sen and Maharana (1972) noticed the reduction in plant height of chrysanthemum in all the concentrations of MH used (250 to 1000 ppm). Shanmugam et al.(1973) observed the suppression of growth in chrysanthemum due to spraying of MH thrice after planting (30th, 45th and 60th day) at 1000 and 2000 ppm. Whereas, 500 ppm of MH increased the shoot dry weight.

Narayanreddy (1977) demonstrated the effect of growth substances on china aster in winter and summer seasons sprayed the MH with 500, 750 and 1000 ppm at 25th, 40th and 55th days after transplanting, respectively and the application of MH at 1000 ppm significantly reduced the plant height, dry weight of the plant, leaf area, leaf area index and leaf area duration at all the stages. Similarly, the application of MH at 1000 and 2000 ppm resulted in the reduction of plant height, leaf number and leaf area in chrysanthemum (Sen and Swaik, 1977).

More number of flowering laterals were observed in chrysanthemum plants treated with 600 ppm of MH and with an increase in the concentration of MH (500 to 1000 ppm) delayed the flowering (Powell and Anderson, 1957). Whereas in Calendula, MH delayed the flowering at all concentrations (5-100 ppm) and the maximum delay of flowering was observed at 100 ppm of MH, by about 12 days as compared to control. The number of flowers were increased at all the concentrations of MH, the maximum increase was noticed at 50 ppm and increase in the concentration of MH decreased the diameter of flowers (Srivastava and Bajpai, 1964). Delayed flowering was also observed in Helianthus sprayed with MH at 1000 ppm (Sen and Sen, 1968). However, the flowering was significantly hastened in Zinnia at both the levels of MH (100 and 1000 ppm), whereas, delayed flowering occured with high level of MH. Similarly, in Dahlia, 500-1000 ppm of MH advanced the flowering by 4-5 days (Bhattacharjee, 1984). Gowda and Gowda (1990) reported that foliar spray with 1000 or 2000 ppm of MH applied before pruning and 15 days later, advanced the flowering in Jasmin and they further concluded that 1000 ppm was most effective. Similarly, in sorghum, 200 ppm of MH (Gawande and Zode, 1987) and 400 ppm of MH (Zode and Durge, 1988) delayed the 50 per cent flowering by 2-3 days when applied to a month old crop.

Effect of CCC, was first described by Tolbert (1960) and reported that plant height, branching, flowering and fruiting are some of the important parameters which are influenced by CCC. Thomas (1964) observed the reduction in elongation of the main stem and fruiting branches of cotton plant. Similarly, Sammell (1972) reported that CCC (0.8 kg/ha) reduces the plant height in sunflower.

Tarvis and Tarvis (1972) noticed retardation effect of chlormequat along with thickening of stem in both early and late maturing cultivars of sunflower. Spraying with succinic acid and CCC at 7th leaf stage in sunflower reduced the plant height by 25 and 15 per cent, respectively and both the chemicals lead to a slight reduction when applied at bud stage (Dorell, 1973). Similar results were noticed by Orchard (1976) with the application of CCC (4000 ppm) during summer season. The reduction in stem growth was due to retardation in transverse cell division, particularly in steelar cambium (El-shaarawi, 1976).

The shorter plant size could also be achieved by spraying ethrel alone or in combination with CCC (Guardia, 1977). Lovett and Orchard (1977) reported that CCC not only reduced the plant growth but also there was a reduction in the accumulation of dry matter in stem, leaves and petioles of sunflower, besides reduction in leaf area.

According to Dorell (1977), the lag phase of growth in sunflower begins 15 days after sowing and the application of CCC during this phase inhibits stem growth without affecting the yield. In a pot culture study, sunflower (cv. EC-68414) seedlings were sprayed with CCC (100, 500, 1000, 2000 and 5000 ug/ml) during the lag phase and the results obtained 33 days after sowing indicated that only the higher concentration

(5000 ug/ml) had significant inhibitory effect on plant height, total dry matter and leaf area (Bhattacharjee and Gupta, 1981). In contrast to earlier results obtained by Tarvis and Tarvis (1972), the use of higher concentrations of CCC resulted in the formation of thin stem, whereas lower concentration of CCC resulted in the formation of thick stem (Bhattacharjee and Gupta, 1981).

The effect of CCC was further demonstrated by Lovett and Orchard (1981) and indicated that the reduction in plant height of sunflower was due to the inhibition of cell division at stem apex. Thus, it was concluded that CCC reduced the plant height by inhibiting the cell division at sub apical region.

Abdushoba et al. (1984) noticed that CCC in combination with boric acid when sprayed at 35 days after sowing resulted in shorter plant (154 to 96 cm) with thick stem (2.01 to 3.1 cm), increased leaf area (39.2 to 43.2 dm^2/plant) particularly at higher concentrations of CCC (2000 or 3000 ppm). The application of CCC was also found to increase the RuBP carboxylase activity, photosynthesis and dry matter partitioning in both rabi and [redacted] seasons (Pando and Srivastava, 1985). However, CCC treatment delayed the flowering process in sunflower (Sawmell, 1972) and soybean (Morandi et al., 1981), whereas, hastened in Jasmin (Zayed et al., 1985 and Gowda and Gowda, 1990).

Mepiquat Chloride (DPC), a growth regulator is known to suppress vegetative growth in cotton (Cothren, 1979; Willard, 1979 and York, 1982). DPC is relatively a new chemical and the literature available on the effect of this chemical on crops other than cotton is very meager.

In cotton, the application of DPC (0.6 1/ha) at the onset of flowering decreased the plant height by 20 cm and further increase in the rate of DPC did not produce any effect (Megie, 1980). Mulder et al.(1981) reported that spraying of DPC (50, 75, 100 or 50+25 g a.i/ha) at an early reproductive stage of cotton reduced the plant height slightly at all concentrations. As cotton produces profused growth, DPC has been found to reduce leaf area (Stuart et al., 1980) and increase leaf thickness (Gausman et al., 1980). In an experiment, DPC applied at first bloom stage in cotton, reduced plant height by 28 per cent, leaf area by 17 per cent and increased the leaf thickness by 16 per cent, and increased the photosynthesis thereby increasing the dry matter production (Walter et al., 1980). Varela and Vallejo (1981) reported that the application of DPC, twice (25, 50, 75 or 50 + 25 g/ha) at 60 days after sowing and 15 days later resulted in the reduction of plant height, daily growth rate, inter-nodal length and number of fruiting branches especially, in lower parts of the plants, whereas, number of leaves was unaffected with an increase in leaf area.

DPC, when treated to crops generally inhibits the growth in both length and width. In cotton, treatment with DPC, resulted in thin and apparently more rigid stem. Whereas in cereals, resulted in thicker culms, more resistant to lodging

(Schott and Fitting, 1982), reduced leaf area but not the leaf volume thereby increasing the infiltration of light (Schoot and Ritting 1982).

In a green house study, Pix (DPC) applied at the onset of flowering in cotton reduced the vegetative growth by 20-30 per cent (Khafaja, 1983). According to Kerby (1983), when treated with DPC, the average lint yield was not affected, whereas the plant height and number of nodes were reduced by 15 per cent and 4 per cent, respectively. Canosand Prado (1983) reported that the application of DPC (1.0 l/ha) at flowering stage reduced the plant height by 31 cm and increased the leaf retention as compared to spraying before or after flowering. Similar delay in leaf senescence was noticed by Gausman et al. (1981).

The application of 50 g of DPC to cotton cv. Paymaster 303 during early square formation stage resulted in the reduction of plant height by 17 days after treatment. Whereas, shoot by dry weight and leaf area index were significantly lower only at 31 days after the treatment. The treated plants maintained higher leaf water potential and solute potential (Wendt et al., 1984). It was observed that the foliar application of Pix (DPC) on cotton at flowering or split application at early flowering (67 ml/mu) and at peak flowering (33 ml/mu) resulted in 22-24.8 per cent decrease in plant height than that of the control. Upper, middle and lower fruiting branches were 41.4-50 per cent, 23.2-32 per cent and 22.6-20.8 per cent shorter, respectively.

leaf area was 28.6-35.7 per cent smaller than that of control (Kerby *et al.*, 1988).

In rape seed, the application of Terpal (DPC+ethephon) resulted in the reduction of plant height (Daniels *et al.*, 1982 and Champme *et al.*, 1983). Ogilvy (1985) reported that, treatment with Terpal at stem extension stage, reduced the plant height by 10 cm to 20 cms. According to Knittel and Lang (1984), reduction in plant height ranged from 10 to 20 per cent and was accompanied by an increase in flower shedding when treated with Terpal. Maize cultivars tolerated the application of 1-3 l/ha of Terpal at 4 to 12 leaf stage and there was a reduction in plant height.

In a pot culture study, there was a reduction in the length of stem and branches whereas,the number of nodes remained unaffected in soybean with DPC. Further, the application of 500 and 1000 mg of DPC modified the growth pattern by lowering the branch to main stem length ratio (Morandi *et al.*, 1983). It was also found that there was higher specific stem weight with lower main stem length. There was a logarithmic relationship between the reduction in stem length and DPC or CCC dose in both green house and field conditions (Morandi *et al.*, 1984). They found that DPC was more active than CCC in reducing the stem length, number of nodes and reducing the stem dry weight, especially in green house condition.

Application of Pix resulted in the delayed flowering and hastened the maturity in Brinjal. Whereas in Okra, Pix hastened the flowering (Zayed *et al.*, 1985). According to York (1983), the application of DPC to cotton reduced the crop cycle and these results are in accordance with the results reported by Kerby (1983). It was noticed that the application of CCC (0.1%) at fruit formation stage accelerated the maturity in cotton (Okhotnik *et al.*, 1984). Similarly Pix (DPC) application initated earliness when seasonal length less than 2400 heat units (Kerby *et al.*, 1988). Later, Sawan and Sakar (1990) reported that cotton matured early with an increase in the concentration of DPC as well as number of applications.

2.2 YIELD AND YIELD COMPONENTS

Sufficient source, a strong sink and better translocation between source and sink are essential for higher seed setting and yield in sunflower. It has been reported that only top six leaves have the most important role in the yield formation and oil synthesis in sunflower (Dhopte and Upadhyay, 1975). It has also been reported that there is no lateral movement of metabolites from leaves to head and the leaves translocate metabolites only to the those parts which are directly connected (Udaykumar *et al.*, 1976).

Translocation of metabolites was more to the seeds of outer region in the capitulum, as they are in the advanced stage of development due to early set and sink size was directly related to the endogenous growth hormones like auxins; which are essential for enlargement and development of ovary in to fruit

(Salisburry and Ross, 1969). In sunflower, after pollination, the synthesised auxins have the tendency to move in basipetal direction and hence the translocation of metabolites to the capitulum will be limited. Translocation of photosynthates from source to sink depends on the endogenous growth harmones, and hence the application of growth regulators induces better translocation of metabolites in sunflower.

While studying the effect of TIBA on cotton, it was noticed that TIBA treated plants out yielded the control plants due to increase in the number of bolls (Pastur and Prakash, 1954). In Bengalgram, 100-seed weight increased from 5.9 g in control to 6.3 g in the plants treated with 10 ppm of TIBA at 50 per cent flowering (Greer and Anderson, 1965). Sinha and Ghildiyal (1973) reported that the application of 300 ppm TIBA increased the number of seeds per plant by 72 per cent and yield by 66 to 108 per cent over control plants.

Application of TIBA changed the morphology of soybean plants, making them photosynthetically more active and thereby increasing the seed yield (Anderson et al., 1965 and Jackson, 1969). The response of determinate varieties of soybean to TIBA was more erratic than the indeterminate types. Hatley (1974) reported that the application of TIBA (38 g/h) one month prior to bloom consistently produced higher yield as compared to control in 'Lee' and 'Hampton 266' varieties. He also reported that yields were reduced by higher concentration of TIBA applied when plant height was reduced more than 10-15 per cent. On the other hand, Stulte and Rudolph (1971) found no significant increase in yield when TIBA was applied six weeks before bloom to the varieties 'Lee 68', 'Davis' and 'Stragg'. Whereas, in alfalfa and sorghum, TIBA application increased the seed yield by 67 and 20 per cent, respectively (Weaver, 1972).

It was found that the foliar application of NAA and TIBA increased the seed setting by 92.2 per cent and 76.2 per - cent, respectively as compared to control (Anon.,1975). In another study, the foliar spray of the combination of TIBA and NAA gave higher yield (376 kg/ha) as compared to control (261 kg/ha) in sunflower (Anon., 1976). Prasad et al. (1977) reported that the application of TIBA (240 ppm) along with NAA (50 ppm) increased the proportion of filled seeds, 1000-seed weight and seed yield as compared to control. They also reported that, TIBA being an auxin transport inhibitor, prevented the basipetal movement of auxin. Consequently, the concentration of auxins and gibberelins in the head increased, thereby increasing the sink capacity of the head due to mobilization of photosynthates from other parts of the plant to head.

The seed yield of sunflower was increased by 12-22 per cent due to the application of TIBA alone or in combination with chlormequat and the exposure of plants to TIBA alone at 15-20 leaf stage was likely to produce the maximum seed yield (Guardia et al., 1977). According to Srivastava et al.(1979), the combination of pre-soaking hardening, higher dose of fertilizer application and spraying of TIBA (120 ppm) gave higher yield in sunflower over the plants treated seperately and these results are in confirmation with those of Krishnagowda *et al.* (1979).

While studying the effect of TIBA under different plant population levels in sunflower, it was observed that the foliar application of TIBA in combination with 'Navaras' at higher plant population gave seed yield similar to that of hand pollinated crop, where, hand pollinated crop produced 75.5 per cent seed set as compared to 50.3 per cent in control (Subbaiah, 1983).

Uppar and Kulkarni (1989) observed that the application of TIBA (250 ppm) produced highest processed seed yield followed by Kinetin (15 ppm) and CCC (2500 ppm). Devendrappa (1989) reported that an application of TIBA (75 ppm) at 50% flowering and at seed filling stage increased the seed yield significantly, which was associated with higher 1000-seed weight, number of filled seeds and HI.

Treatment with MH was found to have considerable impact on the yield and yield components of field crops. Choudhari and Singh (1969) reporte that the foliar application of MH (10 ppm) on seasame resulted in higher seed yield per plant due to increase in number of pods and 1000 seed weight. Whereas, in faba beans, 1000 ppm of MH significantly reduced the number of seeds per pod and the seed weight, while there was no significant effect on number of pods and number of seeds per pod (Hassib *et al.*, 1971).

Patel and Srivastava (1971) in an investigation reported that pea plants of 3 to 4 week old sprayed with MH and GA indicated that MH (400 ppm) resulted in 31 per cent higher yield while, GA resulted in poor yield than control. The increase in seed yield was mainly due to increase in the number of pods per plant.

Suryanarayana(1977), in a study to know the effect of different growth regulators viz., MH, NAA, TIBA, IBA, GA and 2,4-D on pod yield of groundnut reported that the highest pod and oil yield was obtained by MH (100 ppm) followed by NAA. Further, the higher yield was associated with an increase in the total number of pods and filled seeds per cent. In a similar experiment, Gurubaksh Singh et al. (1978) reported that MH (250 ppm) gave higher yield due to increase in the weight of pods per plant, whereas GA (250 ppm) and planofix (10 ppm) gave more yield due to increase in the total number of pods per plant. However, the yield data of two years (1975-76) showed that MH (250 ppm) was the most effective.

Gurubaksh Singh and Sharma (1982) reported that two foliar sprays of MH (250 ppm) or CCC (1000 ppm) at 40 and 50 days after sowing, respectively increased the number of gynophores and pods while dry pod yield, 100-seed weight and shelling percentage were not affected.

In an irrigated trial of groundnut, the application of different growth regulators increased the yield components viz., pod yield, shelling percentage and HI (Rao, 1980). The most effective being MH (50 ppm) followed by NAA (50 ppm) CCC (500 ppm) and SADH (1000 ppm). Similar results were noticed in *kharif* and *rabi* seasons (Reddy and Shah, 1984).

In field and pot trials with spring wheat, spraying of MH (8 x 10^{-3}M), 15 or 20 days after flowering increased the grain yield significantly due to increase in the 1000-grain weight (Sobolev and Dubko, 1985).

Significance of growth retardants, particularly of CCC in growth and yield of several crops has been reported during the past (Gill *et al.*, 1976; Radner, 1976 and Lovett and Orchard, 1977). In the plants, where excessive vegetative growth causes low seed yield due to poor carbon partitioning, CCC has been found to be useful in reducing the foliage and create better conducive environment for seed formation and its growth.

Leaf senescence is one of the common manifesto for poor seed yield in sunflower and CCC (4000 ppm) has been found as a senescence retarding factor and thus may indirectly have a positive effect on seed yield (Orchard, 1976).

Treatment of sunflower plants with CCC at 10 leaf stage resulted in remarkable increase in the dry weight of mature heads and subsequently the seed yield (Lovett and Orchard, 1977). Croutt *et al.* (1978) reported that sunflower exposed to CCC (0, 5 or 10 kg/ha) at two leaf stage did not have any effect on yield. While, the crop exposed to CCC (500 ug/ml) at flowering stage under dry soil conditions resulted in higher seed and oil yield, while under mesic soil condition, yield was lower than control.

The main function of CCC is the regulation and allocation of photosynthates for various growth purposes. The excessive diversion of photosynthates for elongation of stem was arrested and was redirected for filling up of the seeds, which resulted in greater filled seed per cent, seed index and weight of seeds per plant (Patel and Singh, 1979). Further, they reported that the control of LAI and lodging incidence was brought about by the application of CCC (0.03 - per cent) and it was also responsible for higher seed yield.

Lovett and Orchard (1983) demonstrated the effect of CCC (4000 ppm) at different plant densities viz., 12,500, 25,000, 50,000 and 1,00,000 plants per ha and observed that CCC gave higher yield in all the plant populations. However, at higher plant population, the number of seeds while at lower plant population, both number of seeds and their size contributed for the yield.

Lower concentration of CCC (0-2000 ppm) did not have any effect on head diameter and seed yield (Aboushoba et al., 1984). While, higher concentration of CCC (3000 ppm) either of pre or post-flowering stage increased the head diameter (6.84 to 7.66 cm), seed weight (8.69 to 10.4 g/plant) and HI (0.16 to 0.21) (Pande and Srivastava, 1985). Further, they noticed that the rate of carbon dioxide fixation was not much affected, but the translocation of sucrose from leaf to the capitulum was enhanced by the application of CCC. The 100-seed weight also increased from 3.28 g to 4.05 g (Pande and Srivastava, 1987). Under simulated drought conditions at vegetative, anthesis or achene-filling period, the application of CCC (20 or 40 mM) increased the seed size and 100 seed weight in sunflower (Kumari and Bharati, 1988).

The foliar application of DPC (25, 50, 75 or 50 + 25 g/ha) at 60 days after sowing or with split application at 60 and 75 days after sowing increased the lint weight boll^{-1} by 10 per cent, total seed cotton yield by 28-50 per cent and lint yield by 27-50 per cent (Varela and Vallejo, 1982). The most effective range was between 50 and 75 g of DPC/ha. In cotton stem, the xylem was expanded and the increase in the transportability accounted for the heavier bolls produced (Schott and Ritting, 1982).

Under different plant population study of cotton, DPC was found to increase the kapas yield by 10, 23 and 51 per cent under plant densities of 37,000, 1,36,000 and 2,35,000 plants/ha, respectively (York, 1983). The increase in yield was due to changes in the maturity pattern. Hutchinson (1983), in the comparative study of growth regulators and fertilizers reported that pix (DPCc 1 Pint/ac) had little effect on yield as compared to nitrogen treatment.

It was observed in green house study that PIX (DPC) applied at the onset of flowering increased the ripened bolls ($Plant^{-1}$) by 20-25 per cent and boll weight by 10-20 per cent (Khafaga, 1983). Further, he noticed a differential response of cotton genotypes in which Gossypium vitifolieum reacted more strongly than Gossypium hirsutum. Similarly, pot experiment results indicated that the foliar application of 0.01 per cent pix at flowering stage increased the boll weight from 5.6 to 7.79 and seed cotton yield from 132 to 163 g/plant (Pak and Kuzenetsova, 1983). However, results were inconsistant during the years 1977 and 1979. York (1983) in USA reported that DPC (49. g/ha) shortened the crop cycle, increased boll weight and seed weight.

Treatment of cotton plants during the fruit formation stage with 0.1 per cent CCC 0.01 per cent Pix (DPC) or 0.25 - per cent Morfonol (retardant) increased the seed cotton yield in first and second pickings and also the total yield (Okhotnik et al., 1984). In most circumstances, yield was increased due to DPC treatment. Kosmidov (1985) noticed that the split application was less effective as compared to the single spraying, while in some of the treated plots, there was a tendency to increase boll weight and lint per cent.

According to Pol and Thombre (1985), the application of two foliar sprays at 150 or 250 ppm Pix, at the first square formation stage and 15-20 days later significantly increased the seed cotton yield of the hybrid, Varalaxmi and decreased that of the hybrid, Savitri. While studying the response of short duration and full season types, full season types were more flexible than short season types in their response to DPC.

It was revealed that either CCC or Pix (DPC) application at lower concentrations did not have any effect on seed weight and number of bolls (Lala-Buendia, 1989). Whereas, spraying of lower concentration of DPC (6.3-12.3 g/ha) to vigourously growing cotton more than twice at 14 days interval increased the total yield by 5 per cent and it was necessary that intervals between suplimentary application of DPC be adjusted according to the expected growth rate of cotton (Dippenaa *et al.*, 1990). While, the application of DPC to rape did not have effect on number of pods, 1000-seed weight and yield (Daniel *et al.*, 1982; Daniels and Scarisbrick, 1983; Champma *et al.*, 1983 and Knittel and Lang, 1984).

In soybean, it was reported that per cent flower set and per cent of developed seeds were increased with 500 and 1000 mg/l of DPC; reproductive efficiency was increased for both the doses as a consequence of the accumulated effects of DPC over each of the partial reproductive efficiences (Morandi *et al.*, 1983). DPC also increased the HI, probably due to the partitioning of assimilates favouring its accumulation in the seeds.

2.3 BIOCHEMICAL PARAMETERS

2.3.1 Chlorophyll content

Among various functions of growth retardants, in addition to the inhibition of cell division, they cause induction of greening and initiate the development of chloroplasts. In a study to know the effect of MH on chlorophyll content of jasmin leaves, the foliar application of MH (2000 ppm) increase the chlorophyll-b and total chlorophyll contents (Gowda and Gowda, 1990).

The application of CCC produces dark green leaves (Cathey, 1961). In sunflower, the application of CCC at 500 ppm increased the chlorophyll content in the top leaves by 15-30 per cent (Hofner, 1977).

