Effect of plant growth regulators on vegetative, floral and bulb production in tulip (*Tulipa gesneriana* L.)

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(2006-A-791-M)

THESIS

Submitted to

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Sher-e-Kashmir
University of Agricultural Sciences & Technology of Kashmir
in partial fulfilment of requirement for the award of the degree of

MASTER OF SCIENCE IN AGRICULTURE
(Floriculture and Landscaping)

2008

Dedicated to my Revered Parents

Sher-e-Kashmir
University of Agricultural Sciences & Technology of Kashmir
Division of Floriculture, Medicinal & Aromatic Plants
Shalimar Campus, Srinagar
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Certificate – I

This is to certify that the thesis entitled, **"Effect of plant growth regulators on vegetative, floral and bulb production in tulip (*Tulipa gesneriana* L.)"** submitted in partial fulfilment of the requirements for the award of the degree of **Master of Science in Agriculture (Floriculture and Landscaping),** to the Faculty of Postgraduate Studies, Sher-e-Kahsmir University of Agricultural Science and Technology of Kashmir is a record of bonafide research work carried out by **Mr. Zahoor Ahmed Rather (Regd. No. 2006-A-791-M)** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

It is further certified that such helps or information received during the course of investigation have duly been acknowledged.

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Certificate – II

We, the members of the Advisory committee of **Mr. Zahoor Ahmed Rather (Regd. No. 2006-A-791-M)**, a candidate for the degree of **Master of Science in Agriculture (Floriculture and Landscaping)**, have gone through the manuscript of the thesis entitled, **"Effect of plant growth regulators on vegetative, floral and bulb production in tulip (*Tulipa gesneriana* L.)"** and recommend that it may be submitted by the student in partial fulfilment of the requirement for the degree.

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This is to certify that the thesis, **"Effect of plant growth regulators on vegetative, floral and bulb production in tulip (*Tulipa gesneriana*)"** Submitted by **Mr. Zahoor Ahmed Rather** to the Faculty of Postgraduate Studies, Sher-e-Kashmir University of Agricultural Science and Technology of Kashmir, in partial fulfilment of the requirements for the award of the degree of **Master of Science in Agriculture (Floriculture and Landscaping)** was examined and approved by his Advisory Committee and external examiner on ………………..

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ABSTRACT

The present investigation was carried out to study the effect of plant growth regulators on vegetative, floral and bulb production in tulip. The experiment was laid out at experimental plots of Division of Floriculture, Medicinal and Aromatic Plants, SKUAST-K, Shalimar. Twenty treatments comprising of three concentrations each of Indole acetic acid (750, 500, 250 ppm), Cycocel (750, 500, 250 ppm) and 2, 3, 5 triiodobenzoic acid (200, 150, 100 ppm), two varieties, *viz*. Apeldoorn and Golden Oxford and two controls of respective varieties were tested in Randomized Block Design (RBD) which were replicated thrice.

The parameters recorded were days taken to bulb sprouting, plant height (cm), number of leaves per plant, leaf area (cm^2), leaf area index, days taken to floral bud appearance, days to colour break, days to flower opening, flower diameter (cm), scape length (cm), scape thickness (mm), scape weight (g), flowering duration (day), vase life (day), number of bulbs per plant, weight per bulb (g), size of bulb (cm), number of bulblets per plant, weight of bulblets per plant (g) and bulb production ratio.

Results obtained during the investigation revealed that IAA-500 ppm recorded significantly minimum days to bulb sprouting (86.97 days), maximum plant height (40.98 cm), minimum days to floral bud appearance (25.60 days), minimum days to colour break (6.63 days), minimum days to flower opening (3.37 days), maximum scape length (37.98 cm), maximum weight per bulb (17.83 g), maximum size of bulb (11.50 cm) and maximum weight of bulblets per plant (7.40 g). CCC-500 ppm recorded significantly maximum scape thickness (7.50 mm), flower duration (13.76 days), vase life (9.08 days), number of bulbs per plant (1.40), number of bulblets per plant (3.33) and bulb production ratio (1.40). Apeldoorn was observed to be significantly superior to Golden Oxford regarding various vegetative, floral and bulb production characters. IAA-500 ppm was observed to be economically most feasible by giving highest profit.

Key words : Comparison, Plant growth regulators, Concentration, economy, Tulip, Apoeldoorn, Golden Oxford

Signature of Student — Signature of Major Advisor

Dated : ___________ — Dated: ________________

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Place: Srinagar
Dated:

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CHAPTER - 1

INTRODUCTION

Tulip (*Tulipa gesneriana* L.), the premier ornamental flowering bulb, belongs to the family *Liliaceae.* The genus comprises of 100-150 species and is grown in areas from Morocco and Western Europe to Western China (Hoog, 1973). Generally the tulip is found in hilly areas upto 4000 m in the Himalayas (Rees, 1972). Tulip is believed to be the native of Mediterranean region and china but the natural origin of garden tulip seems to be lost, though many workers believe that it is derived from Gesneriana (Hall, 1940). It is one of the commercially important bulbous ornamental plants owing to its unsurpassed beauty and economic value.

Tulips are forced to use as cut flowers, potted plants and popularly grown as bed flower. Owing to large number of cultivars available, there are tulips for all uses and for all climatic zones (Pathania and Sehgal, 1997). Tulips rank high among garden flowers and are suitable for naturalization in grass under the trees and shrubs (Swarup, 1997). Tulips are flowers of rich brilliant colours and of good substance. It is the most showy spring flower, and the habit and shape of the plants are so formal and definite that it is adopted to the vicinity of buildings and to parterres (Bailey, 1949).

Bailey (1949) describes tulip as a plant originating from tunicated bulbs with fleshy scale leaves; having stem like scape which is leaf bearing, solitary and simple, sometimes branched; three to five leaves; flower hypogynous, erect, campanulate to saucer shaped; six perianth segments in two whorls; six stamens included, basi-fixed; style one or lacking; stigma three lobed; fruit three-valved loculicidal capsulate and seeds numerous.

The total area under flower production in different countries of the world is about 3,05,105 ha. of which the total area in Europe is 44,444 ha, North America 22,388 ha, Asia and pacific 2,15,386 ha, Middle East and Africa 5,282 ha and central and south Africa is 17, 605 ha (Bhattacharjee and Lakshman,2003). The largest area of any true bulb crop in the world is that of *Tulipa*¸ followed by *Narcissus* and then *Iris, Hyacinthus* and *Lilium.* However, this order is not always maintained for individual countries (Anonymous, 1985). Tulips were first brought to Europe in 1554 by O, de Busbeeq (the Austrian Ambassador to the sultan of Turkey). He acquired a few bulbs 'at great price' and took them to Vienna and suddenly their cultivation spread across Europe to the Netherlands where the Dutch really took them to their hearts (Perry, 1972).

In Netherlands it is the top most flowering geophyte with over 10,000 ha area under production in the world (Pathania and Sehgal, 1997).

Tulip has consistently ranked behind rose, chrysanthemum and carnation in the world cut flower trade but ahead of gladiolus in Holland (Negi and Raghava, 1986). Tulip is the national flower of Holland and is the largest producer of tulip flowers and bulbs (Scott, 2001). The Netherlands produced 2,224 million bulbs in 1983 which is 86 per cent of total world production followed by Japan, United Kingdom, France, Denmark, USA and Germany together which produced 124, 75, 65, 50, 25 and 16 million bulbs which is 5, 3, 2.5, 2, 1 and 0.4 per cent of total world production, respectively (Le Nard and De Hertough, 1993).

The international trade in cut flower is growing at a rate of 15 per cent while India's share in the world market is hardly growing at 1 per cent (Dharmaraj, 1996). Floriculture is one sector where India has very good opportunities to boost up exports. The floriculture industry has annual growth potential of 25 to 30 per cent and is capable of earning foreign exchange 25 to 30 times more than cereal or any other agricultural crop (Swarup, 1997).

The production capacity of cut flower in India was around 6,806 lakh stems in 1999-2000. Export in floriculture trade has increased from Rs.18.83 crores in 1993-94 to Rs. 123.12 crores in 2000-01 and the major share has come from cut flower category (Kazi, 2002). In India tulips thrive well in hilly areas of Jammu and Kashmir, Himachal Pradesh and Uttar Pradesh but do not grow satisfactorily in plains. In Himachal Pradesh, quality cut flowers are grown in glass houses whereas for bulb production planting in the field is economical (Raj, 1999).