In another experiment, degreening at higher concentrations (5000 ug/ml) followed by regreening suggested that CCC application at seedling stage produced an initial chlorotic effect which was, however, not persistent during the active lag phase of growth (Bhattacharjee and Gupta, 1981). Aboushoba et al. (1984) observed that CCC upto 1000 ppm did not affect chlorphyll a, b and carotenoid contents, while, higher concentration of CCC reduced to lower level for one to three weeks after treatment, and the reverse effect was found during next three to five weeks.

DPC is known to increase the chlorophyll content in the leaves. Gausman et al. (1978) reported that chlorophyll content in cotton was increased when sprayed with DPC (40 and 60 g/ha) while, the chlorophyll a:b ratio was decreased with an increase in the concentration of DPC in SP-37, but increased in cv. Stonevill 213. Gausman *et al*. (1981) noticed that the application of DPC (10-100 g/ha) increased the leaf chlorophyll content in cotton. Similarly, Stein *et al*. (1983) noticed an increase in chlorophyll content of cotton leaf when DPC was sprayed at 7th leaf stage. The increase in chlorophyll content was 24-28 per cent over control when Pix (DPC) was sprayed at flowering stage in cotton (Jiang and Deng, 1986). Eid *et al*. (1986) also reported that DPC (50 g/ha) applied once or twice increased the leaf chlorophyll content in cotton.

2.3.2 Leaf Nitrogen and Protein Content

Choudhari and Singh (1969) reported that the foliar spray of MH (10 ppm) increased the protein nitrogen content of shoots and pods of sesame plants. While, in *Caliminitha officinalis*, Dahab *et al*.(1983) observed that three foliar sprays of MH (500-2000 ppm) increased the plant nitrogen content. Similarly in Okra, MH increased the leaf nitrogen content when applied at five weeks after planting (Zayed *et al*.,1985). Gowda and Gowda (1990) obtained higher leaf nitrogen content in jasmin by spraying MH (1000-2000 ppm) once before pruning and again at 15 days after pruning.

Zayed *et al*. (1985) found that the application of CCC at five weeks after planting increased leaf nitrogen content in in Okra. Similarly, in Pea, CCC was found to increase the nitrogen content of leaf and seed (Sheng et al., 1987). In a study with jasmine, 1000 ppm of CCC was the most effective as compared to 2000 ppm in increasing the nitrogen content of leaf (Gowda and Gowda, 1990). According to Dushkova (1977), under stress conditions, the application of CCC to maize either as seed treatment or as a foliar spray maintained the leaf protein content similar to that of control plants and its effect was more pronounced under stress conditions than under normal conditions. In a similar experiment, Kimenov et al. (1977) reported that CCC applied as seed treatment or as a foliar spray decreased the protein content in maize leaves under moderate soil moisture stress (400 of field capacity) and increased under stress of 30 per cent.

Like CCC, DPC also increased the nitrogen content of Okra leaves (Zayed et al., 1985). The foliar application of DPC at the rate of 1250 or 2500 ppm increased the crude protein content of leaves in fababeans (Sawson and El-Hyatenium, 1984). Whereas in cotton, the leaf protein content decreased with an increase in the concentration of CCC (0.100 g/ha)(Stein et al., 1983).

2.3.3 Seed Protein and Oil Content

In mung bean cultivars, foliar application of TIBA at pre-blooming stage resulted in higher seed protein content as compared to treatment with NAA, Urea and KNO_3 (Kandagal,1988).

Upper and Kulkarni (1989) reported that the application of TIBA (250 ppm) gave highest protein and oil content (17.69 and 40.05 per cent, respectively) in sunflower seeds followed by Kinetin (16.31 and 38.64 per cent, respectively) and CCC (15.18 and 38.33 per cent, respectively).

Although, MH increased the pod protein content it had little effect on seed oil content of sesame and groundnut (Choudhari and Singh, 1969 and Gurubaksh Singh and Sharma, 1982). It has been reported that MH (25-100 ppm) as a foliar spray to groundnut gave higher oil content and further 50 ppm of MH was the most effective (Rao, 1980). According to Nagarjun et al. (1980), 0-500 ppm of MH had no effect on seed protein content in groundnut whereas, 500 ppm and above concentrations of MH significantly increased the seed-oil content. In a similar investigation, MH at 100-200 ppm was found to increase the seed oil content in groundnut (Reddy and Shah, 1984).

Under dry soil conditions, CCC at the rate of 500 ug/ml applied at 79 days after sowing increased the seed oil content of sunflower, but under mesic soil condition, the oil content was reduced and seed protein content was increased as compared to control (Orcutt et al., 1978). In a study with sunflower, CCC along with boric acid solution showed decreasing trend in seed protein content and significantly increased the seed oil content with increasing concentration of CCC viz., 500, 4000 and 2000 ppm, respectively (Aboushoba et al., 1987). The oil content of sunflower seeds was increased by CCC (3000 ppm) when applied either at pre or post-flowering stage, however, no significant difference was noticed between the two applications (Pande and Srivastava, 1987).

In a study to know the effect of DPC on quality of maize seeds, it was observed that DCP increased the seed protein content by 1-3 per cent over control (Gruzdev, 1984). Similar results were obtained in fababeans with DPC application (Sawson and El-Hyatemy, 1984). Abdel et al. (1986) reported that the application of DPC (50.0 g/ha) to barbadense cotton resulted in an increased seed protein and oil contents.

CHAPTER-III

MATERIAL AND METHODS

III MATERIAL AND METHODS

A field experiment was conducted during summer 1992 (January-April), to study the effect of different growth retardants on the production potential of sunflower. The details of the materials used and techniques adopted during the course of investigation are described.

3.1 EXPERIMENTAL SITE

The experiment was conducted in plot No. 125 of 'E' block at the Agricultural College Farm, University of Agricultural Sciences, Dharwad.

3.2 CLIMATE

The College Farm is situated in the transitional tract of Karnataka at 15° 12' N latitude, 75° 07' E longitude and an altitude of 678 m above the mean sea level. The average annual rainfall during the crop growth period was 99.4 mm. The maximum and minimum temperatures during the crop growth period were 33.9°C and 17.8°C respectively. The relative humidity ranged from 64-81 per cent. The meteorological data for the year 1991-92 and the mean of previous 41 years was collected from the meteorological observatory, College of Agriculture, Dharwad and is given in Table 1.

3.3 SOIL AND ITS CHARACTERISTICS

The experimental site consisted of medium black clay loam soil. Composite soil samples from the experimental

Table2 : Physical and Chemical properties of the soil of experimental site

Particular	Values obtained	Method employed
1. <u>Physical properties</u>		
Coarse sand	5.82 per cent	Puri's method (Sankaram, 1966)
Fine sand	14.23 per cent	Puri's method (Sankaram, 1966)
Silt	28.00 per cent	Puri's method (Sankaram, 1966)
Clay	51.95 per cent	Puri's method (Sankaram,
2. <u>Chemical properties</u>		
Total Nitrogen (N)	0.051 per cent	Modified kjeldhahl's method (Jackson, 1967)
Available Phosphorus (P_2O_5)	0.004 per cent	Olsen's method (Muhr *et al.*, 1965)
Available Potassium (K_2O)	0.0249 per cent	Flame photometer (Muhr *et al.*, (1965)
Soil pH (1:25 soil water suspension	7.5	pH meter (Piper, 1966)

Table 1: Mean monthly temperature (minimum and maximum), relative humidity and rainfall during 1992 and the average of 41 years (1950-1991)

Month	Rainfall (mm)		Temperature °C				Realtive humidity (%)	
	1950-1991	1992	1950 -1991	1992	1950-1991	1992	1950-1991	1992
January	0.70	0.00	29.46	29.40	14.36	12.70	58.87	81.00
February	0.07	0.00	34.06	32.00	15.30	15.90	51.00	75.00
March	7.13	0.00	34.93	36.10	18.67	19.30	53.70	67.00
April	51.61	18.10	36.31	37.00	20.47	20.80	58.24	65.00
May	90.00	81.40	35.91	35.30	20.97	20.80	65.05	64.00
June	14.35	18.60	29.25	29.90	20.70	20.60	80.06	64.00
July	159.12	88.70	26.46	27.40	20.48	20.30	86.19	87.00
August	103.15	107.20	26.50	26.40	21.36	19.90	84.36	87.00
September	100.77	121.30	28.11	28.80	19.72	19.30	81.12	84.00
October	134.53	94.60	29.60	29.10	18.69	19.50	73.45	84.00
November	31.80	136.40	28.71	28.70	15.81	16.90	64.82	83.00
December	49.46	0.00	28.61	27.20	13.61	11.40	61.04	87.00

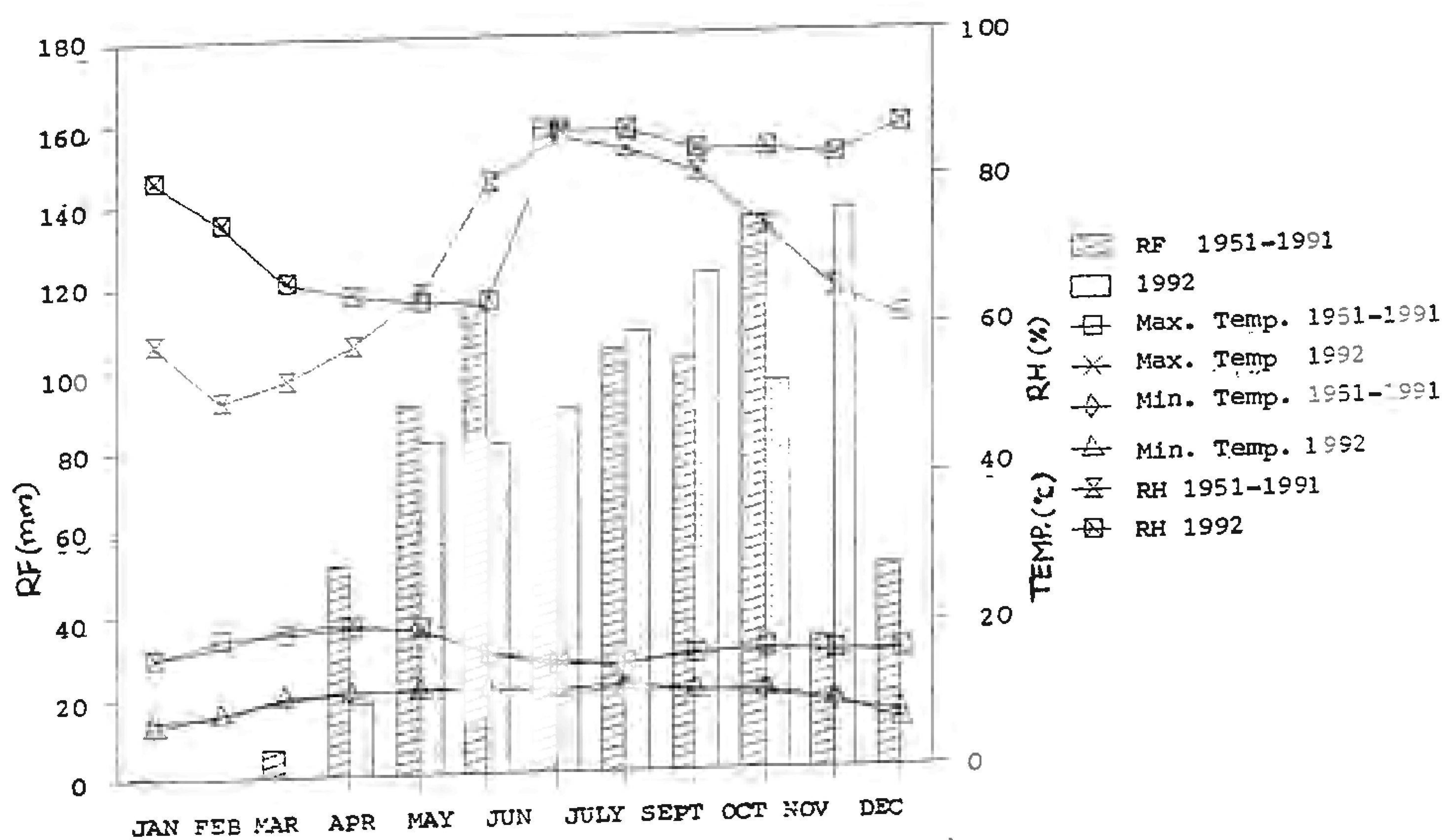

Fig. 1. Mean monthly temperature (minimum and maximum), relative humidity and rainfall during 1992 and the average of 41 years (1950-1991)

site were analysed for various physical and chemical properties. The data of soil analysis and the methods employed are given in table 2.

3.4 EXPERIMENTAL DETAILS

3.4.1 Design and layout

The experiment was laid out in a factorial randomised block design with three replications and the plan of lay out is given in Fig. 2.

3.4.2 Plot size

Gross plot = 4.0 m x 3.0 m

Net plot = 1.2.8 m x 2.6 m

3.4.3 Treatment details

There were 16 treatment combinations comprising of two genotypes and eight treatments as shown below:

Genotypes : V_1 = Moxden (Open pollinated variety)

V_2 = KBSH-1 (Single cross hybrid)

The salient features of the genotypes are given in Table 3.

Treatments :	T_1 = Control	(Water spray)
	T_2 = Maleic hydrazide	(250 ppm)
	T_3 = TIBA	(50 ppm)
	T_4 = Cycocel	(1000 ppm)
	T_5 = Mepiquat chloride	(100 ppm)
	T_6 = Mepiquat chloride	(250 ppm)
	T_7 = Mepiquat chloride	(500 ppm)
	T_8 = Mepiquat chloride	(1000 ppm)

LEGEND

V_1 = Morden

V_2 = KBSH-1

T_1 = Control

T_2 = Maleic hydrazide (250 ppm)

T_3 = TIBA (50 ppm)

T_4 = CCC (1000 ppm)

T_5 = Mepiquat chloride (100 ppm)

T_6 = Mepiquat chloride (250 ppm)

T_7 = Mepiquat chloride (500 ppm)

T_8 = Mepiquat chloride(1000 ppm)

V_1T_8	V_2T_2	V_2T_1	V_1T_4	V_1T_6	V_1T_3
V_2T_1	V_1T_1	V_2T_8	V_1T_6	V_1T_5	V_1T_4
V_1T_5	V_1T_6	V_1T_3	V_2T_2	V_2T_5	V_2T_4
V_1T_7	V_1T_2	V_1T_8	V_2T_5	V_2T_7	V_1T_2
V_2T_5	V_2T_3	V_2T_3	V_2T_7	V_1T_1	V_2T_6
V_1T_3	V_2T_4	V_1T_2	V_2T_6	V_2T_1	V_2T_8
V_2T_6	V_2T_8	V_1T_7	V_1T_5	V_2T_3	V_2T_2
V_2T_7	V_1T_4	V_2T_4	V_1T_1	V_1T_7	V_1T_8
R-I		R-II		R-III	

Fig. 2. Plan of layout of the experiment

Table 3: Salient features of sunflower genotypes for the investigation

Characters	Morden	KBSH-1 ("Kiran")
Parentage	Selection from "Cenianka-65"	CMS 234 x 6D-1
Duration (days)	80-90	95-100
Plant height (cm)	90-120	120-150
Stem diameter (cm)	1.25-1.70	1.75-2.25
Head diameter (cm)	12-15	15-17
100-seed weight (g)	3-4	4.1-4.2
Oil content (%)	38-42	42-44
Yield (kg/ha)	10-15	25-28
Reaction to major diseases	Suceptible to rust and leaf spot diseases	Moderatly resistant to rust and leaf spot diseases

3.4.4 Treatment imposition

Foliar application of growth retardants at different concentrations as described in 3.4.3 was done at 45 days after sowing in both the genotypes.

3.5 CULTURAL PRACTICES

3.5.1 Land preparation

The land was ploughed and harrowed twice and then smoothened with a wooden plank to bring it to a fince tilth to facilitate uniform sowing. Plots were prepared as per the plan given in Fig.2.

3.5.2 Seed source

Seeds were obtained from the Senior Scientist (oilseeds), Main Research Station, Dharwad and Associate Director of Research, Regional Research Station, UAS, Dharwad.

3.5.3 Sowing of seeds and spacing

A seed rate of 8 kg/ha was used and sowing was taken up by hand dibbling with inter-row spacings of 45 and 60 cm for Morden and KBSH-1 respectively. Intra-row spacing of 20 cm was maintained in the two genotypes. Thinning was done 15 days after sowing to maintain one seedling per hill. The seeds were dibbled on 28 January 1992.

3.5.4 Fertilizer application

Furrows were made with the help of a marker at a distance of 60 cm. Recommended dose of 62.5:75:62.5 kg NPK/ha was applied. 50 per cent of nitrogen along with full dose of P_2O_5 and K_2O was applied at the time of sowing and the rest 50 per cent of nitrogen was applied 5 cm away and 5 cm below the soil at 30 days after sowing (DAS).

3.5.7 After care

Only one hand weeding and two interculture operations at 20 and 40 DAS were done in order to keep the plots free from weeds. Mancozeb spray @ 2 ml/l was under takne at 30, 55 and 65 DAS to control leaf spot disease. Endosulfon @ 2 ml/l spray was taken up at flower bud initiation stage and 15 days after it, to control leaf eating catterpillers.

3.5.8 Harvesting

The genotypes differed in their maturity period and hence the crop was harvested at physiological maturity of each of the genotypes as follows:

Morden- 27 April 1992

KBSH - 9 May 1992

3.6 COLLECTION OF EXPERIMENTAL DATA

Five plants from each plot were tagged randomly on 35th day after sowing for recording various morphological observations and yield attributes.

3.6.1 MORPHOLOGICAL CHARACTERS

3.6.1.1 Plant height

Plant height was measured from the base of the plant to the tip of the stem at 30, 55, 65, 75, 85 DAS and at harvest. Measurements were taken from 5 plants in each treatment tagged earlier and the average height was calculated and expressed in cm.

3.6.1.2 Stem diameter

The sunflower stem is tapering both upwords and downwords, except in the centre. To maintain uniformity, the stem girth was measured at the middle internode of the plant using a vernier caliporse (Chidananda, 1974) and given in cm.

3.6.1.3 Number of green leaves

The number of green leaves from top to bottom of the plants was counted in the tagged plants at 30, 55, 65, 75, 85 DAS and at harvest, the average was worked out and expressed as no. of green leaves per plant.

3.6.1.4 Days to 50 per cent flowering

One row was selected in each plot for recording this observation. The number of days required for the florets to appear in 50 per cent of the plants in the selected row was recorded as days to 50 per cent flowering.

3.6.1.5 Days to physiological maturity

The indication of physiological maturity in sunflower is the appearance of lemon yellow colour on the back side of the head. The number of days required for such a change in at least 50% of the total population was recorded and indicated as days to physiological maturity.

3.6.1.6 Dry matter production and its distribution

Five plants were uprooted at random in each treatment and seperated in to leaf, stem and reproductive parts. These samples were air dried and then dried in hot air oven at 80°C to a constant weight and their dry weight was recorded. The dry weight of different plant parts were recorded at 30, 55, 65, 75, 85 DAS and at harvest and expressed on per plant basis.

3.6.1.7 Measurement of leaf area

Leaf area was determined using leaf disc method. Twenty leaf discs having a known diameter were collected randomly from top 4-6 fully expanded leaves of the plant. As far as possible, the mid rib was avoided. The discs thus collected and rest of the leaves were dired seperately in hot air oven at 80°C for 72 hrs. The dry weight of leaf discs and rest of the leaves was recorded and the leaf area was calculated using the following formula.

$$\text{Leaf area} = \frac{a \times w}{b} \times \frac{1}{100} = dm^2/\text{plant}$$

Where,

a = leaf area (cm^2) of 20 circular discs

b = dry weight (g) of 20 circular discs

w = dry weight (g) of rest of the leaves.

3.6.2 GROWTH PARAMETERS

Various growth parameters were calculated from the data obtained on dry weight of different plant parts and the leaf area as described below.

3.6.2.1 <u>Leaf area index</u> (LAI)

The LAI was calculated by using the formula,

$$LAI = \frac{\text{Leaf area/plant}}{\text{Land area/plant}}$$

3.6.2.2 <u>Leaf area duration</u> (LAD)

LAD for various growth periods was worked out as per the formula of power *et al.* (1967)

$$LAD = \frac{L_i + (L_i + 1)}{2} \quad (t_2 - t_1) \text{ days}$$

LAD = Leaf area duration (days)

LI = LAI at i^{th} stage

L_i+1= LAI at $(i + 1)^{th}$ stage

t_1 and t_2 = time interval between i and $(i + 1)^{th}$ stage

3.6.2.3 Absolute growth rate (AGR)

It expresses the dry weight increase per unit time and was calculated by using the following formula of

$$AGR = \frac{W_2 - W_1}{t_2 - t_1} \quad g/day$$

Where,

W_1 and W_2 are the dry weights of the plant at time t_1 and t_2.

3.6.2.4 Relative growth rate (RGR)

It is rate of increase in the dry weight per unit dry weight already present and was calculated by the formula of

$$RGR = \frac{\log_e W_2 - \log_e W_1}{(t_2 - t_1)} \quad g/g/day$$

Where,

W_1 = Dry weight of the plant at time t_1

W_2 = Dry weight of the plant at time t_2

3.6.2.5 Crop growth rate (CGR)

Crop growth rate is the rate of dry matter production per unit ground area per unit time (Watson, 1952). It was calculated by using the formula,

$$CGR = \frac{(W_2 - W_1)}{(t_2 - t_1)} \times \frac{1}{A} \quad g/dm^2/day$$

Where,

W_1 = Dry weight of the plant (g) at time t_1

W_2 = Dry weight of the plant (g) at time t_2

A = Land area (dm^2)

3.6.2.6 Net assimilation rate (NAR)

Net assimilation rate is the rate of dry weight increase per unit leaf area per unit time (Watson, 1952). It was calculated as follows,

$$NAR = \frac{(W_2 - W_1)}{(t_2 - t_1)} \frac{(Log_e L_2 - Log_e L_1)}{(L_2 - L_1)} \times g/dm^2/day$$

Where,

L_1 and W_1 = Leaf area (dm^2) and dry weight of the plant (g) at time t_1

L_2 and W_2 = Leaf area (dm^2) and dry weight of the plant (g) at time t_2

3.6.2.7 Specific leaf weight (SLW)

The specific leaf weight indicates the leaf thickness and was determined by the method of

$$SLW = \frac{\text{Leaf dry weight (g)}}{\text{Leaf area } (dm^2)} \quad g/dm^2$$

3.6.2.8 Specific leaf area (SLA)

The inverse of specific leaf weight is the specific leaf area and was calculated by using the following formula.

$$SLA = \frac{\text{Leaf area } (dm^2)}{\text{Leaf dry weight } (g)} dm^2/g$$

3.6.2.9 Harvest index (HI)

The harvest index was calculated by using the formula of Donald (1962) and expressed as percentage

$$HI = \frac{\text{Economic yield}}{\text{Biological yield}} \times 100$$

3.6.3 YIELD AND YIELD COMPONENTS

Five plants tagged earlier and used for various morphological characters were separated and used for recording yield and other yield components.

3.6.3.1 Head diameter (cm)

The distance between the two diagonally opposite edges of the head was recorded as the head diameter at different stages of crop growth.

3.6.3.2 Seed weight per plant

The dried heads were threshed to seperate the seeds and the weight of the seeds was recorded and expressed as g/plant.

3.6.3.3 100-seed weight

100-seeds were counted from the samples drawn from seed yield of each plot and the weight of 100-seeds was recorded and expressed in g.

3.6.3.4 <u>Per cent of filled seeds per head</u>

Per cent of filled seeds per head was computed by the formula,

$$\text{Seed filling (\%)} = \frac{\text{No. of filled seeds/head}}{\text{Total No. of seeds/head}} \times 100$$

where,

Total No. of seeds/head = filled seeds + unfilled seeds

3.6.3.5 <u>Seed yield</u>

The air dried heads from each net plot were threshed, cleaned and the weight of seeds was recorded and expressed in g. Based on the seed yield per net plot, the seed yield per hectare was calculated and expressed in Q/ha.

3.6.3.6 <u>Oil yield</u>

Oil yield per hectare was worked out by multiplying oil content and seed yield per hectare and expressed in kg/ha.

3.6.4 BIOCHEMICAL STUDIES

3.6.4.1 <u>Estimation of chlorophyll content</u>

Total chlorophyll, Chl.a and Chl. b contents were determined following the method of Arnon (1949) at 55, 65, 75 and 85 MAS.

Fresh leaves from top of the canopy were brought in an ice box from the field and were cut in to small pieces. About

200 mg of leaves were weighed from each sample and were homogenized with pure acetone. The extract was filtered through Whatman No.1 filter paper and washed twice with 80 per cent acetone. The final volume of the extract was made to 25 ml. The absorbance of the extract was measured at 643,652 and 663 nm in ultraspec double beam spectrophotometer (Model CL-54). The total chlorophyll, Chlorophyll and chlorophyll b contents were calculated using the formula.

$$\text{Total chlorophyll} = \frac{(20.2 \times A_{645}) + (8.02 \times A_{663})}{a \times 100 \times w} \text{ mg/g fr.wt.}$$

$$\text{Chl.a } 12.7\ (A_{663}) - 2.69\ (A_{645}) \times \frac{25}{1000 \times 0.25} \text{ mg/g fr. wt.}$$

$$\text{Chl. b} = 22.9\ (A_{645}) - 4.68\ (A_{663}) \times \frac{25}{1000 \times 0.25} \text{ mg/g fr.wt.}$$

Where,

A_{645} = Absorbance of the extract at 645 nm

A_{663} = Absorbance of the extract at 663 nm

A a = Path length of light in the cuvette (1 cm)

a = Volume of the extract (25 ml)

w = Fresh weight of the sample (0.25 g0

3.6.4.2 Estimation of Nitrogen and Protein Content

The total nitrogen was estimated by Microkjeldhal digestion method (Yoshida *et al.*, 1972). To a pre-digested plant material, the mixture of potassium sulphate, copper sulphate and selenium powder were added and heated on hot plate until the clear solution was noticed. After repeated washings, the volume was made up to 25 ml with distilled water and from this, 10 ml of the aliquat was transferred to a distillation assembly. Ammonia was distilled by using 10 ml of 40% NaOH and it was collected in boric acid mixed indicator solution. Nitrogen was estimated by titrating the liberated ammonia against standard sulphuric acid and expressed in percentage on dry weight basis.

The crude protein was calculated by multiplying the nitrogen per cent with correction factor 6.25 (Jackson, 1967). The crude protein content was calculated by using the following formula,

Crude Protein (%) = Nitrogen per cent x 6.25

3.6.4.3 Estimation of soluble protein

Soluble protein content of the leaf material was extracted by using chilled phosphate buffer solution (pH 6.6) and centrifuging the extract for 30 minutes at 4000 rpm at 4°C. Then, 1 ml of 0.5 N NaOH and 5 ml of reagent A (i.e. soidum carbonate(2%) + NaOH + copper reagent) were added to the 2-3 ml aliquat of the extract. After allowing it to stand for 10 minutes, 0.5 ml of reagent B (Folin-ciocculteau reagent) was added rapidly while stirring constantly. Then, after 30 minutes, the absorbance of the solution was measured at 570 nm in a spectrophotometer (Model CL-54). Protein content was calculated from standard curve prepared by using Bovine serum albumin (BSA).

3.6.4.4 Estimation of Oil

The seed oil content was determined by Nuclear Magnetic Resonance (NMR) instrument. It is a rapid and non-destructive method of oil detectron. By NMR 'H' content in the seed is measured. In an atomic nucleus, protons, the charged particles (+) are associated with magnetic field, and protons behave like small magnet and are moving both Clockwise and anti-clockwise. In the sample, threre are 'H' molecules and the sample containing 'H' is kept in the magnetic field. When put in to strong electro-magnet (NMR), a strong electromagnetic field is created in poles and the sample is kept between the poles. The sample 'H' is forced to move in the direction of Magnetic force. Most of the nuclei follow magnetic field, while few move in opposite direction which are at high energy level. More protons are with low energy. The difference in the energy level is proportional to the number of protons.

The oil is in the liquid phase. The 'H' is relatively mobile in the liquid phase than in solid phase that reduces the contribution of solid 'H' and water is avoided by taking further long distance. The sample should be brought to 4% moisture, before taking readings on NMR.

3.7 STATISTICAL ANALYSIS

Fischer's method of analysis of variance was applied for the analysis of the data and the interpretation of results as suggested by Panse and Sukhatme (1967) and Sundaraj et al. (1972). The level of significance used in 'F' and 't' tests was P= 0.05. Critical difference(CD) values were calculated at per cent probability level, wherever 'F' test was significant.

CHAPTER-IV

EXPERIMENTAL RESULTS

IV EXPERIMENTAL RESULTS

A field experiment was conducted during summer 1992 to study the influence of growth retardants on various morphological, biochemical, physiological parameters and yield potentiality of sunflower genotypes. The crop was sprayed with different growth retardants at different concentrations at 45 DAS. The response of genotypes was studied for various morphological, growth, physiological, phenological, biochemical parameters at different growth stages. The results obtained are presented in this chapter.

4.1 OCCURRENCE OF PHENOLOGICAL STAGES

The data indicated that both days to 50 per cent flowering and physiological maturity differed significantly among genotypes, whereas, treatments differed significantly only with respect to days to physiological maturity, and their interaction effects were found to be non-significant in both the parameters (Table 4). Among the genotypes, KBSH-1 took maximum days for 50 per cent flowering and days to physiological maturity. Days to physiological maturity was significantly reduced by the treatment T_8 in both the genotypes as compared to other treatments and rest of the treatments were found to be non-significant with each other.

4.2 MORPHOLOGICAL PARAMETERS

4.2.1 Plant height

The plant height increased continuously from 30 DAS

Table 4: Influence of growth retardants on days to 50 per cent flowering and physiological maturity

Treatments		Days to 50 per cent flowering			Days to physiological maturity		
		Morden	KBSH-1	Mean	Morden	KBSH-1	Mean
T_1 Control		49.3	60.0	54.6	74.3	84.0	79.1
T_2 Maleic hydrazide	(250 ppm)	49.3	60.3	54.8	74.3	84.0	79.1
T_3 TIBA	(50 ppm)	49.3	60.3	54.6	74.3	84.0	79.1
T_4 Cycocel	(1000 ppm)	48.6	60.0	54.3	74.0	84.0	79.0
T_5 Mepiquat chloride	(100 ppm)	48.9	60.0	54.5	74.3	84.0	79.1
T_6 Mepiquat chloride	(250 ppm)	48.6	60.0	54.3	74.0	84.0	79.0
T_7 Mepiquat chloride	(500 ppm)	48.5	61.0	54.8	73.6	83.3	78.5
T_8 Mepiquat chloride	(1000 ppm)	50.0	61.3	55.6	72.3	81.6	76.9
Mean		49.1	60.3	54.7	73.9	83.9	78.7

	Days to 50 per cent flowering: S.Em ±	Days to 50 per cent flowering: C D at 5%	Days to physiological maturity: S.Em ±	Days to physiological maturity: C D at 5%
Genotypes	0.33	0.96	0.26	0.76
Treatments	0.67	N.S	0.53	1.52
Interaction	0.94	N.S	0.75	N.S

until harvest in all the treatments and in both the genotypes (Table 5). It was observed that there was a marginal increase in the plant height between the stages in KBSH-1 as compared to Morden. Genotypes and treatments differed significantly at all the growth stages except, for the treatments at 30 and 55 DAS. However, the interaction effect was non-significant at all the growth stages.

Among the genotypes, the plant height was maximum in KBSH-1 at all the growth stages and in all the treatments over morden. Among the treatments, T_8 recorded a significant reduction in plant height over all the treatments at 65, 75 DAS and at harvest. At 65 DAS, T_8 recorded the least plant height (109.9 cm) followed by T_4 (119.1 cm) and T_7 (118.8 cm). However, no significant differences were observed between the treatments T_2, T_3, T_4, T_5, T_6 and T_7. A similar trend was observed even at 75 DAS and at harvest. The per cent reduction in plant height was maximum at all stages in both the genotypes. The least reduction in plant height was observed in the treatment T_5 in both the genotypes at all the stages.

4.2.2 Number of green leaves

The number of green leaves increased from 30 to 55 DAS in morden and till 75 DAS in KBSH-1 in all the treatments (Table 6). It was observed that there was a marginal increase in the number of leaves between the stages in KBSH-1 as compared to Morden. Genotypes differed significantly at all

Table 5: Influence of growth retardants on plant height (cm) at different growth stages in sunflower genotypes

Treatments		Days after sowing: 30			55			65			75			Harvest		
		Morden	KBSH-1	Mean	Morden	KBSH-1	Mean	Morden	KBSH-1	Mean	Morden	KBSH-1	Mean	Morden	KBSH-1	Mean
T_1 Control		19.6	25.4	25.4	100.0	139.3	119.8	104.5	145.1	124.8	106.1	147.4	126.7	106.5	148.0	127.2
T_2 Maleic hydrazide	(250 ppm)	19.7	25.0	22.4	97.8	135.8	116.8	102.0	141.0	121.6	102.6	142.9	122.8	103.0	143.2	123.1
T_3 TIBA	(50 ppm)	19.7	25.5	22.6	98.3	137.1	117.7	103.0	143.1	123.0	105.7	146.4	126.0	106.0	147.0	126.5
T_4 Cycocel	(1000 ppm)	19.5	25.4	22.4	97.3	130.6	113.9	108.3	137.5	119.1	101.8	139.8	120.8	102.3	140.2	121.2
T_5 Mepiquat chloride	(100 ppm)	19.8	25.2	22.5	99.2	138.1	118.7	103.2	144.3	123.8	105.7	146.7	126.2	106.0	147.0	126.5
T_6 Mepiquat chloride	(250 ppm)	19.5	25.0	22.3	95.6	137.7	116.3	102.7	142.6	122.7	103.1	145.1	124.1	103.0	145.3	124.1
T_7 Mepiquat chloride	(500 ppm)	20.0	25.4	22.7	95.3	132.9	114.1	100.9	138.6	119.8	102.2	141.1	121.6	102.4	141.3	121.3
T_8 Mepiquat chloride	(1000 ppm)	19.9	25.0	22.5	89.9	121.8	105.9	95.5	124.3	109.9	96.0	128.1	112.0	96.2	128.3	112.2
Mean		197	25.2	22.5	97.0	134.1	11[illegible].5	101.6	139.6	120.6	102.9	142.2	122.5	103.2	142.5	122.8

	30: S.Em ±	C D at 5%	55: S.Em ±	C D at 5%	65: S.Em ±	C D at 5%	75: S.Em ±	C D at 5%	Harvest: S.Em ±	C D at 5%
Genotypes	0.93	2.69	2.47	7.14	0.89	2.58	1.49	4.31	1.49	4.31
Treatments	1.87	N.S	4.95	N.S	1.79	6.16	2.98	8.63	2.98	8.62
Interaction	2.65	N.S	6.99	N.S	2.53	N.S	4.22	N.S	4.22	N.S

the growth stages whereas, treatments differed significantly only at 55, 65 and 75 DAS. However, the interaction effect was non significant at all the growth stages.

Among the genotypes, the number of leaves were higher in KBSH-1 at all the growth stages and in all the treatments over Morden. At 55 and 75 DAS, the treatment, T_8 recorded a significant reduction in number of leaves over rest of the treatments except T_4 and T_7. While at 65 DAS, T_8 recorded a significant reduction in number of leaves over all the treatments. At 55 DAS also, T_8 recorded the least number of leaves (13.9) followed by T_4 (15.0) and T_7 (15.2). However, no significant differences were observed between T_2, T_3, T_4, T_5, T_6 and T_7 treatments. A similar trend was noticed even at 65 and 75 DAS. The per cent reduction in number of leaves was maximum in T_8 at all the growth stages in both the genotypes.

4.2.3 Stem diameter

The maximum stem diameter was observed at 60 DAS in all the treatments and in both the genotypes (Table 7). Genotypes differed significantly with respect to stem diameter at all the growth stages, whereas treatments and interaction effects were found to be non-significant. However, at 60 DAS, the treatment T_8 had the least stem diameter (1.46 cm) followed by T_7 (2.59 cm) and T_4 (1.58 cm). A similar trend was observed even at harvest. The per cent decrease in stem diameter was maximum in T_8 at both 60 DAS and at harvest in both the

Table 6 : Influence of growth retardants on number of leaves at different growth stages in sunflower genotypes

Treatments		Days after sowing																	
		30			55			65			75			85			Harvest		
		Morden	KBSH-1	Mean	Morden	KBSH-1	Mean	Morden	KBSH-1	Mean	Morden	KBSH-1	Mean	Morden	KBSH-1	Mean	Morden	KBSH-1	Mean
T_1 Control		7.8	8.4	8.1	14.21	18.51	16.3	12.2	20.3	16.3	9.6	21.3	15.4	3.7	14.9	9.3	3.7	6.2	5.0
T_2 Maleic hydrazide	(250 ppm)	7.7	6.7	8.2	13.9	18.1	16.0	12.0	19.8	15.9	9.3	20.3	14.8	3.6	14.1	8.8	3.6	6.0	4.8
T_3 TIBA	(50 ppm)	7.6	8.4	8.9	13.8	18.2	16.0	12.2	19.8	16.0	9.1	20.6	14.8	3.7	14.5	9.1	3.7	6.2	5.0
T_4 Cycocel	(1000 ppm)	7.5	8.5	8.0	13.3	16.7	15.0	11.0	18.8	14.9	9.2	19.5	14.3	3.7	14.4	9.0	3.7	5.9	4.6
T_5 Mepiquat chloride	(100 ppm)	7.6	9.6	8.1	13.9	18.5	16.2	12.1	20.0	16.1	9.5	21.0	15.2	3.7	14.9	9.3	3.7	6.2	5.0
T_6 Mepiquat chloride	(250 ppm)	7.8	8.5	8.1	13.8	18.2	16.0	11.6	19.9	15.9	9.3	20.6	15.0	3.6	14.5	9.0	3.6	6.0	4.7
T_7 Mepiquat chloride	(500 ppm)	7.5	8.5	8.0	13.7	16.7	15.2	11.8	19.2	15.5	9.3	20.0	14.6	3.6	14.4	9.0	3.6	5.9	4.7
T_8 Mepiquat chloride	(1000 ppm)	7.6	8.5	8.0	12.8	15.1	13.9	10.7	16.2	13.5	8.5	17.5	13.0	3.6	13.4	8.5	3.6	5.7	4.6
Mean		7.6	8.5	8.1	13.7	17.5	15.6	11.7	19.2	15.5	9.1	20.1	14.6	3.6	14.3	8.9	3.6	5.8	4.7
		S.Em ±	C D at 5%		S.Em ±	C D at 5%		S.Em ±	C D at 5%		S.Em ±	C D at 5%		S.Em ±	C D at 5%		S.Em ±	C D at 5%	
Genotypes		0.19	0.56		0.25	0.73		0.24	0.68		0.31	0.89		0.22	0.63		0.19	0.54	
Treatments		0.40	N.S		0.50	1.46		0.47	1.36		0.62	1.78		0.44	N.S		0.38	N.S	
Interaction		0.55	N.S		0.71	N.S		0.67	N.S		0.87	N.S		0.62	N.S		0.53	N.S	

Table 7: Influence of growth retardants on stem diameter (cm) at different growth stages in sunflower genotypes

Treatments		Days after sowing 30			60			Harvest		
		Morden	KBSH-1	Mean	Morden	KBSH-1	Mean	Morden	KBSH-1	Mean
T_1 Control		0.99	1.17	1.08	1.44	1.83	1.63	1.36	1.80	1.58
T_2 Maleic hydrazide	(250 ppm)	0.98	1.15	1.06	1.41	1.78	1.59	1.34	1.77	1.55
T_3 TIBA	(50 ppm)	0.99	1.18	1.08	1.44	1.83	1.63	1.36	1.80	1.58
T_4 Cycocel	(1000 ppm)	0.98	1.19	1.09	1.38	1.78	1.58	1.32	1.75	1.53
T_5 Mepiquat chloride	(100 ppm)	0.99	1.15	1.07	1.44	1.81	1.62	1.36	1.80	1.58
T_6 Mepiquat chloride	(250 ppm)	0.98	1.16	1.07	1.42	1.82	1.62	1.35	1.78	1.56
T_7 Mepiquat chloride	(500 ppm)	0.98	1.17	1.08	1.42	1.77	1.59	1.32	1.74	1.53
T_8 Mepiquat	(1000 ppm)	0.99	1.15	1.06	1.30	1.63	1.46	1.23	1.62	1.42
Mean		0.99	1.16	1.07	1.40	1.78	1.59	1.33	1.77	1.55

	S.Em ±	C D at 5%	S. Em ±	C D at 5%	S.Em ±	C D at 5%
Genotypes	0.02	0.05	0.02	0.07	0.02	0.07
Treatments	0.03	N.S	0.05	N.S	0.05	N.S
Interaction	0.05	N.S	0.07	N.S	0.07	N.S

genotypes. The least decrease was noticed in the treatments T_2 and T_5 in both the genotypes and at both 60 DAS and at harvest.

4.2.4 Head diameter

The data on head diameter revealed an increasing trend from 55 DAS until harvest in all the treatments and in both genotypes (Table 8). There was no significant difference between the genotypes with respect to head diameter at all the stages except at 55 DAS, where Morden had significantly higher head diameter over KBSH-1. None of the treatments and interaction effects were significant at any of their growth stage. However, at harvest, the treatment T_8 had maximum head diameter (14.1 cm) followed by T_4 (13.5 cm) and T_7 (13.3 cm). While T_2 reduced the head diameter at all the stages and in both genotypes. The maximum per cent increase in head diameter was noticed in T_8.

4.2.5 Stem dry weight

Table 9 revealed that the stem dry weight increased from 30 DAS until 65 DAS in Morden and till 75 DAS in KBSH-1 and reduced slightly thereafter. Only the genotypes and treatments differed significantly at all the growth stages except for treatments at 30 and 55 DAS. The interaction effect was non-significant with respect to dry matter accumulation in the stem at all the growth stages.

Table 8: Influence of growth retardants on head diameter (cm) at different growth stages in sunflower genotypes

Treatments		Days after sowing 55			65			75			Harvest		
		Morden	KBSH-1	Mean	Morden	KBSH-1	Mean	Morden	KBSH-1	Mean	Morden	KBSH-1	Mean
T_1 Control		8.7	4.4	6.6	11.6	11.5	11.5	12.5	12.7	12.6	12.7	13.1	12.9
T_2 Maleic hydrazide	(250 ppm)	8.4	4.2	6.3	11.4	11.2	11.3	12.3	12.5	12.4	12.5	12.7	12.6
T_3 TIBA	(50 ppm)	8.8	4.4	6.6	11.7	11.5	11.6	12.5	12.8	12.6	12.8	13.3	13.0
T_4 Cycocel	(1000 ppm)	8.9	4.5	6.7	12.1	11.8	12.0	12.9	13.2	13.0	13.0	13.8	13.5
T_5 Mepiquat chloride	(100 ppm)	8.7	4.5	6.6	11.7	11.5	11.6	12.5	13.0	12.8	12.8	13.4	13.1
T_6 Mepiquat chloride	(250 ppm)	8.9	4.5	6.7	11.7	11.5	11.6	12.6	13.3	12.9	12.8	13.5	13.1
T_7 Mepiquat chloride	(500 ppm)	8.9	4.6	6.7	11.7	11.8	11.8	12.7	13.3	13.0	12.9	13.8	13.3
T_8 Mepiquat chloride	(1000 ppm)	9.3	4.6	7.0	12.5	12.6	12.6	13.5	14.3	13.9	13.8	14.4	14.1
Mean		8.8	4.5	6.6	11.8	11.6	11.7	12.6	13.2	12.9	12.9	13.5	13.2
		S.Em ±	C D at 5%		S.Em ±	C D at 5%		S.Em ±	C D at 5%		S.Em ±	C D at 5%	
Genotypes		0.22	0.66		0.30	N.S		0.24	N.S		0.24	N.S	
Treatments		0.46	N.S		0.60	N.S		0.47	N.S		0.48	N.S	
Interaction		0.65	N.S		0.86	N.S		0.67	N.S		0.69	N.S	

Table 9: **Influence of growth retardants on stem dry weight (g/plant) at different growth stages in sunflower genotypes**

Treatments		Days after sowing: 30			55			65			75			Harvest		
		Morden	KBSH-1	Mean	Morden	KBSH-1	Mean	Morden	KBSH-1	Mean	Morden	KBSH-1	Mean	Morden	KBSH-1	Mean
T_1 Control		3.51	4.69	4.10	19.05	23.68	20.36	19.41	27.01	23.21	19.29	26.69	22.99	19.00	26.42	22.7[illegible]
T_2 Maleic hydrazide	(250 ppm)	3.68	4.12	4.12	18.21	22.98	20.59	18.54	26.19	22.36	18.50	24.33	21.42	18.60	25.65	22.12
T_3 TIBA	(50 ppm)	3.60	4.74	4.17	18.22	22.38	20.55	18.88	26.08	22.48	18.71	24.39	21.55	18.51	25.44	21.97
T_4 Cycocel	(1000 ppm)	3.34	4.72	4.03	17.96	22.32	20.14	18.09	25.76	21.93	18.51	23.87	21.19	18.20	24.93	21.56
T_5 Mepiquat chloride	(100 ppm)	3.52	4.70	4.12	18.61	23.04	20.82	18.50	26.41	22.45	19.10	24.96	22.03	18.90	26.29	22.59
T_6 Mepiquat chloride	(250 ppm)	3.42	4.69	4.06	18.32	22.94	20.63	18.69	26.44	22.56	18.72	24.44	22.58	18.55	25.99	22.27
T_7 Mepiquat chloride	(500 ppm)	3.40	4.70	4.05	17.73	22.50	20.12	18.11	25.69	21.90	18.57	24.29	21.43	18.31	25.30	21.80
T_8 Mepiquat chloride	(1000 ppm)	3.36	4.67	4.12	16.27	19.23	17.75	15.89	22.33	10.11	16.84	22.57	19.70	15.92	21.50	18.71
Mean		3.45	4.68	4.10	18.05	22.44	20.25	18.26	25.74	22.00	18.53	24.44	21.49	18.25	25.19	21.72

	S.Em ±	C D at 5%	S.Em ±	C D at 5%	S.Em ±	C D at 5%	S.Em ±	C D at 5%	S.Em ±	C D at 5%
Genotypes	0.07	0.22	0.38	1.11	0.36	1.05	0.25	0.68	0.31	0.89
Treatments	0.15	N.S	0.77	N.S	0.73	2.11	0.50	1.44	0.62	1.79
Interaction	0.22	N.S	1.08	N.S	1.03	N.S	0.88	N.S	0.87	N.S

Among the genotypes, KBSH-1 recorded higher stem dry weight over Morden at all the growth stages. Among the treatments, T_8 recorded a significant reduction in stem dry weight over rest of the treatments at 65, 75 DAS and at harvest. At 65 DAS, T_8 had the least stem dry weight (19.11 g/plant) followed by T_7 (21.9 g/plant) and T_4 (21.93 g/plant). However, no significant differences were noticed between T_2, T_3, T_5, T_6 and T_7 treatments. The same trend was continued at 75 DAS and at harvest.