Kashmir valley has an added advantage that tulips can be successfully and economically grown here for ‘off season’ cut flower production and can be readily marketed to plains thus having a very good potential of this trade. Presently, there are only a few growers in the trade of tulip cut flower in the valley. Evidently tulip occupies a premier position in the Kashmir valley among other ornamentals available for exploitation on a commercial scale. Recognizing this fact Jammu and Kashmir Government has recently started a project on tulip by importing about twelve (12) new varieties of tulip from Netherlands for bioasthetic and commercial propagation aspect.

The valley of Kashmir serves the most congenial climatic conditions for economic exploitation of tulip. It is gaining popularity among the flower growers in Kashmir valley because of ever increasing demand of its cut flowers and bulbs. Therefore, in order to increase the production of tulip, it is necessary to bring improvement in its production technology. Various attempts have been carried out in this regard and one such attempt is the use of plant growth regulators. In fact, the floriculture sector has made extensive use of growth regulators in commercial crop production than any other segment of agriculture. Growth regulators have first been studied and used on floriculture crops rather than on food crops. The high economic value of floriculture crops have also made them tempting targets for growth regulator applications.

Studies on plant growth regulators in relation to tulips have received attention only during the past three decades. Endogenous-auxins, abscissic acid (ABA), cytokinins, ethylene and gibberellins have been identified in tulips. The basic information on the precise use of plant growth regulators in improving the performance of tulip crop is lacking in the country in general and in the valley particular. Therefore keeping this fact in view, the present study was planned to study the effect of plant growth regulators on vegetative, floral and bulb production of tulip in Kashmir valley with the following objectives.

1. To find out the suitable plant growth regulator for growth, flowering and bulb production.
2. To find out the optimum concentration of the plant growth regulators.
3. To workout the economics of tulip production.

CHAPTER - 2

REVIEW OF LITERATURE

Tulip (*Tulipa gesneriana* L.) is a unique ornamental flower crop, wonder of nature and gift to mankind. Plant growth regulators are being extensively used for controlling plant growth and development in floriculture to improve quality and acceptability. Evidence for involvement of the different plant growth substances alone and in combination is based on the correlation of their concentrations with specific developmental stages and the relationship of plant growth substances to metabolic activity. Studies on plant growth regulators in relation to tulips have received attention only during last three decades. Varying levels of endogenous auxins, gibberellins, cytokinins, abscissic acid (ABA) and ethylene had been identified in tulip. However, the basic information on the precise use of plant growth regulators in tulip is lacking. The recent literature pertaining to the use of plant growth regulators on tulip has been reviewed critically and presented in this part of thesis. The information available regarding the effect of growth regulators on vegetative growth, flowering and bulb production has been summarised as under.

Bragt and Dekker (1973) applied chlormequat (0-16 g/pot) to soil when tulip shoots were about 3 cm above the soil and reported that the number of days to flowering and flower duration was not affected by chlormequat, but stem length at flowering time and the length of lowest and highest internodes and of perianth were all reduced in proportion to amount applied.

Hanks and Rees (1977a) reported that stem length in tulip was increased by applying indole acetic acid (IAA). Similarly, Saniewski *et al.* (1990) found that the stem elongation was markedly induced when IAA (0.1%) was applied to the site of the removed flower bud.

In another separate experiment, Shanmugam and Muthuswamy (1974) reported that TIBA at all levels increased plant height and flower size in *Chrysanthemum indicum* cv. White but lessened it in cv. Yellow. Further, it was found that all treatments except 400 ppm TIBA hastened flowering in White and delayed it in Yellow. On the contrary, Mohariya *et al.* (2003) reported that TIBA (100 ppm) reduced the plant height, increased the size of flowers and delayed flowering in chrysanthemum.

Bulbil production from twin scales cut from narcissus bulbs was investigated by incorporating plant growth regulators into the vermiculite in which the twin-scales were incubated and it was reported that IAA (1-10 ppm) increased the weight of bulbils produced by stimulating their early sprouting (Hanks and Rees, 1977b).

El-Shafie and Hassan (1978) while studying the effect of chlormequat on the growth and flowering of gerbera observed that chlormequat produced fewer but heavier florets and markedly reduced the number of leaves per plant and increased the flower diameter. Similarly, Nair *et al.* (2002) reported that chlormequat @ 800 ppm gave largest flower diameter (8.22 cm) and CCC @ 600ppm gave the longest vase lives (14.86 days).

Sharma *et al.* (1978) sprayed IAA on the plants of chrysanthemum cv. Marguerite and observed that IAA @ 20ppm gave best results with regard to plant height, stem diameter, number of leaves, time taken to flower (69 days) and flower longevity (9.2 days).