4.2.6 <u>Leaf dry weight</u>

The leaf dry weight increased from 30 to 55 DAS in Morden and 40 to 65 DAS in KBSH-1 in all the treatments (Table 10). Significant differences in leaf dry weight among the genotypes and treatments were noticed at all the growth stages except at 40, 85 DAS and at harvest for treatments. No interaction effect was found significant with respect to dry matter accumulation in leaves at any growth stage.

The genotype KBSH-1 recorded higher leaf dry weight over Morden at all the growth stages and in all the treatments. Among the treatments, T_8 registered a significant reduction in leaf dry weight over all the treatments at 65 and 75 DAS. At 55 DAS, T_8 registered the least leaf dry weight (14.29 g/plant) followed by T_4 (15.13 g/plant) and T_7 (15.48 g/plant). However, the treatments T_2, T_3 T_4, T_5, T_6 and T_7 were all on par with each other. A similar trend was noticed in subsequent growth stages.

Table 10: Influence of growth retardants on leaf dry weight (g/plant) at different growth stages in sunflower genotypes

Treatments	Days after sowing																	
	30			55			65			75			85			Harvest		
	Morden	KBSH-1	Mean	Morden	KBSH-1	Mean	Morden	KBSH-1	Mean	Morden	KBSH-1	Mean	Morden	KBSH-1	Mean	Morden	KBSH-1	Mean
T_1 Control	5.12	6.03	5.57	12.99	20.53	16.76	10.41	24.70	17.55	7.01	21.96	14.49	4.00	15.51	9.75	4.00	7.62	5.81
T_2 Maleic hydrazide (250 ppm)	5.22	6.10	5.66	11.99	19.59	15.77	9.65	23.79	16.72	6.63	20.86	13.74	3.40	14.47	8.93	3.40	7.00	5.20
T_3 TIBA (50 ppm)	5.33	6.00	5.67	12.40	20.79	16.59	9.46	24.29	16.87	7.04	21.40	14.22	3.74	13.80	8.77	3.74	7.60	5.74
T_4 Cycocel (1000 ppm)	5.08	6.15	5.62	11.36	18.90	15.13	9.11	23.01	16.06	6.05	20.00	13.03	3.42	13.71	8.56	3.42	6.46	4.93
T_5 Mepiquat chloride (100 ppm)	5.32	6.09	5.70	12.71	19.77	16.24	9.70	24.18	16.94	6.86	21.22	14.04	3.51	15.33	9.42	3.51	7.25	5.38
T_6 Mepiquat chloride (250 ppm)	5.21	6.04	5.62	12.36	19.70	16.03	9.65	23.72	16.69	6.69	21.12	13.91	3.40	14.91	9.15	3.40	7.25	5.33
T_7 Mepiquat chloride (500 ppm)	5.20	6.21	5.70	12.05	18.91	15.48	9.59	23.80	16.70	6.58	20.40	13.50	3.42	13.91	8.66	3.42	6.25	4.83
T_8 Mepiquat chloride (1000 ppm)	5.19	6.16	5.70	10.54	18.04	14.29	8.88	21.09	14.98	5.37	17.72	11.54	3.03	13.34	8.18	3.03	4.80	3.64
Mean	5.17	6.10	5.64	12.05	19.53	15.79	9.56	23.57	16.57	6.53	20.59	13.55	3.61	14.37	8.98	3.61	6.80	6.76

	30 S.Em ±	30 C D at 5%	55 S.Em ±	55 C D at 5%	65 S.Em ±	65 C D at 5%	75 S.Em ±	75 C D at 5%	85 S.Em ±	85 C D at 5%	Harvest S.Em ±	Harvest C D at 5%
Genotypes	0.14	0.41	0.19	0.56	0.18	0.53	0.28	0.81	0.25	0.72	0.28	0.81
Treatments	0.28	N.S	0.38	1.12	0.37	1.07	0.56	1.61	0.50	N.S	0.56	N.S
Interaction	0.40	N.S	0.55	N.S	0.52	N.S	0.79	N.S	0.71	N.S	0.79	N.S

4.2.7 Head dry weight

Table 11 revealed that head dry weight increased continuously from 55 DAS till harvest in both the genotypes and in all the treatments. It was observed that only genotypes and treatments differed significantly except for the treatments at 55, 65 and 75 DAS. The interaction effect was not significant with respect to dry matter accumulation in the head at all the growth stage.

Morden recorded significantly higher head weight at 55, 65 and 75 DAS as compared to KBSH-1 and thereafter a reverse trend was observed. During 85 DAS and at harvest, the treatment T_8 registered significant increase in head dry weight over all other treatments. At 85 DAS, the maximum head dry weight was recorded by T_8 (48.7 g/plant) followed by T_4 (46.0 g/plant) and T_7 (45.82 g/plant). However, treatments T_2, T_3, T_4, T_5, T_6 and T_7 did not differ significantly with each other. A similar trend was observed even at harvest.

4.2.8 Total dry matter accumulation

The total dry matter increased continuously from 30 to 75 DAS in Morden and till 85 DAS in KBSH-1 in all the treatments, and reduced thereafter at harvest (Table 12). It was observed that there was a marginal increase in the total dry weight between the stages in KBSH-1 as compared to Morden. Genotypes differed significantly at all the growth stages, while treatments differed significantly only at 55 DAS and the interaction effect was non-significant at all the growth stages.

Table 11. Influence of growth retardants on head dry weight (g/plant) at different growth stages in sunflower genotypes

Treatments		Days after sowing														
		55			65			75			85			Harvest		
		Morden	KBSH-1	Mean	Morden	KBSH-1	Mean	Morden	KBSH-1	Mean	Morden	KBSH-1	Mean	Morden	KBSH-1	Mean
T1 Control		6.31	3.09	4.70	20.47	10.99	15.23	37.62	26.17	31.89	39.31	49.37	44.33	39.31	52.62	45.96
T_2 Maleic hydrazide	(250 ppm)	5.94	2.79	4.36	20.58	10.02	15.30	38.17	25.99	32.18	39.95	51.37	45.66	39.95	53.62	46.78
T_3 TIBA	(50 ppm)	6.30	3.09	4.69	20.49	10.05	15.05	37.82	26.24	32.03	39.50	51.39	45.45	39.50	53.64	46.57
T_4 Cycocel	(1000 ppm)	6.45	3.51	4.98	21.04	10.40	15.72	38.75	27.11	32.93	40.88	51.82	46.00	40.88	54.86	47.87
T_5 Mepiquat chloride	(100 ppm)	6.34	3.16	4.75	20.69	10.01	15.35	37.80	26.50	32.15	39.52	50.57	45.04	39.52	52.65	46.09
T_6 Mepiquat chloride	(250 ppm)	6.35	3.11	4.73	20.55	10.17	15.36	38.02	26.56	32.29	39.83	50.55	45.19	39.83	53.04	46.44
T_7 Mepiquat chloride	(500 ppm)	6.45	3.15	4.80	20.77	10.21	15.49	38.24	27.11	32.67	39.93	51.71	45.82	39.93	53.70	46.82
T_8 Mepiquat chloride	(1000 ppm)	6.23	3.36	4.94	21.62	10.53	16.07	39.64	27.41	33.52	41.86	53.71	47.79	41.88	56.92	49.39
Mean		6.30	3.16	4.73	20.73	10.17	15.15	38.26	26.64	32.45	40.10	51.31	45.83	40.10	53.80	46.95

	55 S.Em ±	55 C D at 5%	65 S.Em ±	65 C D at 5%	75 S.Em ±	75 C D at 5%	85 S.Em ±	85 C D at 5%	Harvest S.Em ±	Harvest C D at 5%
Genotypes	0.41	0.40	0.33	0.96	0.33	0.97	0.32	0.93	0.30	0.82
Treatments	0.28	N.S	0.66	N.S	0.67	N.S	0.64	1.87	0.55	1.61
Interaction	0.40	N.S	0.94	N.S	0.95	N.S	0.91	N.S	0.78	N.S

It was noticed that the total dry matter production was maximum in KBSH-1 at all the growth stages and in all treatments as compared to Morden. While, among the treatments T_8 recorded significantly lower dry weight as compared to other treatments at 55 DAS. No significant differences were obtained between T_2, T_3, T_4, T_5, T_6 and T_7 treatments.

4.2.9 Leaf area

The leaf area measured at different growth stages indicated that it increased from 30 to 55 DAS in Morden and from 40 to 65 DAS in KBSH-1 and declined thereafter in all treatments (Table 13). Genotypes differed significantly at all growth stages except at 40 DAS. While significant effects on leaf area per plant due to treatments were observed only 65 and 75 DAS. However, the interaction effect was non-significant at all the growth stages.

Among the genotypes, KBSH-1 produced maximum leaf area as compared to Morden in all the treatments and at all the growth stages. During 65 and 75 DAS, the least leaf area per plant was registered in the treatment T_8 which was significantly lower over all the treatments. At 65 DAS, the least area per plant was recorded by T_8 (21.57 dm^2/plant) followed by T_4 (25.02 dm^2/plant) and T_7 (25.81 dm^2/plant). However, treatments T_2, T_3, T_4, T_5, T_6 and T_7 were on par with each other. At 75 DAS also, the least leaf area was recorded in T_8 in both Morden (8.59 dm^2/plant) and KBSH-1 (24.53 dm^2/plant).

Table 12: Influence of growth retardants on total dry matter production (g/plant) at different growth stages in sunflower genotypes

Treatments		30			55			65			75			85			Harvest		
		Morden	KBSH-1	Mean	Morden	KBSH-1	Mean	Morden	KBSH-1	Mean	Morden	KBSH-1	Mean	Morden	KBSH-1	Mean	Morden	KBSH-1	Mean
T_1 Control		8.63	10.72	9.67	38.35	47.30	42.82	50.29	62.70	56.49	63.92	74.82	69.37	62.31	91.57	76.94	62.31	86.66	74.46
T_2 Maleic hydrazide	(250 ppm)	8.90	10.22	9.56	36.15	45.35	40.75	48.77	60.00	55.12	63.30	71.18	67.24	61.95	90.17	76.06	61.95	86.18	74.06
T_3 TIBA	(50 ppm)	8.93	10.41	9.67	36.92	46.76	41.84	48.83	61.42	55.12	63.57	72.03	67.80	61.75	90.58	76.18	61.79	85.68	73.73
T_4 Cycocel	(1000 ppm)	8.42	10.87	9.64	35.77	44.73	40.25	48.24	59.17	53.70	63.31	70.98	67.14	62.50	90.00	76.25	61.50	84.12	72.81
T_5 Mepiquat chloride	(100 ppm)	8.84	10.79	9.81	37.66	45.18	41.42	48.89	60.60	54.74	63.76	72.68	68.22	61.93	90.83	76.38	61.93	86.19	74.06
T_6 Mepiquat chloride	(250 ppm)	8.63	10.73	9.68	37.03	45.75	41.39	48.89	60.33	54.61	63.47	72.12	67.79	61.78	89.90	75.84	61.78	86.28	74.03
T_7 Mepiquat chloride	(500 ppm)	8.60	10.91	9.75	36.23	44.56	40.39	48.47	59.70	54.18	63.39	71.80	67.59	61.66	89.91	75.78	61.66	85.25	73.45
T_8 Mepiquat chloride	(1000 ppm)	8.75	10.83	9.79	33.34	40.63	36.98	46.39	53.95	50.17	61.85	67.71	64.78	60.83	89.62	75.22	60.83	83.22	72.02
Mean		8.71	10.68	9.69	36.43	45.13	40.78	46.59	59.73	54.16	63.32	71.66	67.49	61.83	90.32	76.07	61.83	85.44	73.63

	S.Em ± (30)	C D at 5% (30)	S.Em ± (55)	C D at 5% (55)	S.Em ± (65)	C D at 5% (65)	S.Em ± (75)	C D at 5% (75)	S.Em ± (85)	C D at 5% (85)	S.Em ± (Harvest)	C D at 5% (Harvest)
Genotypes	0.18	0.52	0.54	1.56	0.69	1.99	0.55	1.60	0.85	2.47	1.28	3.71
Treatments	0.36	N.S	1.08	3.11	1.38	N.S	1.11	N.S	1.71	N.S	2.57	N.S
Interaction	0.51	N.S	1.53	N.S	1.95	N.S	1.57	N.S	2.41	N.S	3.63	N.S

Table 13: Influence of growth retardants on leaf area (dm²/plant) at different growth stages in sunflower genotypes

Treatments		Days after sowing (DAS) 30			55			65			75			85			Harvest		
		Morden	KBSH-1	Mean	Morden	KBSH-1	Mean	Morden	KBSH-1	Mean	Morden	KBSH-1	Mean	Morden	KBSH-1	Mean	Morden	KBSH-1	Mean
T_1 Control		11.48	12.18	11.83	25.72	33.30	29.51	17.42	32.56	27.99	10.99	33.70	22.18	6.17	23.59	14.85	0.68	0.96	0.82
T_2 Maleic hydrazide	(250 ppm)	11.15	12.32	11.74	24.12	31.63	27.87	15.39	37.17	26.28	9.93	20.35	20.14	5.09	21.05	13.07	0.56	0.84	0.70
T_3 TIBA	(50 ppm)	11.06	12.34	11.70	25.23	32.31	28.77	28.77	37.30	27.08	10.99	33.05	22.02	5.77	21.31	13.54	0.64	0.96	0.80
T_4 Cycocel	(1000 ppm)	11.58	12.05	11.79	23.23	31.32	27.27	14.75	34.69	24.72	9.00	28.63	18.77	4.90	19.38	12.14	0.54	0.77	0.65
T_5 Mepiquat chloride	(100 ppm)	10.86	12.20	11.56	25.61	31.96	28.78	16.37	38.25	27.61	10.76	32.29	21.52	5.42	22.97	14.08	0.60	0.90	0.75
T_6 Mepiquat chloride	(250 ppm)	11.05	12.37	11.71	24.50	31.74	28.12	15.47	37.92	26.70	10.17	[illegible]	20.61	5.25	21.69	13.47	0.58	0.87	0.72
T_7 Mepiquat chloride	(500 ppm)	10.69	12.44	11.56	24.12	30.15	27.13	14.94	36.69	25.81	10.16	29.63	20.09	5.20	20.24	12.72	0.57	0.75	0.66
T_8 Mepiquat chloride	(1000 ppm)	10.58	12.56	11.57	21.49	29.10	25.29	12.65	30.50	21.57	8.59	24.53	16.21	4.22	16.95	10.58	0.46	0.50	0.48
Mean		11.05	12.31	11.68	24.25	31.44	27.84	15.24	36.46	25.85	10.07	30.15	20.11	5.21	20.90	13.06	0.57	0.82	0.69

	30 S.Em ±	30 C D at 5%	55 S.Em ±	55 C D at 5%	65 S.Em ±	65 C D at 5%	75 S.Em ±	75 C D at 5%	85 S.Em ±	85 C D at 5%	Harvest S.Em ±	Harvest C D at 5%
Genotypes	0.45	N.S	0.68	1.96	0.58	1.68	0.62	1.80	0.56	1.62	0.06	0.17
Treatments	0.91	N.S	1.35	N.S	1.16	3.36	1.24	3.60	1.11	N.S	0.12	N.S
Interaction	1.28	N.S	1.91	N.S	1.65	N.S	1.76	1.58	N.S	1.40	0.16	N.S

LEGEND

T_1	=	Control	
T_2	=	Maleic hydrazide	(250 ppm)
T_3	=	TIBA	(50 ppm)
T_4	=	CCC	(1000 ppm)
T_5	=	Mepiquat chloride	(100 ppm)
T_6	=	Mepiquat chloride	(250 ppm)
T_7	=	Mepiquat chloride	(500 ppm)
T_8	=	Mepiquat chloride	(1000 ppm)

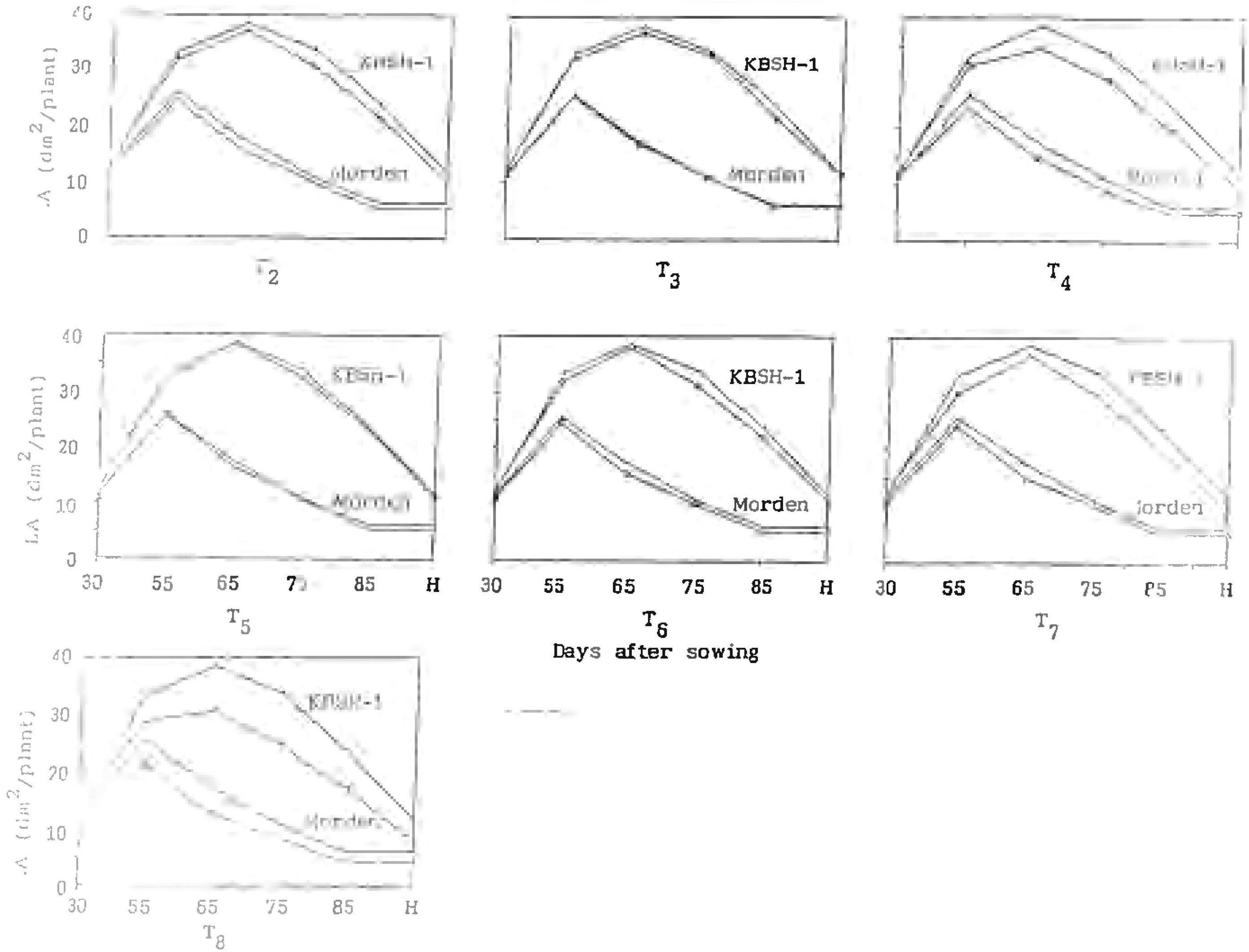

FIG.2 INFLUENCE OF GROWTH RETARDANTS ON LEAF AREA (dm^2/plant) AT DIFFERENT GROWTH STAGES IN SUNFLOWER GENOTYPES.

The maximum leaf area was recorded in control of both the varieties followed by T_3 and T_5.

4.2.10 Leaf area index

The data on LAI (Table 14) indicated that the leaf area index was maximum at 55 and 65 DAS in Morden and KBSH-1, respectively and decreased thereafter in all the treatments of both the genotypes. Genotypes differed significantly at all the growth stages except at 55 DAS. Significant effects on leaf area index due to treatments were observed only at 65 and 75 DAS. However, the interaction effect was non-significant with respect to leaf area index at all the growth stages.

It was observed that the genotype Morden had higher leaf area index at 30 and 55 DAS over KBSH-1 and thereafter a reverse trend was obtained in all the treatments. During 65 and 75 DAS, T_8 recorded significantly lower leaf area index over all other treatments. At 65 DAS, the least leaf index was recorded in T_8 (106), and non-significant differences were observed between T_2, T_3, T_4, T_5, T_6 and T_7 treatments. A similar trend was noticed at other growth stages also.

4.2.10 [illegible]

The leaf area duration decreased continuously from 30-55 DAS until harvest in both the genotypes (Table 15). Genotypes and treatments differed significantly at all growth stages except for the treatments at 30-55 DAS. The interaction effect was significant at any of the growth stages.

Table 14: Influence of growth retardants on leaf area index (LAI) at different growth stages in sunflower genotypes

Treatments		Days after sowing 30			55			65			75			85			At Harvest		
		Morden	KBSH-1	Mean	Morden	KBSH-1	Mean	Morden	KBSH-1	Mean	Morden	KBSH-1	Mean	Morden	KBSH-1	Mean	Morden	KBSH-1	Mean
T_1 Control		1.27	1.01	1.14	2.86	2.77	2.81	1.76	3.18	2.47	1.22	2.82	2.02	0.68	1.96	1.32	6.17	11.59	8.88
T_2 Maleic hydrazide	(250 ppm)	1.24	1.02	1.13	2.68	2.63	2.65	1.67	3.03	2.35	1.10	2.53	1.81	0.56	1.75	1.15	5.09	10.18	7.63
T_3 TIBA	(50 ppm)	1.22	1.02	1.12	2.81	2.70	2.75	1.71	3.10	2.40	1.22	2.75	1.98	0.64	1.77	1.20	5.77	11.56	8.66
T_4 Cycocel	(1000 ppm)	1.28	0.99	1.14	2.58	2.61	2.59	1.63	2.89	2.26	1.00	2.38	1.69	0.54	1.61	1.07	4.90	9.26	7.08
T_5 Mepiquat chloride	(100 ppm)	1.20	1.01	1.11	2.84	2.70	2.77	1.73	3.29	2.51	1.19	2.69	1.94	0.60	1.91	1.25	5.42	10.86	8.14
T_6 Mepiquat chloride	(250 ppm)	1.22	1.02	1.12	2.72	2.64	2.68	1.72	3.15	2.44	1.13	2.59	1.86	0.58	1.80	1.19	5.25	10.54	7.89
T_7 Mepiquat chloride	(500 ppm)	1.18	1.03	1.11	2.68	2.51	2.59	1.67	3.06	2.36	1.12	2.47	1.79	0.57	1.68	1.12	5.20	9.09	7.14
T_8 Mepiquat chloride	(1000 ppm)	1.17	1.04	1.10	2.39	2.42	2.40	1.38	2.54	1.96	0.95	2.04	1.49	0.46	1.41	0.93	4.22	8.00	6.11
Mean		1.22	1.02	1.12	2.69	2.62	2.65	1.65	3.03	2.34	1.11	2.53	1.82	0.57	1.73	1.15	5.25	10.13	7.69

	30 S.Em ±	30 C D at 5%	55 S.Em ±	55 C D at 5%	65 S.Em ±	65 C D at 5%	75 S.Em ±	75 C D at 5%	85 S.Em ±	85 C D at 5%	At Harvest S.Em ±	At Harvest C D at 5%
Genotypes	0.05	0.14	0.07	N.S	0.06	0.16	0.05	0.016	0.05	0.14	0.50	1.43
Treatments	0.09	N.S	0.13	N.S	0.11	0.32	0.11	0.31	0.09	N.S	0.99	N.S
Interaction	0.13	N.S	0.19	N.S	0.16	N.S	0.12	N.S	0.14	N.S	1.40	N.S

It was observed that the genotypes KBSH-1 had higher leaf area duration over Morden at all the growth stages except at 30-55 DAS. The treatment T_8 recorded a significant reduction in leaf area duration over all the treatments at all the growth stages except at 30-55 DAS where it did not differ significantly with T_4 and T_7. At 55-65 DAS, T_8 registered the minimum leaf area duration (21.83 days) followed by T_4 (24.12 days) and T_7 (24.79 days). There were no significant differences between T_2, T_3, T_4, T_5, T_6 and T_7 treatments and similar trend continued at other growth stages.

4.2.12 Specific leaf area

Specific leaf area (SLA) as influenced by the application of growth retardants at various growth stages is presented in Table 16. The data indicated that SLA reduced continuously from 30 to 75 DAS in Morden and from 30 to 85 DAS in KBSH-1. Genotypes differed significantly only at 55 and 75 DAS, while treatments differed significantly at 65, 75, 85 DAS at maturity and their interaction effect was non significant at all the growth stages.

Among the genotypes, Morden recorded a slight increase in SLA at all the growth stages except at harvest, where KBSH-1 had higher SLA. Among the treatments, T_8 registered a significant reduction in specific leaf area over rest of the treatments at 65, 75, 85 DAS and at harvest. It did not differ significantly with T_4 and T_7 at all the stages except

Table 15: Influence of growth retardants on LAD (days) at different growth stages in sunflower genotypes

Treatments		Days after sowing														
		30-55			55-65			65-75			75-85			At Harvest		
		Morden	KBSH-1	Mean	Morden	KBSH-1	Mean	Morden	KBSH-1	Mean	Morden	KBSH-1	Mean	Morden	KBSH-1	Mean
T_1 Control		51.6	47.2	49.4	23.1	29.7	26.4	14.9	29.9	22.4	9.8	23.9	16.8	9.5	14.6	12.0
T_2 Maleic hydrazide	(250 ppm)	49.0	45.6	47.3	21.9	28.3	25.1	13.8	27.8	20.8	8.4	21.5	15.0	8.3	12.9	10.6
T_3 TIBA	(50 ppm)	50.3	46.5	48.4	22.6	28.9	25.8	14.6	29.2	21.9	9.3	22.6	15.9	9.3	13.6	11.4
T_4 Cycocel	(1000 ppm)	48.2	45.0	48.6	19.7	28.4	24.1	12.5	26.4	19.4	7.7	20.2	13.9	7.7	11.9	9.8
T_5 Mepiquat chloride	(100 ppm)	50.5	46.3	48.4	23.6	29.7	26.7	14.6	29.9	22.2	8.9	23.0	15.8	8.9	14.0	11.5
T_6 Mepiquat chloride	(250 ppm)	49.2	45.7	47.5	23.0	29.0	26.0	14.2	28.7	21.5	8.5	21.9	15.2	8.5	13.3	10.9
T_7 Mepiquat chloride	(500 ppm)	48.2	44.2	46.2	21.7	27.8	24.7	13.9	27.1	20.9	8.4	20.7	14.7	8.4	12.1	10.3
T_8 Mepiquat chloride	(1000 ppm)	44.5	43.2	43.8	18.8	24.7	21.8	11.1	22.9	17.0	7.0	17.2	12.1	7.0	9.5	3.0
Mean		48.9	45.5	47.2	21.8	28.3	25.0	13.7	27.8	20.7	8.5	21.0	14.7	8.5	10.7	9.6
		S.Em ±	C D at 5%		S.Em ±	C D at 5%		S.Em ±	C D at 5%		S.Em ±	C D at 5%		S.Em ±	C D at 5%	
Genotypes		0.59	1.67		0.53	1.55		0.54	1.57		0.49	1.41		0.49	1.43	
Treatments		1.15	N.S		1.07	3.10		1.09	3.15		0.97	2.82		0.99	2.88	
Interaction		1.64	N.S		1.52	N.S		1.54	N.S		1.36	N.S		1.40	N.S	

Table 16: Influence of growth retardants on specific leaf area (dm^2/g) at different growth stages in sunflower genotypes

Treatments		Days after sowing														
		30			55			65			75			85			At Harvest		
		Morden	KBSH-1	Mean	Morden	KBSH-1	Mean	Morden	KBSH-1	Mean	Morden	KBSH-1	Mean	Morden	KBSH-1	Mean	Morden	KBSH-1	Mean
T_1 Control		2.11	1.97	2.04	2.15	1.64	1.89	1.61	1.59	1.60	1.56	1.54	1.55	1.53	1.51	1.52	1.53	1.51	1.52
T_2 Maleic hydrazide	(250 ppm)	2.10	2.02	2.05	2.07	1.63	1.85	1.57	1.57	1.57	1.49	1.47	1.48	1.49	1.45	1.47	1.49	1.45	1.47
T_3 TIBA	(50 ppm)	2.09	2.03	2.06	2.07	1.63	1.85	1.59	1.56	1.58	1.56	1.50	1.52	1.53	1.53	1.53	1.53	1.51	1.52
T_4 Cycocel	(1000 ppm)	2.11	2.01	2.06	2.03	1.60	1.81	1.51	1.53	1.52	1.48	1.45	1.56	1.42	1.41	1.42	1.42	1.42	1.42
T_5 Mepiquat chloride	(100 ppm)	2.15	1.97	2.06	2.08	1.64	1.86	1.59	1.68	1.64	1.56	1.52	1.54	1.53	1.49	1.51	1.53	1.49	1.51
T_6 Mepiquat chloride	(250 ppm)	2.13	1.98	2.05	2.09	1.63	1.86	1.58	1.56	1.57	1.51	1.49	1.50	1.53	1.45	1.49	1.53	1.45	1.49
T_7 Mepiquat chloride	(500 ppm)	2.04	1.98	2.01	2.04	1.62	1.83	1.57	1.53	1.55	1.53	1.43	1.48	1.51	1.45	1.48	1.51	1.45	1.48
T_8 Mepiquat chloride	(1000 ppm)	2.07	2.01	2.04	2.00	1.61	1.81	1.50	1.39	1.46	1.41	1.29	1.34	1.26	1.33	1.40	1.40	1.27	1.34
Mean		2.09	1.99	2.03	2.06	1.62	1.85	1.55	1.56	1.55	1.51	1.45	1.48	1.49	1.44	1.46	1.49	1.44	1.46
		S.Em ±	C D at 5%		S.Em ±	C D at 5%		S.Em ±	C D at 5%		S.Em ±	C D at 5%		S.Em ±	C D at 5%		S.Em ±	C D at 5%	
Genotypes		0.06	N.S		0.05	0.13		0.01	N.S		0.02	0.06		0.01	N.S		0.02	N.S	
Treatments		0.13	N.S		0.09	N.S		0.03	0.08		0.04	0.12		0.04	0.11		0.04	0.12	
Interaction		0.18	N.S		0.13	N.S		0.05	N.S		0.06	N.S		0.05	N.S		0.06	N.S	

at 75 DAS. During 65 DAS, T_8 registered least SLA (1.43 dm^2/g) followed by T_4 (1.52 dm^2/g) and T_7 (1.55 dm^2/g). However, T_2, T_3, T_4, T_5, T_6 and T_7 treatments were non-significant with each other.

4.2.13 Specific Leaf Weight

The data indicated that the specific leaf weight (SLW) increased from 30-75 DAS in Morden and 30-85 DAS in KBSH-1 (Table 17). Genotypes did not differ significantly with respect SLW at any growth stage except at 55 and 75 DAS, while, treatments differed significantly at all the growth stages except at 40 and 55 DAS. The interaction effect was found to be non significant at all the growth stages.

It was observed that KBSH-1 recorded slightly higher SLW over Morden at all growth stages except at 65 DAS and at harvest, where Morden showed slight increase in SLW over KBSH-1 in all the treatments. Treatment T_8 recorded an increase in SLW which was significant over all the treatments at all the growth stages except at 30 and 55 DAS, and at 65 DAS it did not differ significantly with T_4 and T_7 and T_8 recorded the maximum SLW (0.71 g/dm^2) followed by T_4 (0.68 g/dm^2) and T_7 (0.66 g/dm^2). And no significant differences were observed between the treatments T_2, T_3, T_4, T_5, T_6 and T_7. A similar trend was observed at other stages also.

Table 17 . Influence of growth retardants on specific leaf weight (g/dm^2) at different growth stages in sunflower genotypes

Treatments		Days after sowing: 30			55			65			75			85			At harvest		
		Morden	KBSH-1	Mean	Morden	KBSH-1	Mean	Morden	KBSH-1	Mean	Morden	KBSH-1	Mean	Morden	KBSH-1	Mean	Morden	KBSH-1	Mean
T_1 Control		0.48	0.51	0.49	0.50	0.62	0.56	0.63	0.64	0.64	0.64	0.55	0.64	0.65	0.66	0.65	0.65	0.66	0.66
T_2 Maleic hydrazide	(250 ppm)	0.49	0.50	0.49	0.51	0.62	0.56	0.67	0.67	0.6[illegible]	0.57	0.69	0.65	0.67	0.69	0.68	0.67	0.69	0.68
T_3 TIBA	(50 ppm)	0.49	0.49	0.49	0.50	0.62	0.56	0.64	0.66	0.65	0.64	0.65	0.64	0.65	0.65	0.55	0.65	0.66	0.66
T_4 Cycocel	(2000 ppm)	0.48	0.50	0.49	0.51	0.63	0.57	0.70	0.66	0.66	0.69	0.70	0.69	0.70	0.71	0.70	0.70	0.69	0.69
T_5 Mepiquat chloride	(100 ppm)	0.48	0.51	0.49	0.51	0.62	0.56	0.64	0.62	0.63	0.64	0.66	0.65	0.55	0.57	0.56	0.65	0.67	0.66
T_6 Mepiquat chloride	(250 ppm)	0.48	0.52	0.50	0.51	0.63	0.57	0.65	0.65	0.65	0.66	0.69	0.67	0.65	0.69	0.57	0.65	0.68	0.67
T_7 Mepiquat chloride	(500 ppm)	0.49	0.51	0.50	0.51	0.53	0.57	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.69	0.68	0.66	0.69	0.68
T_8 Mepiquat chloride	(1000 ppm)	0.48	0.51	0.49	0.53	0.63	0.57	0.72	0.70	0.71	0.7[illegible]	0.79	0.75	0.72	0.79	0.76	0.72	0.80	0.76
Mean		0.48	0.51	0.49	0.51	0.67	0.57	0.67	0.6[illegible]	0.67	0.65	0.69	0.67	0.67	0.69	0.65	0.67	0.69	0.68

	S.Em ± (30)	C D at 5% (30)	S.Em ± (55)	C D at 5% (55)	S.Em ± (65)	C D at 5% (65)	S.Em ± (75)	C D at 5% (75)	S.Em ± (85)	C D at 5% (85)	S.Em ± (At harvest)	C D at 5% (At harvest)
Genotypes	0.02	N.S	0.0[illegible]	0.03	0.09	S	0.01	0.0[illegible]	0.01	N.S	0.01	S
Treatments	0.03	N.S	0.02	N.S	0.02	0.05	0.02	0.05	0.02	0.06	0.02	0.06
Interaction	0.05	N.S	0.03	N.S	0.03	S	0.03	S	0.03	N.S	0.03	S

It is seen from the table that KBSH-1 recorded the maximum AGR over Morden at all the growth stages in all the treatments. At 55 DAS, the plants treated with the treatment T_8 registered significantly lower AGR as compared to rest of the treatments including T_4 and T_7 and they also showed significant reduction over T_2, T_3, T_5 and T_6. The least AGR was recorded by T_8 (106.78 x 10^{-2} g/day) followed by T_4 (122.4 x 10^{-2} g/day) and T_7 (122.5 x 10^{-2} g/day). However, no significant differences were observed between T_2, T_3, T_4, T_5, T_6 and T_7 treatments.

Although, no significant differences were observed between the treatments at 65 DAS, genotypes showed differential response to the treatments. Morden recorded lower AGR, whereas KBSH-1 recorded higher AGR in all the treatments as compared to control.

At maturity, both the genotypes showed increasing trend in response to treatments. Among the treatments, maximum AGR was recorded by T_8 which was significant over rest of the treatments. The treatment T_8 had maximum AGR (206.15 x 10^{-2} g/day) followed by T_4 (170.4 x 10^{-2} g/day) and T_7 (165.1 x 10^{-2} g/day). However, no significant differences were noticed between T_2, T_3, T_4, T_5, T_6 and T_7 treatments.

4.2.15 Crop growth rate (CGR)

The data on CGR revealed that the maximum and minimum CGR values were recorded at harvest and at 30-55 DAS.

Table 18: Influence of growth retardants on absolute growth rate ($X10^{-2}$ g/day) at different growth stages in sunflower genotypes

Treatments		Days after sowing 40-55			55-65			Maturity		
		Morden	KBSH-1	Mean	Morden	KBSH-1	Mean	Morden	KBSH-1	Mean
T_1 Control		111.8	146.3	132.5	120.0	154.0	137.0	136.3	167.5	151.9
T_2 Maleic hydrazide	(250 ppm)	109.4	140.5	124.8	126.2	146.5	136.3	145.3	189.9	167.6
T_3 TIBA	(50 ppm)	111.9	145.4	128.6	120.1	146.6	133.3	147.6	185.5	166.5
T_4 Cycocel	(1000 ppm)	109.0	135.4	122.4	124.7	144.7	134.7	150.7	190.2	170.4
T_5 Mepiquat chloride	(100 ppm)	115.3	140.7	128.0	112.3	146.2	129.2	148.7	181.6	165.1
T_6 Mepiquat chloride	(250 ppm)	113.6	140.0	126.8	119.6	145.8	132.7	145.8	177.8	161.8
T_7 Mepiquat chloride	(500 ppm)	110.5	134.6	122.5	122.4	149.4	135.9	149.2	181.1	165.1
T_8 Mepiquat chloride	(1000 ppm)	98.4	119.2	108.8	130.5	133.2	131.8	194.2	219.1	206.1
Mean		110.8	137.7	124.3	121.9	145.8	133.8	152.1	186.6	169.3

	S.Em ±	C D at 5%	S.Em ±	C D at 5%	S.Em ±	C D at 5%
Genotypes	2.30	6.67	2.37	6.85	3.55	10.27
Treatments	4.60	13.34	4.74	N.S	7.11	10.54
Interaction	6.50	N.S	6.70	N.S	10.06	N.s

respectively in all the treatments of both the genotypes (Table 19). Significant differences were noticed at 55 and 65 DAS for genotypes and 55 DAS and maturity for treatments. However, none of the interaction effects were significant at any of the growth stage.

The genotype, Morden produced the maximum CGR during all the growth stages over KBSH-1 in all the treatments. Among the treatments, T_8 produced significant reduction in CGR (10.32×10^{-2} g/dm^2/day) over all the treatments except with T_4 and T_7. Treatments T_4 (11.69×10^{-2} g/dm^2/day) and T_7 (11.74×10^{-2} g/dm^2/day) also produced considerable reduction in CGR. No significant differences were observed between the treatments T_2, T_3, T_4, T_5, T_6 and T_7.

Although, no significant differences were obtained between the treatments at 65 DAS, genotypes differed in their response towards the treatments. Morden showed increasing and KBSH-1 showed decreasing values of CGR in response to treatments as compared to control.

At maturity, both the genotypes showed increasing trend in response to treatments. Among the treatments, T_8 registered the maximum CGR, which was significant over rest of the treatments, (16.29×10^{-2} g/dm^2/day) and T_7 (15.83×10^{-2} g/dm^2/day). The treatments T_2, T_3, T_4, T_5, T_6 and T_7 were all on par with each other.

Table 19: Influence of growth retardants on crop growth rate ($X10^{-2}$ $g/dm^2/day$) at different growth stages in sunflower genotypes

Treatments			Days after sowing 40–55			55–65			Maturity		
			Morden	KBSH-1	Mean	Morden	KBSH-1	Mean	Morden	KBSH-1	Mean
T_1	Control	-	13.00	12.19	12.60	13.33	12.83	13.08	15.14	13.95	14.54
T_2	Maleic hydrazide	(250 ppm)	12.15	11.71	11.93	14.02	12.21	13.11	16.14	15.82	15.98
T_3	TIBA	(50 ppm)	12.44	12.11	12.27	13.30	12.21	12.75	16.40	15.45	15.92
T_4	Cycocel	(1000 ppm)	12.11	11.28	11.69	13.85	12.05	12.95	16.74	15.85	16.29
T_5	Mepiquat chloride	(100 ppm)	12.60	11.73	12.26	12.15	12.18	12.16	16.52	15.13	15.82
T_6	Mepiquat chloride	(250 ppm)	12.62	11.67	12.14	13.28	12.15	12.71	16.20	14.81	15.50
T_7	Mepiquat chloride	(500 ppm)	12.28	11.21	11.74	13.60	12.61	13.10	16.57	15.09	15.83
T_8	Mepiquat chloride	(1000 ppm)	10.92	9.93	10.32	14.50	11.10	12.80	21.46	18.25	19.85
Mean			12.29	11.47	11.88	13.50	12.16	12.83	16.89	15.54	16.21

	S.Em ±	C D at 5%	S.Em ±	C D at 5%	S.Em ±	C D at 5%
Genotypes	0.26	0.70	0.23	0.66	0.46	N.S
Treatments	0.55	1.60	0.46	N.S	0.91	2.64
Interaction	0.78	N.S	0.65	N.S	1.29	N.S

4.2.16 Relative growth rate (RGR)

Unlike AGR and CGR, RGR values were in decreasing trend from 30-55 DAS to maturity in all the treatments and in both the genotypes (Table 20). It was observed that only treatments differed significantly at 55 DAS and at maturity, whereas, genotypes and their interaction effects were non significant at all the growth stages.

During 30-55 DAS T_8 recorded significantly lower over control but was on par with other treatments. The least RGR was recorded by T_8 (5.31×10^{-2} g/g/day) followed by T_7 (5.68×10^{-2} g/g/day) and T_4 (5.71×10^{-2} g/g/day). Although, no significant differences were observed between any of the treatments, there was differential responses between genotypes between the treatments. Morden showed increasing trend whereas, KBSH-1 showed decreasing trend in response to treatments in comparison with control.

At maturity, the treatment T_8 had significantly higher RGR values over rest of the treatments. The maximum was recorded by T_8 (3.02×10^{-2} g/g/day) followed by T_6 (2.40×10^{-2} g/g/day) and T_2 (2.36×10^{-2} g/g/day). No significant interaction effect was observed between T_2, T_3, T_4, T_5, T_6 and T_7 treatments at any of the growth stages.