Castro *et al.* (1979) determined the effect of growth regulators on development of *Lilium longiflorum* and they reported that flower quality was improved when bulbs were soaked for 12 h in IAA (1000 ppm). Similarly, Ashutosh *et al.* (2000) while investigating the effect of IAA on growth and flowering of football lily (*Haemanthus multiflorus* cv. Martyn) reported that plant height and number of leaves per plant were increased as compared to control.

Sharga (1979) observed that best results with respect to sprouting

(100%), plant survival (100%), time taken to sprout (8.17 days), time taken to flower (92.85 days), duration of flowering (16.21 days) and spike length (59.95 cm) were obtained by application of NAA (50 ppm) in gladiolus. Similarly, gladiolus corms soaked for 24 h in IAA (100, 500, 1000 or 2000 mg/litre) hastened the differentiation of floral primordia (Tonecki, 1980).

Mohamed and Fawzi (1980) sprayed tulip cv. Golden Oxford with chlormequat and reported that weight of mother and daughter bulbs was greater at 400 and 200 ppm, respectively. However in double flowered variety of *Polianthes tuberosa*, chlormequat (1000, 2000 or 3000 ppm) significantly decreased leaf weight and, especially, bulb fresh weight and at the higher rates it delayed flowering (Hassan and Agina, 1980).

Biswas *et al.* (1983) reported that leaf emergence in tuberose was quickest (11 days) when rhizomes were soaked in IAA (10 ppm). Similarly, Bhattacharjee (1984) reported marked improvements in flowering and cormel formation of gladiolus with IAA (100 ppm) treatment and found that application of CCC generally increased the flower size.

Banasik and Saniewski (1985) compared the action of IAA (0.005 or 0.2%) with NAA or 2, 4-D (both at 0.05 or 0.2%) or TIBA (0.2%) on the growth of stalks in tulip cv. Gudoshnik by applying auxins to different internodes, *viz*. top of stem, middle internode, third and second internode or upper part of first internode. It was observed that all auxins induced stem growth when applied to stem apex and application of IAA or NAA to the middle of internode promoted stem growth in basipetal direction. On the other hand, 2,4-D or IBA promoted stem growth both in basipetal and acropetal direction.

In another study on bulbous crops, Flint and Alderson (1986) reported that treatment of chips in narcissus with TIBA and CCC resulted in an increased number of bulbils per chip, but individual bulbil size was generally reduced and TIBA (1000 ppm) resulted in fewer and smaller bulbils than in the untreated controls.

Mugge and Richter (1988) reported in their study that application of chlormequat (CCC) on tulip cv. Oxford immediately after harvesting of the flowers improved the bulb yield and obtained 74% of bulbs that were of sufficient circumference to be forced in second year. Similarly, spraying the foliage of tulip cv. Oxford with CCC (0.5%) immediately after flower harvest increased the size of bulbs recovered (Mugge and Richter, 1989).

Application of IAA (0.19%) as a lanolin paste to tulip stem, after excision of all leaves and flower bud, promoted the elongation of stem (Kawa and Saniewski, 1989; Kawa *et al.*, 1998 and Saniewski *et al.,* 1999).

Hetman *et al*.(1992) reported that tulip cv. Polka plants when treated with CCC (0 or 1.0%) as an aqueous foliar spray either at the green bud stage, immediately after heading or 10 days after heading increased the bulb yield compared with control. They also found that most effective treatment was chlormequat (0.1%) applied at the green bud stage, which increased the yield of bulbs with a circumference greater than 12 cm by 56%.

In another separate experiment, Leena Ravidas *et al.* (1992) while studying the effect of foliar application of growth regulators on the growth, flowering and corm yield of gladiolus cv. Friendship reported that greatest corm weight (70.20 g) and size (71.00 cm^3) was obtained with NAA at 100 ppm and the greatest number and weight of cormels (93.33 and 17.57 g, respectively) was obtained with CCC at 500 ppm.

Saniewski and Wegrzynowicz (1993) reported that continuous supply of auxin is necessary for stem growth by conducting an experiment on tulip cv. Gudoshnik in which flower buds were removed at various stages of growth and replaced by lanolin paste containing IAA (0 or 0.1%) for 1-4 days. It was further noticed that removing this exogenous supply of auxin caused induction of stem growth only during the next 24 h.

Aswath *et al.* (1995) found that among various pre-harvest sprays of cycocel (500, 1000 or 1500 ppm) and TIBA (100, 150 or 200 ppm) on *Callistephus chinensis*, the vase life was increased by two days by application of cycocel at a concentration of 500 ppm.

Hetman *et al*. (1996) sprayed tulip cv. Polka with CCC (0, 0.1, 0.5 and 1.0%) at three stages, *viz*. green bud stage, heading stage and 10 days after heading and observed that best results were obtained by spraying plants with CCC (1000ppm)when buds were green.

Saniewski and Okubo (1997) reported that IAA (0.1%) in lanolin paste applied to the cut surface of the top internode of non pre-cooled (kept at 17°C) and pre-cooled (5°C), derooted and rooted tulip (cultivars Apeldoorn and Gudoshnik) bulbs after decapitation, promoted the elongation of entire stem. They further noticed that application of auxin transport inhibitor, 2,3,5-triiodobenzoic acid or TIBA (0.5%) in lanolin paste to the middle of last internode, after IAA treatment, promoted the elongation of top half of the last internode but retarded the elongation of the lower half of the last internode and lower internodes. Thus it was suggested that auxin controls stem elongation in tulip. Similarly, TIBA inhibited IAA- and NAA-induced elongation of pre-cooled rooted tulip (*Tulipa gesneriana* cv. Gudoshnik) bulbs above and below the point of treatment. In an another experiment, reapplication of IAA to the middle of the third internode at one day after TIBA treatment stimulated growth of the first three internodes, but internode length did not recover to reach that after IAA treatment alone

(Saniewski and Okubo, 1998).

Weryszko *et al.* (1997) observed that application of chlormequat or CCC (0, 0.5, 1.0 and 1.5%) on tulip increased the stem diameter and showed an increasing trend in stem thickness with increase in concentration but had no effect on leaf thickness.

Laskowska *et al.* (1998) observed that chlormequat caused the shortening of flower stem in tulip and found that spraying the plants with chlormequat solution (0.25%) increased the yield of marketable bulbs by 33.7 per cent and yield of first grade bulbs by 51.5 per cent. Moreover in another study on tulip, foliar sprays of chlormequat (1000 ppm) increased the bulb yield by 48.2 per cent, bulb weight by 116.2 per cent, bulb circumference by 19.3 per cent, bulblet production by 29.1 per cent and bulblet weight by 56.8 per cent compared with the untreated plants (Mukherjee *et al.*, 1999).

Devendra *et al.* (1999) observed that foliar application of chlormequat (4000ppm) on tuberose significantly reduced the plant height (47.13 cm) as compared to control (49.80 cm). It was further reported that clump weight and shelf life of cut flowers were greatest (427.3 g and 14.06 days, respectively) when bulbs were treated with chlormequat (4000ppm).

Meher *et al.* (1999) carried out a field experiment in chrysanthemum and reported that plants treated with IAA (20ppm) took least number of days to 50 per cent flowering from planting.

Al-Humaid (2001) reported that *Gladiolus gandavensis* plants sprayed with CCC (800 ppm) flowered about 17-25 days later and stem thickness was increased by 45 per cent compared to control. Moreover, new corm and cormel production was markedly increased as CCC concentration increased compared to control.

Tawar *et al.* (2002) reported that number of days before emergence of spike, number of days before the opening of the first floret and number of days to flowering in gladiolus was decreased with increasing dose of IAA up to 250ppm.

Dantuluri *et al*. (2002) conducted an experiment to study the effect of IBA (200 and 300 ppm) and chlormequat (1500 and 3000 ppm) on Asiatic hybrid lily (*Lilium maculatum* cv. Corrida). They observed that IBA at both concentrations improved the plant height whereas, CCC at a concentration of 3000ppm reduced the plant height, exhibited maximum number of days to bud formation and flowering, produced maximum number of leaves and increased the vase life. However, enzyme linked immunosorbent assay (ELISA) showed that IAA level increased constantly during vase life and could induce ethylene production thereby, causing premature leaf wilting, yellowing, and shortened vase life (Guo Wei Ming *et al.*, 2003).

Chauhan and Chauhan *et al*. (2002) observed that gladiolus corms dipped in IAA (150 and 200 ppm) exhibited early sprouting and IAA at a concentration of 200 ppm accelerated the emergence of spike (77 days) compared to the untreated corms (85 days). These treatments were found to enhance spike length, the opening of first basal florets, number of days in-between emergence of spike and blooming of terminal floret and fading of terminal floret.