4.2.17 Net assimilation rate (NAR)

The data on NAR revealed maximum and minimum NAR values at maturity and 55-56 DAS, respectively in case of

Table 20: Influence of growth retardants on relative growth rate ($X10^{-2}$ g/g/day) at different growth stages in sunflower genotypes

Treatments		Days after sowing 40-55			55-65			Maturity		
		Morden	KBSH-1	Mean	Morden	KBSH-1	Mean	Morden	KBSH-1	Mean
T_1 Control		5.96	5.93	5.94	2.71	2.81	2.76	2.39	2.02	2.20
T_2 Maleic hydrazida	(250 ppm)	5.60	5.90	5.75	2.99	2.79	2.89	2.36	2.36	2.36
T_3 TIBA	(50 ppm)	5.67	5.90	5.78	2.79	2.80	2.80	2.35	2.29	2.32
T_4 Cycocel	(1000 ppm)	5.78	5.65	5.71	2.99	2.79	2.89	2.43	2.37	2.40
T_5 Mepiquat chloride	(100 ppm)	5.79	5.79	5.79	2.62	2.79	2.70	2.27	2.23	2.25
T_6 Mepiquat chloride	(250 ppm)	5.82	5.80	5.81	2.77	2.79	2.78	2.34	2.20	2.27
T_7 Mepiquat chloride	(500 ppm)	5.75	5.62	5.68	2.91	2.79	2.81	2.40	2.24	2.32
T_8 Mepiquat chloride	(1000 ppm)	5.35	5.28	5.31	3.30	2.75	3.02	2.54	3.50	3.02
Mean		5.71	5.73	5.72	2.88	2.88	2.83	2.38	2.40	2.39

	S.Em ±	C D at 5%	S.Em ±	C D at 5%	S.Em ±	C D at 5%
Genotypes	0.10	N.S	0.05	N.S	0.04	0.13
Treatments	0.20	0.60	0.10	N.S	0.09	0.27
Interaction	0.29	N.S	0.14	N.S	0.13	N.S

Morden. Whereas, in case of KBSH-1, maximum was observed at 30-55 DAS and minimum at 55-65 DAS in all the treatments (Table 21). Significant differences in NAR values among the genotypes were noticed at 55-65 DAS and at maturity. While the treatments produced significant differences only at maturity and the interaction effects were found non significant at all the growth stages.

Among the genotypes, Morden recorded greater NAR in all the treatments at 55-65 DAS and at maturity. Although, no significant differences were found between the treatments at 30-55, NAR was found to be low in all the treatments as compared to control. During 55-65 DAS, Morden showed numerically higher NAR values in response to all the treatments, whereas KBSH-1 showed only for the treatments T_8 and T_7.

At maturity, both the genotypes were found to have NAR values in all the treatments as compared to control. Among the treatments, T_8 recorded a significant increase in NAR over all other treatments. The maximum NAR was recorded by (T_8 (14.53 x 10^{-2} g/dm^2/day) followed by T_4 (10.5 x 10^{-2} g/dm^2/day) and T_7 (9.65 x 10^{-2} g dm^2/day). However, no significant differences were obtained between T_2, T_3, T_4,T_5, T_6 and T_7 treatments.

Table 21: Influence of growth retardants on net assimilation rate ($\times 10^{-2}$ g/dm^2/day) at different growth stages in sunflower genotypes

	Treatments		Days after sowing 40-55			55-65			Maturity		
			Morden	KBSH-1	Mean	Morden	KBSH-1	Mean	Morden	KBSH-1	Mean
T_1	Control		6.73	6.93	6.83	5.62	4.27	4.94	9.32	5.89	7.60
T_2	Meleic hydrazide	(250 ppm)	6.64	6.85	6.74	6.61	4.24	5.42	11.64	7.45	9.55
T_3	TIBA	(50 ppm)	6.54	7.01	6.77	6.14	4.20	5.17	10.73	6.92	8.82
T_4	Cycocel	(1000 ppm)	6.40	6.58	6.49	6.09	4.09	5.09	13.22	7.79	10.50
T_5	Mepiquat chloride	(100 ppm)	6.61	6.90	6.75	6.47	4.22	5.34	11.10	6.63	8.86
T_6	Mepiquat chloride	(250 ppm)	6.78	6.81	6.79	6.14	4.19	5.16	11.52	6.78	9.15
T_7	Mepiquat chloride	(500 ppm)	6.63	6.77	6.70	6.51	4.30	5.35	12.02	7.32	9.65
T_8	Mepiquat chloride	(1000 ppm)	6.18	6.04	6.10	7.86	4.46	5.96	18.41	10.66	14.53
	Mean		6.57	6.73	6.64	6.43	4.25	5.34	12.27	7.45	9.86

	S.Em ±	C D at 5%	S.Em ±	C D at 5%	S.Em ±	C D at 5%
Genotypes	0.22	N.S	0.17	0.51	0.54	1.06
Treatments	0.44	N.S	0.35	N.S	1.06	3.12
Interaction	0.60	N.S	0.50	N.S	1.53	N.S

4.3 YIELD AND YIELD COMPONENTS

The data on the influence of growth retardants on number of filled and unfilled seeds per head, total number of seeds per head, per cent seed filling, seed weight per plant, 100-seed weight, seed yield per hectare and HI are presented in Table 22 a and b.

4.3.1 Number of filled seeds per head

Significant differences in the number of seeds per head were observed among the genotypes and treatments and the interaction effect was found to be non significant (Table 22a). The maximum values were recorded in KBSH-1 as compared to Morden in all the treatments. Among the treatments, T_8 recorded significantly higher number of filled seeds per head over all the treatments except T_4 and T_7. The maximum number of filled seeds per head recorded in T_8 was 596.3 followed by T_4 (565.4) and T_7 (559.7). There was no significant difference between the treatments T_2, T_3, T_4, T_5, T_6 and T_7.

4.3.2 Number of unfilled seeds

The data indicated significant differences in the number of unfilled seeds per head among the genotypes and treatments, and their interaction was found to be non significant (Table 22a). The minimum number of unfilled seeds per head was noticed in KBSH-1 as compared to Morden in all the treatments. The treatment T_8 registered significantly lower number of unfilled seeds per head over all the treatments. The least number of unfilled seeds in T_8 was 168.6 followed by T_7 (202.8) and T_4 (203.0). However, the treatments T_2, T_3, T_4, T_5, T_6 and T_7 were on par with each other.

4.3.3 Number of seeds per head

The data on the number of seeds per head indicated significant differences only between the genotypes (Table 22a). Among the genotypes, the maximum number of seeds per head was noticed in KBSH-1 as compared to Morden. The treatments and interaction did not show any significant differences. However, T_8 had the maximum number of seeds per head (783.1) followed by T_4 (768.6) and T_7 (766.5).

4.3.4 Seed filling per cent

Significant differences in seed filling per cent were observed among the genotypes and treatment, whereas the interaction effects were found to be non-significant (Table 22a). The genotype KBSH-1 registered the maximum seed filling per cent as compared to Morden. Among the treatments, T_8 had significantly higher seed filling per cent over all the treatments. The maximum seed filling per cent was achieved in T_8 (75.0%) followed by T_4 (72.6%) and T_7 (72.1%).

4.3.5 Seed weight per plant

The genotypes and treatments recorded significant differences in seed weight per plant, and the interaction

Table 22 a: Influence of growth retardants on number of filled seeds, unfilled seeds, total number of seeds and seed filling percentage in sunflower genotypes

Treatments		Number of filled seeds			Number of Unfilled seeds			Total Number of seeds			Seed filling %		
		Morden	KBSH-1	Mean	Morden	KBSH-1	Mean	Morden	KBSH-1	Mean	Morden	KBSH-1	Mean
T_1 Control		407.4	654.8	531.1	258.0	183.1	225.5	675.4	837.9	756.6	60.31	78.1	69.2
T_2 Maleic hydrazin	(250 ppm)	426.0	679.8	553.2	255.1	160.0	207.0	681.1	840.4	760.1	62.7	80.9	71.8
T_3 TIBA	(50 ppm)	422.8	672.0	547.4	257.0	169.4	217.2	680.2	841.3	760.8	62.1	79.9	71.0
T_4 Cycocel	(1000 ppm)	438.1	692.9	565.4	249.2	156.9	203.0	687.3	849.3	768.6	63.7	81.6	72.6
T_5 Mepiquat chloride	(100 ppm)	420.9	671.0	545.9	254.5	169.0	211.8	675.6	842.1	758.8	62.3	79.7	71.0
T_6 Mepiquat chloride	(250 ppm)	420.9	675.6	548.3	257.5	167.4	212.5	678.5	843.2	760.8	62.0	80.1	71.0
T_7 Mepiquat chloride	(500 ppm)	4[illegible].9	685.5	559.7	244.3	101.5	202.8	684.0	847.0	766.5	63.4	80.9	72.1
T_8 Mepiquat chloride	(1000 ppm)	456.7	735.9	596.3	206.8	129.4	168.6	700.0	865.3	78[illegible].1	65.1	85.0	75.0
Mean		428.3	683.4	557.2	249.0	162.1	205.5	682.9	845.8	764.3	62.7	80.8	71.8

	S.Em ±	C D at 5%	S.Em ±	C D at 5%	S.Em ±	C D at 5%	S.Em ±	C D at 5%
Genotypes	6.62	19.10	4.07	11.76	5.47	15.80	0.61	1.75
Treatments	13.22	38.20	8.14	23.52	10.94	N.S	1.22	3.50
Interaction	18.71	N.S	11.52	N.S	15.47	N.S	1.78	N.S

effect was non-significant (Table 22b). Among the genotypes, KBSH-1 registered the maximum seed weight per plant as compared to Morden. The treatment T_8 recorded significantly higher seed weight per plant over all the treatments. However, the treatments T_2, T_3, T_4, T_5, T_6 and T_7 did not differ significantly with each other. The maximum per cent increase in seed weight per plant in both the genotypes were recorded in T_8 and the least was with T_3 and T_5 in the genotypes Morden and KBSH-1, respectively.

4.3.6 100-seed weight

The data on 100-seed weight indicated significant differences only among the genotypes and treatments, but interaction effects were non-significant (Table 22b). The maximum 100-seed weight was noticed in KBSH-1 as compared to Morden in all the treatments. Among the treatments, T_8 registered significantly higher 100-seed weight over all the treatments, which was found to have 3.96 g followed by T_4 and T_7 (3.71 g).

4.3.7 Seed yield per hectare

The seed yield data revealed significant differences among the genotypes and treatments but their interaction effect was found to be non-significant (Table 22b). Among the genotypes, KBSH-1 recorded the maximum seed yield per hectare as compared to Morden. Among treatments, T_8 (23.0 Q/ha) registered significantly higher seed yield over all the

Table 22 b: Influence of growth retardants on seed weight (g/plant), 100 seed weight (g), seed weight (g/net plot), seed yield (g/ha) and harvest index (%) in sunflower genotypes

Treatments		Seed weight (g/plant)			100 seed weight (g)			Seed yield (q/ha)			Harvest Index (%)		
		Morden	KBSH-1	Mean	Morden	KBSH-1	Mean	Morden	KBSH-1	Mean	Morden	KBSH-1	Mean
T_1 Control		14.04	26.50	20.26	3.34	3.98	3.66	17.9	24.5	21.2	22.51	29.55	26.03
T_2 Maleic hydrazide	(250 ppm)	14.38	27.31	20.84	3.34	3.99	3.66	18.3	24.8	21.5	23.00	30.68	26.84
T_3 TIBA	(50 ppm)	14.16	26.73	20.44	3.34	3.98	3.66	18.2	24.6	21.4	22.20	29.94	26.17
T_4 Cycocel	(1000 ppm)	14.99	28.20	21.50	3.30	4.10	3.73	18.4	25.1	21.8	24.21	31.69	27.95
T_5 Mepiquat chloride	(1000 ppm)	14.20	26.58	20.34	3.34	3.98	3.66	18.1	24.7	21.4	22.81	29.84	26.32
T_6 Mepiquat chloride	(250 ppm)	14.35	26.90	20.62	3.36	3.99	3.67	18.2	24.7	21.5	23.22	30.12	26.67
T_7 Mepiquat chloride	(500 ppm)	14.55	28.10	21.32	3.42	4.05	3.73	18.4	24.9	21.6	23.61	31.98	27.79
T_8 Mepiquat chloride	(1000 ppm)	16.59	30.56	23.58	3.50	4.23	3.86	19.3	26.8	23.0	27.49	35.88	31.68
Mean		14.65	27.60	21.13	3.37	4.03	3.70	18.4	24.9	21.7	23.63	31.21	27.42
		S.Em ±		C D at 5%	S.Em ±		C D at 5%	S.Em ±		C D at 5%	S.Em ±		C D at 5%
Genotypes (A)		0.32		0.92	0.03		0.08	0.13		0.39	0.48		1.37
Treatments (B)		0.64		1.85	0.06		0.17	0.24		0.78	0.95		2.74
Interaction		0.90		N.S	0.08		N.S	0.33		N.S	1.34		N.S

treatments followed by T_4 (21.8 Q/ha) and T_7 (21.69 Q/ha).

4.3.8 Harvest index (HI)

Significant differences in the HI was observed among the genotypes, treatments and their interaction effects were non-significant (Table 22b). The genotype KBSH-1 registered the maximum HI over Morden. While, among treatments, T_8 (31.68%) registered significantly higher HI over all the treatments and in both genotypes followed by T_4 (17.95%) and T_7 (27.79%). However, no significant differences were observed between the treatments T_2, T_3, T_4, T_5, T_6 and T_7.

4.4 BIOCHEMICAL PARAMETERS

Various biochemical parameters such as Chl.a, Chl.b total chlorophyll, soluble protein seed protein and seed oil contents studied in response to different growth retardants are given in tables 23 to 28.

4.4.1 Chlorophyll-a content

The maximum Chl.a content was recorded at 65 and 75 DAS in Morden and KBSH-1, respectively, and the Chl.a content decreased gradually thereafter till harvest in all the treatments (Table 23). Genotypes differed significantly with each other only at 75 and 85 DAS, while the treatments differed significantly during all the growth stages except at 55 DAS However, the interaction effect was not significant.

Among the genotypes, KBSH-1 had the maximum Chl.a content as compared to Morden. While, among the treatments, T_8 had significantly higher values at all the stages except at 55 DAS. At 65 and 75 DAS also T_8 recorded significantly higher Chl.a content over all the treatments except T_4 and T_7. The Chl.a content was maximum in T_8 (1.218 mg/g fr.wt) followed by T_4 (133 mg/g fr.wt) and T_7 (132 mg/g fr.wt) at 65 DAS. A similar trend was observed in other growth stages also.

4.4.2 <u>Chlorophyll b [illegible]</u>

The Chl.b content increased from 55 to 65 DAS in Morden and 75 DAS in KBSH-1, and it decreased thereafter gradually till harvest in both the varieties of all the treatments (Table 24). Genotypes and treatments differed significantly at all the growth stages except for the genotypes at harvest and for the treatments at 55 DAS and harvest. The interaction effect was not significant at any growth stage.

It was observed that KBSH-1 had higher Chl.b content at all the growth stages except at harvest. Among treatments, T_8 registered significantly higher Chl.b content at 65 (0.446 mg/g fr.wt) 75 (0.429 mg/g fr.wt) and 85 DAS (0.284 mg/g fr.wt) over other treatments except T_2, T_4 and T_7 at 65 DAS; T_2, T_4, T_6 and T_7 at 75 DAS.

Table 23: Influence of growth retardants on Chlorophyll 'a' content (mg/g fr.wt) at different growth stages in sunflower genotypes

Treatments	Days after sowing														
	55			65			75			85			At Harvest		
	Morden	KBSH-1	Mean	Morden	KBSH-1	Mean	Morden	KBSH-1	Mean	Morden	KBSH-1	Mean	Morden	KBSH-1	Mean
T_1 Control	0.509	0.520	0.515	1.047	1.054	1.050	1.005	1.117	1.061	0.467	1.085	0.776	0.467	0.476	0.476
T_2 Maleic hydrazide (250 ppm)	0.547	0.544	0.546	1.097	1.112	1.105	1.075	1.182	1.129	0.475	1.136	0.805	0.475	0.494	0.484
T_3 TIBA (50 ppm)	0.524	0.533	0.529	1.072	1.084	1.078	1.035	1.145	1.090	0.477	1.105	0.791	0.477	0.489	0.483
T_4 Cycocel (1000 ppm)	0.551	0.556	0.553	1.127	1.140	1.133	1.105	1.207	1.156	0.497	1.109	0.833	0.511	0.500	0.505
T_5 Mepiquat chloride (100 ppm)	0.512	0.530	0.521	1.065	1.070	1.068	1.035	1.132	1.083	0.469	1.094	0.782	0.469	0.486	0.477
T_6 Mepiquat chloride (250 ppm)	0.540	0.545	0.543	1.097	1.114	1.106	1.075	1.186	1.131	0.475	1.159	0.817	0.475	0.490	0.483
T_7 Mepiquat chloride (500 ppm)	0.552	0.554	0.553	1.125	1.138	1.132	1.105	1.209	1.257	0.501	1.185	0.843	0.497	0.507	0.502
T_8 Mepiquat chloride (1000 ppm)	0.560	0.566	0.563	1.209	1.227	1.218	1.200	1.299	1.250	0.557	1.305	0.931	0.557	0.565	0.561
Mean	0.537	0.544	0.540	1.063	1.117	1.111	1.079	1.185	1.132	0.491	1.151	0.821	0.491	0.502	0.496
	S.Em ±	C D at 5%		S.Em ±	C D at 5%		S.Em ±	C D at 5%		S.Em ±	C D at 5%		S.Em ±	C D at 5%	
Genotypes	0.007	N.S		0.016	N.S		0.017	0.048		0.013	0.037		0.006	N.S	
Treatments	0.014	N.S		0.032	0.091		0.035	0.102		0.026	0.074		0.012	0.033	
Interaction	0.020	N.S		0.045	N.S		0.049	N.S		0.036	N.S		0.016	N.S	

Table 24: Influence of growth retardants on Chlorophyll 'b' content (mg/g fr.wt) at different growth stages in sunflower gentypes

Treatments		Days after sowing 55			65			75			85			At Harvest		
		Morden	KBSH-1	Mean	Morden	KBSH-1	Mean	Morden	KBSH-1	Mean	Morden	KBSH-1	Mean	Morden	KBSH-1	Mean
T_1 Control		0.240	0.260	0.250	0.392	0.410	0.401	0.350	0.419	0.385	0.116	0.375	0.246	0.123	0.113	0.118
T_2 Maleic hydrazide	(250 ppm)	0.250	0.267	0.258	0.416	0.431	0.424	0.367	0.445	0.406	0.131	0.390	0.260	0.131	0.120	0.125
T_3 TIBA	(50 ppm)	0.245	0.263	0.254	0.400	0.415	0.407	0.353	0.425	0.389	0.125	0.380	0.253	0.125	0.114	0.120
T_4 Cycocel	(1000 ppm)	0.255	0.273	0.264	0.418	0.436	0.427	0.368	0.455	0.412	0.134	0.392	0.264	0.136	0.124	0.130
T_5 Mepiquat chloride	(100 ppm)	0.236	0.264	0.250	0.398	0.412	0.405	0.353	0.420	0.387	0.123	0.376	0.250	0.123	0.113	0.118
T_6 Mepiquat chloride	(250 ppm)	0.250	0.267	0.258	0.412	0.425	0.419	0.363	0.435	0.399	0.128	0.388	0.258	0.128	0.118	0.123
T_7 Mepiquat chloride	(500 ppm)	0.254	0.273	0.264	0.425	0.440	4.433	0.370	0.457	0.413	0.133	0.394	0.264	0.135	0.122	0.129
T_8 Mepiquat chloride	(1000 ppm)	0.260	0.278	0.269	0.440	0.453	0.446	0.388	0.470	0.429	0.154	0.416	0.284	0.151	0.132	0.142
Mean		0.249	0.268	0.258	0.411	0.427	0.219	0.364	0.441	0.402	0.130	0.389	0.259	0.130	0.119	0.125

	55 S.Em ±	55 C D at 5%	65 S.Em ±	65 C D at 5%	75 S.Em ±	75 C D at 5%	85 S.Em ±	85 C D at 5%	At Harvest S.Em ±	At Harvest C D at 5%
Genotypes	0.004	0.012	0.005	0.013	0.006	0.016	0.003	0.010	0.004	N.S
Treatments	0.009	N.S	0.009	0.027	0.012	0.033	0.007	0.019	0.009	N.S
Interaction	0.012	N.S	0.013	N.S	0.017	N.S	0.009	N.S	0.012	N.S

4.4.3 Total chlorophyll content

Table 25 revealed that the total chlorophyll content increased upto 65 and 75 DAS in Morden and KBSH-1, respectively, and decreased thereafter in all the treatments and in both the genotypes. The genotypes differed significantly only at 65 and 75 DAS, while the treatments differed significantly at all the growth stages except at 55 DAS. However, the interaction effect was non-significant at all the growth stages.

The genotype KBSH-1 recorded the maximum total Chlorophyll content over Morden at all the growth stages except at harvest, where both the genotypes had equal amount of total chlorophyll. Among the treatments, T_8 registered the maximum total chlorophyll content which was significantly superior over all the treatments at 65 DAS. At this stage, the treatments T_4 and T_7 also recorded significantly higher chlorophyll content as compared to control. At 75 DAS, T_6 recorded the maximum total chlorophyll content (1.679 mg/g fr.wt) followed by T_7 (1.581 mg/g fr.wt). However, the treatments T_2, T_3, T_5, and T_6 did not differ significantly with each other A similar trend was observed in other growth stages.

4.4.4 Soluble leaf protein content

The soluble protein content increased from 55 DAS to maturity in both the genotypes and in all the treatments (Table 26). At maturity both genotypes and treatment showed significant differences, while at 55 DAS, only treatments

Table 25: Influence of growth retardants on total chlorophyll content (mg/g fr.wt) at different growth stages in sunflower genotypes

Treatments		Days after sowing (DAS) 55			65			75			85			At Harvest		
		Morden	KBSH-1	Mean	Morden	KBSH-1	Mean	Morden	KBSH-1	Mean	Morden	KBSH-1	Mean	Morden	KBSH-1	Mean
T_1 Control		0.749	0.780	0.765	1.442	1.462	1.452	1.355	1.537	1.446	0.590	1.461	1.026	0.590	0.599	0.595
T_2 Maleic hydrazide	(250 ppm)	0.797	0.816	0.807	1.513	1.544	1.529	1.442	1.627	1.535	0.606	1.486	1.046	0.628	0.607	0.617
T_3 TIBA	(50 ppm)	0.769	0.798	0.784	1.472	1.499	1.486	1.388	1.570	1.479	0.602	1.485	1.043	0.602	0.603	0.602
T_4 Cycocel	(1000 ppm)	0.806	0.829	0.818	1.547	1.581	1.564	1.473	1.662	1.568	0.634	1.577	1.105	0.647	0.624	0.636
T_5 Mepiquat chloride	(100 ppm)	0.755	0.794	0.775	1.463	1.482	1.473	1.371	1.558	1.465	0.592	1.470	1.031	0.592	0.599	0.596
T_6 Mepiquat chloride	(250 ppm)	0.790	0.816	0.803	1.509	1.539	1.524	1.438	1.621	1.530	0.599	1.492	1.645	0.599	0.608	0.604
T_7 Mepiquat chloride	(500 ppm)	0.806	0.827	0.816	1.550	1.545	1.547	1.475	1.667	1.581	0.632	1.554	1.093	0.610	0.632	0.621
T_8 Mepiquat chloride	(1000 ppm)	0.820	0.844	0.832	1.649	1.680	1.665	1.588	1.769	1.679	0.708	1.718	1.213	0.708	0.697	0.703
Mean		0.787	0.813	0.800	1.518	1.542	1.530	1.441	1.626	1.534	0.622	1.541	1.082	0.622	0.622	0.622

	S.Em ±	C D at 5%	S.Em ±	C D at 5%	S.Em ±	C D at 5%	S.Em ±	C D at 5%	S.Em ±	C D at 5%
Genotypes	0.015	N.S	0.016	N.S	0.017	0.040	0.015	0.040	0.009	N.S
Treatments	0.030	N.S	0.032	0.093	0.034	0.097	0.029	0.081	0.016	0.046
Interaction	0.043	N.S	0.046	N.S	0.048	N.S	0.038	N.S	0.024	N.S

showed significant differences. However, the interaction effect was not significant in both the stages.

Among the genotypes, KBSH-1 recorded the maximum leaf protein content as compared to Morden at both the stages and in all the treatments except during 55 DAS KBSH-1 recorded slightly lower leaf protein as compared to Morden in the treatments T_6 and T_8. Among the treatments, T_8 showed as showed a significant differences over all other treatments while, T_7 also showed significant differences only over T_5, T_3 and T_1 at both the stages. At maturity, T_7 was found to be significantly superior over T_6. At 55 DAS, the least value was recorded in T_8 (19.59 mg/g fr.wt) followed by T_7 (28.97 mg/g fr. wt) and T_4 (29.73 mg/g fr.wt). A similar trend was observed during maturity also.

4.8.5 Leaf nitrogen

The effect on the leaf nitrogen of two sunflower genotypes due to treatments and their interaction with genotypes did not show any significant difference (Table 26b). Whereas, the genotypes recorded significant difference at both the stages. Among the genotypes, KBSH-1 recorded maximum leaf nitrogen in all the treatments at both stages. Although, treatments did not differ significantly with each other, but mepiquat chloride showed slightly higher leaf nitrogen content as compared to control.

Table 26 : Influence of growth retardants on soluble protein content of leaf (mg/g fr.wt) at different growth stage in sunflower genotypes

Treatments		Days after sowing 55 Morden	55 KBSH-1	55 Mean	Maturity Morden	Maturity KBSH-1	Maturity Mean
T_1 Control		32.1	33.4	32.8	39.1	44.3	41.7
T_2 Maleic hydrazide	(250 ppm)	29.5	30.6	30.1	38.6	43.0	40.8
T_3 TIBA	(50 ppm)	32.0	33.5	32.7	39.2	44.1	41.7
T_4 Cycocel	(1000 ppm)	29.2	30.2	29.7	36.2	42.3	39.3
T_5 Mepiquat chloride	(1000 ppm)	32.0	33.2	32.6	39.1	44.6	41.6
T_6 Mepiquat chloride	(250 ppm)	31.6	31.3	31.4	39.3	43.6	41.4
T_7 Mepiquat chloride	(500 ppm)	28.6	29.2	28.9	36.3	41.1	38.7
T_8 Mepiquat chloride	(1000 ppm)	20.0	19.1	19.5	32.2	35.5	33.9
Mean		29.1	30.1	29.0	37.5	42.2	39.9

	S.Em ±	C D at 5%	S.Em ±	C D at 5%
Genotypes	0.580	N.S	0.653	1.887
Treatments	1.159	3.348	1.307	3.774
Interaction	1.639	N.S	1.848	N.S

Table 27 : Influence of growth retardants on leaf nitrogen (%) at different growth stages in sunflower genotypes.

Treatments		Days after sowing 55			Maturity		
		Morden	KBSH-1	Mean	Morden	KBSH-1	Mean
T_1 Control		0.72	1.85	1.28	1.08	2.26	1.67
T_2 Maleic hydrazide	(250 ppm)	0.72	1.87	1.29	1.11	2.29	1.69
T_3 TIBA	(50 ppm)	0.73	1.89	1.31	1.09	2.26	1.67
T_4 Cycocel	(1000 ppm)	0.75	1.93	1.34	1.11	2.32	1.71
T_5 Mepiquat chloride	(100 ppm)	0.73	1.85	1.29	1.09	2.26	1.68
T_6 Mepiquat chloride	(250 ppm)	0.73	1.85	1.29	1.12	2.29	1.71
T_7 Mepiquat chloride	(500 ppm)	0.76	1.89	1.32	1.12	2.34	1.73
T_8 Mepiquat chloride	(1000 ppm)	0.79	1.93	1.36	1.19	2.41	1.80
Mean		0.74	1.88	1.31	1.11	2.30	1.71

	S.Em ±	C D at 5%	S.Em ±	C D at 5%
Genotypes	0.04	0.12	0.04	0.12
Treatments	0.08	N.S	0.08	N.S
Interaction	0.12	N.S	0.12	N.S

Table 28: Influence of growth retardants on seed protein and oil contents (%) in sunflower genotypes

Treatments		Seed protein content (%)			Seed oil content (%)		
		Morden	KBSH-1	Mean	Morden	KBSH-1	Mean
T_1 Control		15.21	17.08	16.14	28.20	32.46	30.33
T_2 Maleic hydrazide	(250 ppm)	15.33	17.31	16.32	28.35	32.53	30.44
T_3 TIBA	(50 ppm)	15.21	17.10	16.14	28.31	32.50	30.40
T_4 Cycocel	(1000 ppm)	15.41	17.20	16.30	28.43	30.30	29.36
T_5 Mepiquat chloride	(100 ppm)	15.21	17.10	16.15	28.50	32.50	30.50
T_6 Mepiquat chloride	(250 ppm)	15.40	17.31	16.35	28.20	32.52	30.36
T_7 Mepiquat chloride	(500 ppm)	15.66	17.67	16.66	28.56	32.93	30.75
T_8 Mepiquat chloride	(1000 ppm)	16.49	18.78	17.63	29.17	33.90	31.53
Mean		15.45	17.43	16.44	28.46	32.46	30.46

	Protein S.Em ±	Protein C D at 5%	Oil S.Em ±	Oil C D at 5%
Genotypes	0.351	1.013	0.634	1.831
Treatments	0.701	N.S	1.208	N.S
Interaction	0.992	N.S	1.793	N.S

4.4.5 Seed protein and oil contents

The data on seed protein and oil per cent of two sunflower genotypes as influenced by different growth retardants is presented in table 27.

Only genotypes differed significantly with respect to seed protein and oil per cent. Among them, KBSH-1 had significantly higher values for both the parameters as compared to Morden. And growth retardants did not have any significant effect on seed protein and oil per cent. However, Mepiquat chloride (1000 ppm) had higher seed protein content (17.63%) and oil content (31.53%) as compared to control (16.14% and 30.33%, respectively).

CHAPTER - V

DISCUSSION

V DISCUSSION

Plant growth and development is dependent upon various intrinsic and external factors such as mineral nutrient status of plants, growth hormones, light photoperiod, water supply and CO_2. There are several ways of modifying the plant growth and development by manipulating both internal and external factors. Plant growth regulators have become more popular due to many-fold increase in the response of plants. Recently, new type of organic chemicals (growth retardants, which retard the stem elongation, increase the greenness of leaves, and indirectly affect flowering without causing malformation of the plants have been extensively studied. Patel and Srivastava (1971) reported that the application of Maleic hydrazide increased the seed yield of peas by 30.7 per cent by reducing the height of the plant. Similarly, Upper and Kulkarni (1989) noticed an increase in seed yield and oil content of sunflower in response to the application of TIBA. While studying with CCC in sunflower, Pande and Srivastava (1985) observed an increase in seed yield by reducing the plant height, leaf area and increase in photosynthesis and translocation of photosynthates towards the using CCC either at pre or post-flowering stage. Another chemical, Mepiquat chloride has also been reported to have similar impact on growth and yield of cotton (Dippenaar *et al*., 199).

With this background, the present investigation was undertaken with two sunflower genotypes to study the effect of different growth retardants on morphological, phenological, biochemical characters, and yield and its components. The results obtained on these aspects are discussed in this chapter in light of the work done by others on sunflower and related crops.

5.1 MORPHOLOGICAL CHARACTERS

The influence of growth retardants on various morphological characters such as plant height, number of leaves, stem diameter, head diameter, dry matter production and its distribution in to different parts, leaf area and other growth parameters indicated that the treatments differed significantly with respect to all the parameters and no significant response was observed between genotypes. Still, the genotype KBSH-1 responded better than Morden towords growth retardants. Among varous treatments, Mepiquat chloride (1000 ppm) performed better than any of the chemicals used.

Basically, plant height is a genetically controlled character. But, there are many reports which indicate that the foliar application of growth retardants leads to shorter plant stature. Initially (30 DAS), the treated and untreated plants of both the genotypes did not show any significant difference in plant height. Because, at this stage growth retardants were not sprayed. Similarly at 55 DAS, treatments did not show significant differences among them. This could be due to slow action of the chemicals. Significant reduction in plant height was noticed in response to mepiquat chloride (1000 ppm) from 65 DAS onwards till harvest. Similarly in soybean, Morandi et al.(1984) observed logarithmic relationship between stem shortening and Mepiquat chloride or CCC doses, and concluded that Mepiquat chloride is more active than CCC in reducing the stem length and node number. Both the genotypes, Morden and KBSH-1 showed almost equal reduction in plant height in response to Mepiquat chloride (1000 ppm). However, KBSH-1 showed maximum reduction (19.7 cm) as compared to Morden (10.3 cm) under treatment T_8.

The mechanism of reduction in plant height appears to be due to slowing down of cell division and reduction in cell elongation because of inhibitory action of growth retardants in the biosynthetic path way of GA (Moore, 1980).

The data on the number of green leaves revealed that KBSH-1 was significantly superior over Morden in all the treatments from 30 DAS till harvest. At 30 DAS, there was no significant difference between the treatments, because, treatments were not imposed at that stage. Significant reduction in the number of leaves was observed only at 55, 65 and 75 DAS while, at 85 DAS and at harvest differences were non-significant. Similarly, Bhattacharjee and Gupta (1981) observed a reduction in the number of leaves per plant when the plants were treated with chlormequat chloride which is similar to Mepiquat chloride in its mode of action. Non-significant differences at 85 DAS and harvest could be attributed to the leaf senescence and leaf fall at this stage in all the treatments. Canor and Prado (1983) also noticed an increase in leaf retention in cotton sprayed with Mepiquat chloride.

Among the genotypes, KBSH-1 recorded significantly higher stem diameter over Morden throughout the crop growth period. At harvest, both the genotypes showed slight reduction in stem diameter as compared to previous stages, which could be attributed to the translocation of food towards reproductives structures and also due to desiccation of the stem. The growth retardants resulted in a slight reduction of stem diameter as compared to control at 60 DAS and at harvest. The maximum decrease (10.2%) was noticed with the plants treated with Mepiquat chloride (1000 ppm). The results of present investigation are in accordance with the results obtained by Schott and Ritting (1982) and Lala-Duenalia (1989) in cotton. Similarly in sunflower, Bhattacharjee and Gupta (1981) reported a reduction in stem diameter when the plants were treated with CCC.

Due to early setting up of button in Morden, the head was significantly bigger as compared to KBSH-1 at 55 DAS. With an advancement in the plant age, KBSH-1 produced slightly bigger size head as compared to Morden. Although, no treatments showed significant effect on head diameter.

Mepiquat chloride (1000 ppm) produced bigger sized capitulum (9.2%) followed by 1000 ppm CCC (3.8%) and 500 ppm of Mepiquat chloride (3.4%) over control. The reason for bigger sized capitulum may be due to 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. Similar results were obtained by Pande and Srivastava (1985) in sunflower sprayed with CCC, who stated that increase in head diameter could be due to better translocation of photosynthates.

The accumulation of dry matter was maximum in the capitulum followed by stem and minimum in leaves of both treated and untreated plants of Morden and KBSH-1 (Table 28). In addition to this, both the genotypes had maximum increase in head dry weight in the plants treated with Mepiquat chloride (1000 ppm) as compared to all other treatments including control. This increase in the head dry weight could be at the cost of reduced stem and leaf dry weight and also due to increase in the photosynthetic capacity and efficient translocation of photosynthates by shortening the distance between the source and sink. Morandi **et al.** (1984) reported a decrease in stem dry weight of soybean in response to Mepiquat chloride. Walter **et al.** (1980) reported that the application of Mepiquat chloride increased the boll dry weight by 16 per cent through reducing the plant height by 28 per cent, leaf area by 17 per cent. The decrease in TDM was significant only at 55 DAS.

LEGEND

T_1	=	Control	
T_2	=	Maleic hydrazide	(250 ppm)
T_3	=	TIBA	(50 ppm)
T_4	=	CCC	(1000 ppm)
T_5	=	Mepiquat chloride	(100 ppm)
T_6	=	Mepiquat chloride	(250 ppm)
T_7	=	Mepiquat chloride	(500 ppm)
T_8	=	Mepiquat chloride	(1000 ppm)

=Head dry weight

=Leaf dry weight

=Stem dry weight

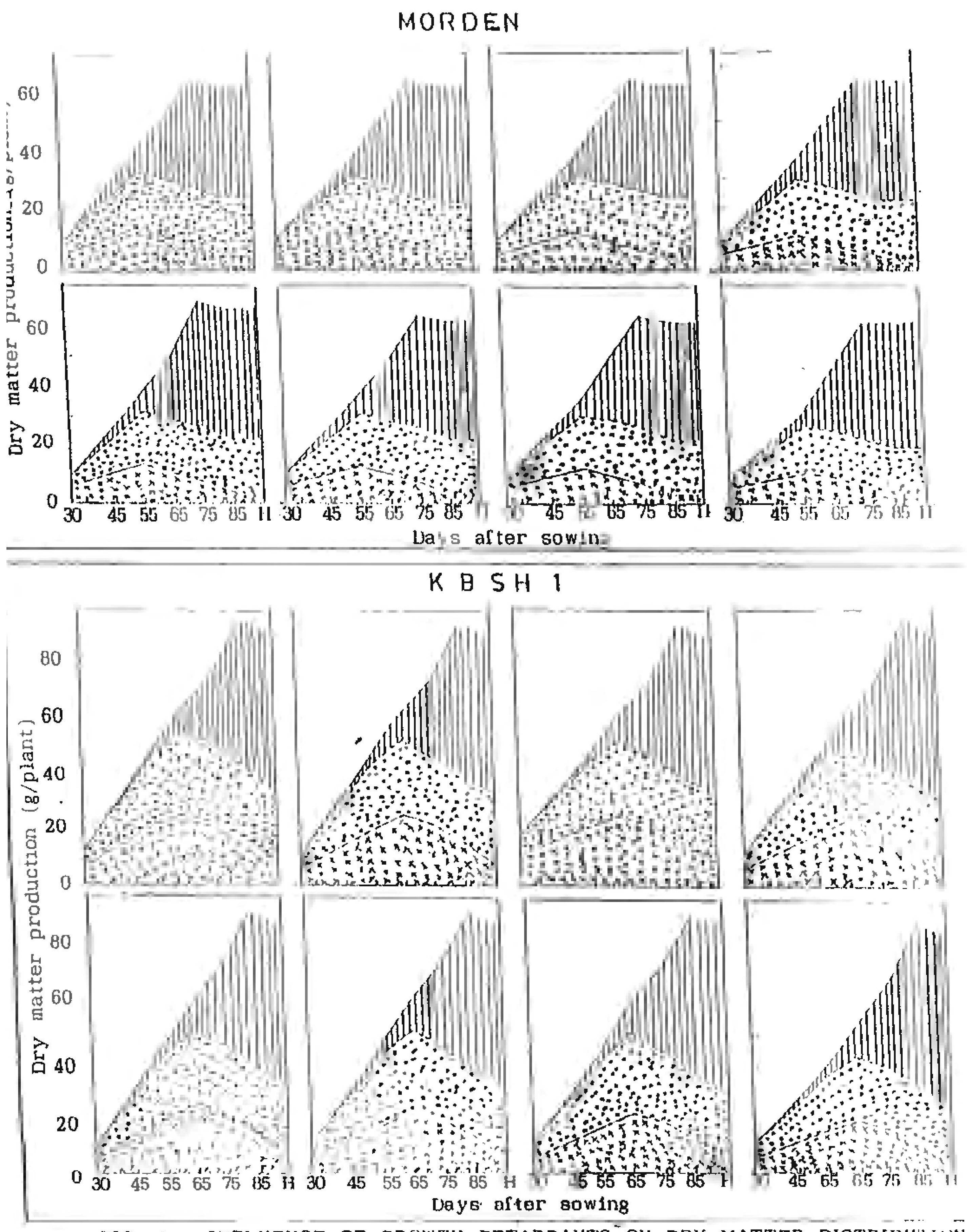

FIG. 4 : INFLUENCE OF GROWTH RETARDANTS ON DRY MATTER DISTRIBUTION IN DIFFERENT PLANT PARTS IN SUN FLOWER GENOTYPES.

but at later stages, the reduction was non significant in response to Mepiquat chloride (1000 ppm) because of rapid increase in seed filling rate. These results are in agreement with the results obtained by Wendt et al. (1984) in cotton.

As Morden reached its peak growth at 55 DAS, it produced maximum leaf whereas, KBSH-1 produced maximum leaf area at 65 DAS and then decreased, because of ageing and senescence of leaves. These differences in the peak leaf area could be attributed to the differential growth habit. The foliar application of Mepiquat chloride (1000 ppm) had marked effect on the assimilatory surface area resulting in the significant reduction of leaf area in both the genotypes at 65 and 75 DAS. This could be attributed to the reduction in the number of leaves and as well as leaf expansion rate. According to Lovett and Campwell (1973), growth retardants inhibit the cell elongation and thus the leaf expansion rate. Riedell and Ingett (1985) demonstrated that seed treatment with Mepiquat chloride resulted in the reduction of leaf length in maize. Similarly in cotton, the application of Mepiquat chloride resulted in the reduction of leaf area by 28.6-35.7 per cent (Jiang and Deng, 1986). However, at alter stages, the reduction in leaf area was non significant, which could be due to delayed leaf senescence. Gausman et al. (1985) reported that the application of 10-100 g a.i/ha Mepiquat chloride, delayed the leaf senescence and increased leaf chlorophyll contents in cotton.

Though, the leaf area per plant revealed that KBSH-1 was superior over Morden at all the growth stages, the leaf area per unit area was quite reverse at 40 and 55 DAS. Because, KBSH-1 being a long duration variety, did not have its peak growth. The least LAI was recorded by the plants treated with Mepiquat chloride (1000 ppm). Similar reduction of LAI was noticed in cotton at 31 days after treatment with Mepiquat chloride by Wendt et al.(1984).

The another parameter which is determined by leaf area index of two consecutive growth stages is leaf area duration (LAD). As KBSH-1 was having maximum leaf area than Morden during all its growth stages, it showed significantly higher LAD than Morden throughout its life cycle except during 30-55 DAS, since the leaf area produced in KBSH-1 was less at these stages because of initial slow growth. Mepiquat chloride (1000 ppm) reduced the LAD superiorly from all treatments during all the growth stages. The extent of reduction in LAD was gradually in decreasing trend in response to treatments. At harvest, there was very least reduction in LAD of the treated plants due to retention of greener leaves. The studies of Canor and Prado (1983) showed that the application of Mepiquat chloride either at pre or post-flowering stage increase leaf retention.