Low IAA concentrations improved the plant height, number and size (width and length) of leaves, promoted earliness in spike emergence, enhanced colour break in the first floret and flowering, increased the length of spikes and diameter of corms and cormels in gladiolus (*Gaur et al*., 2003).

Yet in another experiment, Geng-Xing Min *et al*. (2005) while investigating the effects of 2,3,5-triiodobenzoic acid (TIBA) in combination with gibberellic acid (GA_3) on the growth and flowering of non pre-cooled tulip cv. Oxford bulbs, reported that GA_3 partly replaced the cold requirement of bulbs and when TIBA was applied alongwith GA_3, growth and flowering were promoted even more. Further, the later the treatment with GA_3 or GA_3 + TIBA, the earlier the flowering and longer the flower stalks.

In another experiment, Kawa *et al.* (2005) while studying the effect of auxins (IAA) on tulip stem and leaf senescence observed that senescence was greatly delayed after application of IAA. In all experiments, it was reported that auxin retarded the chlorophyll degradation and high concentrations of IAA (1.0 or 2.0%) were more effective. Even 34 days after treatment, stems were still stiff and green. It was, therefore, concluded that auxin (IAA) applied exogenously, is an important anti-senescence factor of tulip shoot.

Kurtar and Ayan (2005) carried out an experiment to determine the effect of indole-3-acetic acid (IAA) on flower and bulb yield of tulip (*Tulipa gesneriana* var. Cassini) by spraying the plants with four concentrations of IAA (500, 1000, 2500 or 5000 ppm). They observed that lowest number of earlier flower (5.56 flowers per m^2) was obtained by application of IAA at a concentration of 5000 ppm. On the contrary, highest bulb yield (671.7 per m^2) and bulb weight (6.25 g) was recorded by IAA at a concentration of 5000 ppm.Thus these results clearly indicated that high dose of IAA application was detrimental but bulb yield and individual bulb weight were increased.

Bulb and bulblet production from medium sized tuberose bulbs increased with increasing rates of chlormequat, and treatment with chlormequat (200 ppm) resulted in highest bulb and bulblet production of small and large tuberose bulbs (Satya Prakash and Shukla, 2006).

Haque *et al.* (2007) reported that chlormequat chloride (1000 and 2000 mg/l) increased the single flower weight and decreased the plant height in chrysanthemum.

CHAPTER – 3

MATERIALS AND METHODS

The present study on effect of plant growth regulators on vegetative, floral and bulb production of tulip was conducted during 2007-08 in the experimental farm of Division of Floriculture, Medicinal and Aromatic Plants, Sher-e-Kashmir University of Agricultural Sciences & Technology of Kashmir, Shalimar. The details of the materials used and methodology adopted during the experiment to achieve the objectives of the study are described as under:

3.1 Experimental site

The investigation was conducted at the experimental plots of Division of Floriculture, Medicinal and Aromatic Plants at main campus of Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Shalimar, Srinagar which is situated 16 km away from city centre and lies between 34^{o} 05′ N latitude and 74^{o} 98′ longitude at an altitude of 1587 meters above the mean sea level (Plate-1).

Vegetative view of research trial

Field in full bloom

Plate-1 : Overall view of research trial of tulip

3.2 Climate

The climate is temperate-cum-mediterranean and continental type characterized by hot summers and severe winters. During winter the temperature sometimes goes below freezing point and whole of the valley is covered with snow. The average annual precipitation is 944.6 mm (average over past 30 years) and more than 80 per cent of precipitation is received from western disturbances. The mean monthly meteorological data collected during the growing season is appended in Appendix II. It can be observed from the data that mean maximum temperature ranged from 0.83°C to 19.41°C and minimum temperature ranged from -2.61°C to 6.32°C in January and April, respectively. The relative humidity ranged between 85.63 percent in January to 65.30 percent in April, during the entire growing season. The total rainfall received during the entire growing season of tulip (Nov, 2007 to June, 2008) amounted to 386.30 mm. Highest rainfall of 108 mm was received during the month of April, 2008. The snow fall was encountered in the early week of February followed by light rain fall. The span of dry spell was observed in the month of March.