Table 29 : Influence of growth retardants on per cent distribution of dry matter in different plant parts at different growth stages in sunflower genotypes

Treatments			Days after sowing: 55 Morden	55 KBSH-1	55 Mean	65 Morden	65 KBSH-1	65 Mean	75 Morden	75 KBSH-1	75 Mean	85 Morden	85 KBSH-1	85 Mean	At Harvest Morden	At Harvest KBSH-1	At Harvest Mean
T_1 Control		S	46.0	52.0	49.0	38.5	43.7	41.1	30.1	34.7	32.4	30.4	28.8	29.6	30.4	30.4	30.4
		L	31.4	41.6	36.5	20.6	38.1	29.4	10.9	25.5	18.2	6.4	16.9	11.6	6.4	8.7	7.6
		H	22.5	5.2	14.4	40.7	18.0	44.4	58.8	36.6	47.9	63.1	53.9	58.5	63.1	60.7	61.9
T_2 Maleic hydrazide	(250 ppm)	S	46.5	52.7	49.6	38.0	42.2	40.1	29.2	32.2	30.7	30.0	28.4	29.2	30.0	29.7	29.8
		L	30.6	41.3	30.0	19.7	38.3	29.0	10.4	28.5	19.4	5.4	16.0	10.7	5.4	8.1	6.8
		H	22.8	5.8	14.3	42.1	19.3	30.7	60.3	38.2	49.2	64.5	55.5	60.0	64.5	62.1	63.3
T_3 TIBA	(50 ppm)	S	45.1	51.0	48.3	38.6	42.7	40.6	29.4	32.9	31.1	29.9	28.0	29.6	29.9	29.6	29.8
		L	31.0	42.6	38.8	19.3	38.3	28.8	11.0	28.9	19.9	6.0	15.2	10.6	6.0	8.8	7.4
		H	23.2	6.3	15.1	41.9	19.0	30.4	59.5	38.1	48.6	63.9	56.6	60.3	63.9	61.4	62.7
T_4 Cycocel	(1000 ppm)	S	46.2	52.0	49.1	37.5	42.1	39.8	29.2	32.7	30.9	29.1	27.7	28.4	29.1	29.6	29.3
		L	29.3	40.4	34.8	18.8	37.6	28.2	9.5	27.4	18.4	5.4	15.2	10.3	5.4	7.6	6.5
		H	24.3	7.5	15.9	43.6	20.2	31.9	61.2	39.9	50.5	63.8	57.0	60.4	63.8	62.7	63.2
T_5 Mepiquat chloride	(100 ppm)	S	45.7	52.1	48.9	37.8	42.1	40.0	29.9	33.4	31.6	30.5	28.9	29.7	30.5	30.5	30.5
		L	31.2	41.2	36.2	19.8	38.6	29.2	10.7	28.4	19.5	5.6	16.8	11.2	5.6	8.4	7.0
		H	22.9	6.5	17.7	42.3	19.2	30.7	59.3	30.1	48.7	61.9	54.1	58.0	61.9	61.0	51.5
T_6 Mepiquat chloride	(250 ppm)	S	45.7	52.2	49.0	38.2	42.4	40.3	29.4	32.9	31.2	30.0	28.9	29.4	30.0	30.1	30.1
		L	30.9	41.2	36.0	19.7	38.0	28.8	10.5	28.4	19.5	5.5	16.5	11.0	5.5	8.4	6.9
		H	23.3	6.5	14.9	42.0	19.5	30.8	59.9	38.5	49.2	64.4	54.5	59.5	64.4	61.4	62.9
T_7 Mepiquat chloride	(500 ppm)	S	45.1	52.6	48.9	37.3	41.6	39.4	29.2	32.9	31.1	29.6	28.1	28.9	29.6	29.6	29.6
		L	30.7	40.6	35.6	19.7	38.5	29.1	10.3	27.6	19.0	5.5	15.4	10.5	5.5	7.3	64.3
		H	24.0	6.7	15.4	42.8	19.8	31.3	60.3	39.4	49.8	64.7	56.4	60.5	64.7	63.0	63.8
T_8 Mepiquat chloride	(1000 ppm)	S	44.7	49.8	47.2	34.2	39.9	37.0	27.2	32.3	29.8	26.1	23.9	25.0	26.1	28.8	27.5
		L	29.0	41.3	35.6	19.1	37.6	28.4	8.6	25.4	17.0	4.9	14.8	9.8	4.9	5.7	5.3
		H	26.2	7.8	10.0	46.6	22.4	34.5	64.1	42.2	53.1	68.8	61.1	64.9	68.8	65.4	67.1

S = Stem L= Leaves H = Head

Table 30 : Influence of growth retardants on per cent reduction of total dry matter at different growth stages in sunflower genotypes

Treatments	Days after sowing: 55			65			75			85			At Harvest		
	Morden	KBSH-1	Mean	Morden	KBSH-1	Mean	Morden	KBSH-1	Mean	Morden	KBSH-1	Mean	Morden	KBSH-1	Mean
T_1 Control	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
T_2 Maleic hydrazide (250 ppm)	5.32	3.95	4.63	3.02	4.17	3.59	0.96	4.73	2.84	0.57	1.52	1.04	0.57	0.55	0.56
T_3 TIBA (50 ppm)	3.45	1.09	2.27	2.90	1.97	2.43	0.54	3.63	2.08	0.81	1.68	1.24	0.81	1.13	0.97
T_4 Cycocel (1000 ppm)	6.33	5.21	5.72	4.07	5.47	4.76	0.95	4.99	2.97	0.30	1.71	1.00	0.30	2.93	1.61
T_5 Mepiquat chloride (100 ppm)	1.66	2.67	2.16	2.78	3.24	3.01	0.25	2.78	1.51	0.60	0.79	0.69	0.60	0.54	0.57
T_6 Mepiquat chloride (250 ppm)	3.19	3.14	3.16	2.76	3.66	3.22	0.70	3.51	2.10	0.85	1.82	1.33	0.85	0.43	0.64
T_7 Mepiquat chloride (500 ppm)	5.12	5.55	5.33	3.61	4.63	4.12	0.89	3.93	2.41	1.04	1.82	1.43	1.04	1.62	1.33
T_8 Mepiquat chloride (1000 ppm)	12.11	13.52	12.81	7.25	13.52	10.63	3.23	9.25	6.24	2.37	2.12	2.24	2.37	3.96	3.16

It was observed that the SLA decreased with an increase in SLW in treated plants of both the genotypes. KBSH-1 recorded significantly higher SLW and lower SLA than Morden indicating that the leaves of KBSH-1 are thicker because of the accumulation of photosynthates and thickening of Mesophyll cells. In glass house trial of cotton, Gausman et al.(1978) reported that the application of Mepiquat chloride at different concentrations increased the leaf thickness by 29 per cent, having longer plisade and more spongy parenchyma cells within the leaf Mesphyll and had more chlorophyll content per unit area. Similarly, Walter et al.(1980) reported that the application of Mepiquat chloride (75 g a.i/ha) at first bloom stage of cotton increased the leaf thickness and thereby increased the photosynthesis. Results pertaining to SLA are in conformity with Reddy et al. (1990).

5.2 GROWTH PARAMETERS

The computation of various growth parameters indicated differential response of genotypes and treatments at different growth stages because of their differential crop duration. The maximum AGR, CGR and RGR values were observed at 55 DAS, but at maturity, both the genotypes found to have rapid increase in the AGR, CGR, RGR and NAR values as compared to previous stages i.e. 55 and 65 DAS, due to rapid seed filling and their development. At 55 DAS, the decrease in AGR, CGR, RGR and NAR was maximum in the plants treated with Mepiquat chloride (1000 ppm) followed by CCC (1000 ppm). Mepiquat chloride (500 ppm) and least in Mepiquat chloride (100 ppm). This was mainly because of the reduction in the total dry matter and assimilatory surface area under treated plants. The data also indicated that the per cent decrease in TDM ranged from 2.12 to 13.52 per cent in the genotype KBSH-1, while it was 2.37 to 12.11 per cent in Morden in response to 1000 ppm Mepiquat chloride (Table 29).

At 65 DAS, Morden showed increasing trend and KBSH-1 showed decreasing trend in AGR, CGR, RGR and NAR in response to treatments, because, the vegetative growth was completely stopped and seed filling and development was already initiated in Morden, whereas, in KBSH-1, which is long duration crop, the vegetative growth still continued and seed filling and development had not yet started. But at maturity, Mepiquat chloride (1000 ppm) significantly increased AGR, CGR, RGR and NAR over all the treatments. This could be attributed to increased photosynthetic effeciency by increasing leaf thickness and retaining chlorophyll content, and efficient translocation of photosynthates by reducing the distance between source and sink.

The data on the number of days to 50 per cent flowering and physiological maturity revealed that the genotype KBSH-1 required maximum days as compared to Morden. Both the genotypes attained physiological maturity early by two days in response to Mepiquat chloride (1000 ppm). This could be due to increased photosynthetic capacity of treated plants during seed filling period (Walter et al., 1980). The results of the present investigatin are in conformity with the results obtained by many scientists (Kerby 1983; York, 1983; Abdel-Al et al., 1986; Kerby et al., 1988; and Sawan and Sarkar, 1990). However, treatments did not differ in days to 50 per cent flowering. The reason could be, the late application of the growth retardants. According to the reports, the application of growth retardants in Chrysanthemum (Cathey, 1959), Petunia (Cathey, 1961), tomato (Wilter and Tolbert, 1961) and Wheat (Tolbert, 1960) did not alter the plants response to photoperiod, light quality or night temperatures.

5.3 YIELD AND YIELD PARAMETERS

In general, the yield of crop plants is attributed to total assimilation achieved during the growing season and the way it is partitioned between the desired storage structures and rest of the plant. Among the genotypes, KBSH-1 produced maximum seed yield as compared to Morden, and among treatments, Mepiquat chloride (1000 ppm) produced maximum yield. This is attributed to the superior values of yield components viz., higher number of filled seeds, least number of unfilled seeds, higher seed filling per cent, higher 100-seed weight, harvest index, seed yield per plant and seed yield per net plot. It was observed in the present study that the increase in seed yield was highest in the treatment

Mepiquat chloride (1000 ppm) which was significantly superior over all other treatments. Similarly, significant increase in seed cotton yield was obtained by the application of Mepiquat chloride by many scientists (Okhotnik et al.,1984; Sawson El-Hyatemy, 1984; Pol and Thombre, 1985; Jiang and Deng, 1986; Khasanor et al., 1986 and Dipponaar et al., 1990). It has also been reported that the application of Mepiquat chloride produced short statured plants with reduced leaf area in cotton which resulted in increased light infiltration in to the canopies (Bader, 1986), photosynthetic capacity of the canopies (Walter et al., 1980), expansion of the xylem and increased transport ability and intrurn produced heavier bolls (Schott and Ritting, 1982). Similarly, Pande and Srivastava (1985) reported that the application of CCC enhanced the photosynthetic carbon dioxide fixation rate, RuBP carboxylase activity and translocation of carbon towards capitulum and thereby increasing the seed yield in sunflower.

Increased seed yield levels in the treated plants is attributed to corresponding increase in head weight, number of filled seeds, seed filling per cent, 100-seed weight and corresponding decrease in the number of unfilled seeds. Whereas, the treatment with 1000 ppm Mepiquat chloride did not increase seed number significantly but, enhanced the seed filling process towards the centre. Morandi et al. (1983) noticed an increase in flower set and developed seeds per cent in soybean by applying Mepiquat chloride. In a similar experiment, Mishriky et al. (1990) reported an increase in the number and weight of pods and the total yield of pea when treated with CCC.

The increase in the seed yield could also be attributed to the reduction in partitioning of TDM towards stem and leaves, increased towards capitulum, reduced leaf area, increased SLW and chlorophyll content, which have direct bearing on the productivity. The data on harvest index (HI) indicated a significant increase due to the application of Mepiquat chloride (1000 ppm). Our results are in conformity with the results of Morandi et al. (1983) in soybean, who reported that such increase in harvest index was due to increase in the partitioning of dry matter in to seeds.

Although, KBSH-1 had numerically higher values than Morden in almost all the growth, yield and biochemical parameters, but statistically and on percentage basis both genotypes responded similarly towards growth retardants. Similarly, Wittwer and Tolbert (1960) observed that all cultivars of Tomato had tremendous variation in their sensitivity towards growth retardants. Of these, short cultivars were as responsive as tall ones when compared on per cent basis.

The lack of response for MH (250 ppm), TIBA (50 ppm), CCC (1000 ppm), Mepiquat chloride (500 ppm) might be due to use of lower concentrations. Bhattacharjee and Gupta (1981) reported that lower concentration of CCC did not have effect on sunflower growth. Similarly, Watson *et al.* (1970) reported that spraying of Mepiquat chloride (0.2 oz/ac) had no effect on growth or dry matter yield.

5.4 BIOCHEMICAL PARAMETERS

The study on chlorophyll content revealed that Chl.a, Chl.b and total chlorophyll contents increased in treated plants of both the genotypes. Chl.a, Chl.b and total chlorophyll contents increased upto 65 DAS in Morden and till 75 DAS in KBSH-1 and decreased thereafter due to ageing of leaves and senescence. KBSH-1 recorded significantly higher Chl. a content and differed significantly only at 75 and 85 DAS, because of their differential crop duration. Similarly, KBSH-1 recorded significantly higher total chlorophyll content only at 65 and 75 DAS and at remaining stages it recorded a slight increase. Whereas, with respect to Ch.b content, KBSH-1 recorded significantly higher values than Morden in all the growth stages except at harvest.

The maximum contents of Chl.a, Chl.b and total chlorophyll were recorded by Mepiquat chloride (1000 ppm), which significantly differed from other treatments at 65, 75 and 85 DAS. At 65 and 75 DAS, Mepiquat chloride (1000 ppm) differed significantly with all other treatments except with Mepiquat chloride (500 ppm) and CCC (1000 ppm), and at 85 DAS it differed significantly from rest of the treatments. In regard to Chl.b, during 65 DAS, Mepiquat chloride (1000 ppm) did not differ significantly with Mepiquat chloride (500 ppm) also had significantly higher Chl.b content as compared to palnts treated with Mepiquat chloride (100 ppm) and untreated plants. Similarly at 75 DAS, Mepiquat chloride (500 ppm) showed significant difference only over TIBA (50 ppm), Mepiquat chloride (100 ppm) and control plants. But at 85 DAS, Mepiquat chloride (1000 ppm) differed significantly from all the treatments. This clearly indicates that the effect of treatments other than Mepiquat chloride (1000 ppm) was not long losting.

Whereas, total chlorophyll content differed significantly at all the stages except during 55 DAS and at harvest in response to Mepiquat chloride (1000 ppm). The differences at earlier stages was due to increase in chlorophyll synthesis and at later stage it was due to mentainance of chlorophyll as compared other treatments including control. The per cent increase in total chlorophyll content was maximum in the plants treated with Mepiquat chloride (1000 ppm) in both the genotypes. Both genotypes responded in a similar way to growth retardants. The results of our investigation are in conformity with the results of other workers (Gausman et al., 1978; Stein et al., 1983; Gausman et al., 1985; Zid et al., 1986; and Abdel-Al et al.,1986). Jiang and Deng (1986) reported that the foliar application of Mepiquat chloride on cotton plant increased the chlorophyll content by 24.4-28 per cent. Vasilenko et al. (1991) reported that seed treatment with growth retardants accelerated the formation of reaction centres of PS II.

It has been observed that the soluble leaf protein was maximum at maturity in both the genotypes and in both untreated and treated plants (Table 26). KBSH-1 recorded significantly higher leaf soluble protein at maturity over Morden. At both stages, soluble leaf protein significantly reduced by Mepiquat chloride at 1000 and 500 ppm as compared to Mepiquat chloride (100 ppm), TIBA (50 ppm) and control. At maturity, Mepiquat chloride (500 ppm) also reduced significantly from Mepiquat chloride (250 ppm). Although, there was no interaction effect, the per cent decrease in soluble leaf protein ranged from 19.77 to 42.72 per cent in KBSH-1 and 17.61 to 37.81 per cent in Morden. Stein et al. (1983) found decreased levels of soluble proteins with increasing concentrations of Mepiquat chloride in cotton.

As KBSH-1 was high yielding one, it has registered significantly higher seed oil and protein contents. There was no significant difference in oil and protein contents of sunflower seeds due to treatments. In general, the oil and protein contents were increased with increasing concentration of mepiquat chloride to 1000 ppm. As there is no information available to suggest direct involvement of mepiquat chloride in oil biosynthesis, its possible effect on enzymes involved in oil synthesis may not be ignored. Abdel et al. (1986) reported that the application of mepiquat chloride to cotton increased both seed oil and protein contents.

5.5 CORRELATION STUDIES

The correlation coefficients between different characters are presented in table 30. It is evident from the see yield per plant showed very strong positive association with 100-seed weight harvest index, number of filled seeds, seed filling percentage, days to 50 per cent flowering head dry weight, SLW. RGR, NAR and total chlorophyll content. But it is negatively and strongly correlated with days to physiological maturity, plant height, number of leaves, leaf dry weight, total dry matter, leaf area, leaf area index, leaf area duration and leaf soluble protein. Similarly, 100-seed weight, harvest, index, number of filled seeds, seed filling percentage days to 50 per cent flowering head dry weight, SLW, RGR, NAR and total chlorophyll content had strong positive correlation among themselves. Whereas, days to physiological maturity, plant height, number of leaves, leaf dry weight, total dry matter, leaf area, leaf area index, leaf area duration and leaf soluble protein content were strongly and negatively correlated with the above characters.

5.6 FUTURE LINE OF WORK

Based on the results obtained in the present investigation, suggestions for further studies in the field of hormonal regulation of plant growth and development and its subsequent influence on the productivity are given below.

Table 30. Correlation co-efficients between different characters as influenced by growth retardants.

	Seed Weight/ Plant	100-seed Weight	Harvest Index	Number of filled seeds	Seed filling percentage	Days to 50% flowering	Days to physiological maturity	Plant Height (harvest)	Number of leaves (65 DAS)	Leaf dry weight (65 DAS)	Head dry weight (harvest)	TDM (harvest)	LA (65 DAS)	LAI (65 DAS)	LAD (55-65 DAS)	SLW (65 DAS)	RGR (MATURITY)	NAR (MATURITY)	Total Chlorophyll (65 DAS)	Leaf sol. protein (55 DAS)
Seed wt./plant		0.985**	0.996**	0.974**	0.942**	0.989**	-0.938**	-0.991**	-0.991**	-0.953**	0.976**	-0.979**	-0.991**	-0.979**	-0.982**	0.935**	0.96**	0.98**	0.97**	-0.983**
100-seed weight			0.988**	0.944**	0.898**	0.779**	-0.955**	-0.963**	-0.977**	-0.914**	0.941**	-0.943**	-0.96**	-0.943**	-0.949**	0.872**	0.931**	0.948**	0.932**	-0.962**
Harvest index				0.967**	0.932**	0.811**	-0.96**	-0.989**	-0.983**	-0.944**	-0.959**	-0.968**	-0.979**	-0.965**	-0.963**	0.906**	0.964**	0.981**	0.961**	-0.991**
No.of filled seeds					0.992**	0.734**	-0.888**	-0.974**	-0.974**	-0.983**	0.969**	-0.988**	-0.985**	-0.953**	-0.964**	0.921**	0.938**	0.986**	0.979**	-0.949**
Seed filling (%)						0.698**	-0.837**	-0.949**	-0.942**	-0.973**	0.944**	-0.976**	-0.962**	-0.922**	-0.941**	0.907**	0.903**	0.967**	0.966**	-0.915**
Days to 50% flowering							-0.899**	-0.782**	-0.72**	-0.656**	0.703**	-0.706**	-0.731**	-0.791**	-0.754**	0.694**	0.861**	0.781**	0.701**	-0.868**
Days to phy.maturity								0.926**	0.906**	0.848**	-0.562**	0.871**	0.894**	0.895**	0.877**	-0.792**	-0.949**	-0.923**	-0.872**	0.971**
Plant Ht.(Harvest)									0.973**	0.953**	-0.961**	0.988**	0.988**	[illegible]	0.974**	-0.941**	-0.948**	-0.979**	-0.987**	0.986**
No.of leaves (65 DAS)										0.972**	-0.989**	0.975**	0.991**	[illegible]	0.973**	-0.927**	-0.949**	-0.978**	-0.961**	0.954**
Leaf dry wt.(65 DAS)											-0.974**	0.975**	0.977**	0.944**	0.942**	-0.915**	-0.932**	-0.982**	-0.966**	0.918**
Head dry wt. (harvest)												-0.973**	-0.991**	[illegible]	-0.985**	0.962**	0.945**	0.971**	0.958**	-0.933**
TDM (harvest)													0.993**	0.961**	0.975**	-0.953**	-0.921**	-0.975**	-0.996**	0.952**
LA (65 DAS)														0.983**	0.989**	-0.961**	-0.947**	-0.982**	-0.986**	0.962**
LAI (65 DAS)															0.989**	-0.971**	-0.967**	-0.966**	-0.951**	-0.959**
55-65 DAS)																-0.979**	-0.931**	-0.955**	-0.971**	0.951**
SLW (65 DAS)																	0.891**	0.916**	0.949**	-0.904**
GR (MATURITY)																		0.977**	0.911**	-0.971**
AR (MATURITY)																			0.966**	-0.972**
tal chl.(65 DAS)																				-0.951**
af sol.prot.(55 DAS)																				

Significant at 0.05 and 0.01 level.

1. The study on the influence of various growth retardants on the principle enzymes of photosynthesis would be useful.

2. The growth regulators also influence the translocation efficiency within the plants and hence it is worth while to study the anotomical changes brought about by these chemicals.

3. It is also important to study the interaction of growth retardants with growth promoters like, auxins gibberlins and cytokinins and their ultimate influence on the endogenous level of these growth promoters.

CHAPTER - VI

SUMMARY

VI SUMMARY

A field study was undertaken to find out the response of sunflower genotypes to the application of different growth retardants during summer, 1992 at Agricultural College Farm, UAS, Dharwad. The experiment consisted of 16 treatment combinations with two genotypes (Morden and KBSH-1) laid out in randomised block design (factorial) with three replications. The results obtained from the present investigation are summarised in this chapter.

1. The hybrid, KBSH-1 was found to be superior over Morden in almost all the parameters studied. Among the treatments, Mepiquat chloride (1000 ppm) was found to be superior over all other treatments.

2. The plant height reduced significantly due to the application of growth retardants in both the genotypes and the extent of reduction was more in the treatment Mepiquat chloride (1000 ppm).

3. The number of leaves per plant decreased only at 65 and 75 DAS while at later stages of crop growth period, no significant differences in the number of green leaves were observed between the growth retardant treatments and control in both the genotypes.

4. The stem and head diameter of both the genotypes id not respond significantly with any of the treatments.

However, Mepiquat chloride (1000 ppm) reduced the stem diameter and increased the head diameter considerably in both the genotypes.

The data on phenological parameters indicated that Mepiquat chloride (1000 ppm) resulted in early physiological maturity by two days and there was no effect of growth retardants on 50 per cent flowering.

It was found that the maximum amount of dry matter was accumulated in the head of the plants treated with 1000 ppm of Mepiquat chloride as compared to other treatments and in this treatment, there was a significant reduction in the stem dry weight from 65 DAS onwards till harvest. Whereas, the leaf dry weight showed significant reduction only at 65 and 75 DAS due to delayed leaf senescence. A significant reduction in the TDM was observed only at 55 DAS.

A significant reduction in the assimilatory surface area and LAI was observed due to the application of 1000 ppm of Mepiquat chloride only at 65 and 75 DAS whereas, the reduction was minimum and non significant at later stages of crop growth in both the genotypes.

LAD and SLA decreased significantly with a significant increase in SLW at all the growth stages except at 40 and 55 DAS in both the genotypes.

9. The results of various growth parameters indicated that AGR, CGR, RGR and NAR decreased at 55 DAS and increased at maturity significantly in both genotypes treated with Mepiquat chloride (1000 ppm).

10. Significant increase in yield and yield components were obtained in the plants treated with Mepiquat chloride (1000 ppm). The harvest index was also significantly higher in this treatment in both the genotypes. However, there was no significant difference in the head diameter. In both genotypes, the maximum increase in yield and yield components were recorded in the treatment Mepiquat chloride (1000 ppm).

11. Though, both Chl. a and Chl.b contents increased due to the application of Mepiquat chloride (1000 ppm) in both genotypes, the per cent increase in Chl.a was more as compared to per cent increase in Chl.b. The lowest increase in Chl.a, Chl.b and total chlorophyll content was observed in case of Mepiquat chloride (100 ppm) and TIBA (50 ppm).

12. Among the treatments, significantly lower soluble protein content in the leaf was recorded in the treatment Mepiquat chloride (1000 ppm) and least reduction was noticed with Mepiquat chloride (100 ppm) and TIBA (50 ppm) in both the genotypes.

13. The genotype KBSH-1 had significantly higher leaf nitrogen as compared to Morden. Whereas, treatments did not differ significantly.

14. Oil content and seed protein contents were maximum in the seeds of plants treated with Mepiquat chloride (1000 ppm) as compared to rest of the treatments.

CHAPTER - VII

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VII REFERENCES

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