3.3 Soil characteristics

The soil of the experimental plot was silty clay loam in texture having organic carbon 0.98 per cent, pH 6.93, available nitrogen 335.71 kg ha^{-1}, phosphorus 15.38 kg ha^{-1} and potassium 198.28 kg ha^{-1}.

3.4 Varietal description

Apeldoorn – Darwin hybrid group tulip bearing cherry-red flowers with signal-red margins. Insides are signal-red with yellow-bordered black marks and black anthers. Mid-spring flowering.

Golden Oxford – Darwin hybrid grou-tulip producing pure yellow flowers, sometimes narrowly margined red, with black anthers, mid-Spring flowering.

Bulbs of the above two cultivars, approximately of 10 cm circumference or size were used as planting material.

3.5 Experimental details

I. Treatments

a) Varieties

1) V_1	Apeldoorn
2) V_2	Golden oxford

b) Plant growth regulators Concentration

1) Indole acetic acid (IAA)

A_1	750 ppm
A_2	500 ppm
A_3	250 ppm

2) Cycocel (CCC)

C_1	750 ppm
C_2	500 ppm
C_3	250 ppm

3) Triiodobenzoic acid (TIBA)

T_1	200 ppm
T_2	150 ppm
T_3	100 ppm

c) Control (s)

S_1 (For V_1)	Distilled water
S_2 (For V_2)	Distilled water

II.	Treatment combinations	: 20 (Twenty)
III.	Design	: **Randomized Block Design**
IV.	Replications	: 3 (Three)
V.	Number of bulbs/ treatment/ replication	: 30 (Thirty)
VI.	Net plot size	: 1.0 x 0.9 m^2
VII.	Spacing	: 15 x 20 cm
VIII.	Duration of bulb dip	: 2 hours

3.6 Field/ Cultural operations

3.6.1 Preparation of Land

The land was ploughed two times with the help of tractor followed by planking and deweeding. The field was then leveled and sixty plots were prepared as per the desired layout plan.

3.6.2 Application of manure and fertilizers

The organic manure in the form of well decomposed farmyard manure was applied and thoroughly mixed with the soil two weeks before the planting of bulbs. The recommended basal dose of N, P and K @ 120, 100 and 100 kg ha^{-1} through urea, single super phosphate and murate of potash, respectively were applied a week before the planting of bulbs. Top dressing of nitrogen @ 30 kg ha^{-1} was given during the third week of February.

3.6.2 Cultural operations

The experimental plots were kept free from weeds by regular hoeing-cum-weeding and experimental field was flood irrigated as per the requirement. Timely pest and disease control measures were adopted and the details about the different cultural operations adopted throughout the growth period are presented in Table-1.

Table-1: Calendar of operations

S. No.	Operation	2007-08
1.	Land preparation and layout	October 29, 2007
2.	FYM application	November 05, 2007
3.	Fertilizer application	
	Basal dose (N, P, K)	November 12, 2007
	Top dressing (N)	February 21, 2008
4.	Planting of bulbs	November 20, 2007

5.	Hoeing-cum-weeding	
	Ist	March 01, 2008
	2nd	March 24, 2008
	3rd	April 19, 2008
6.	Irrigation	
	Ist	March 10, 2008
	2nd	March 22, 2008
	3rd	April 02, 2008
	4th	May 18, 2008
7.	Plant protection measures	
	Fungicide spraying (Carbendazim @ 0.05%)	March 20, 2008
8.	Harvesting of bulbs	June 06, 2008

3.7 Preparation of Plant Growth Regulator solutions

Before planting the tulip bulbs were soaked in different plant growth regulator solutions for about two hours. First of all the volume of growth regulator solutions required for dipping of thirty bulbs was determined by dipping the thirty tulip bulbs in a measured quantity of tap water. With the help of this the stock solution of IAA and TIBA was prepared by dissolving the weighed quantity of the growth regulators in weak alcohol or 2N alkali. Subsequently the stock solution of these two chemicals and CCC was diluted with distilled water to prepare the required concentration and volume. These solutions were poured into the containers of suitable capacity and were divided into two sets in which the bulbs of two varieties (Apeldoorn and Golden oxford) were dipped for two hours. After dipping the bulbs for stipulated period of time, they were taken out and then planted in the field.

Two sets of controls were used for the two different varieties in which only distilled water was used.

3.8 Observations recorded

The biometrical observations were recorded on five randomly selected plants to asses the effect of treatments on growth, flowering and bulb production. In each experimental plot from the middle rows, to avoid border effect, five randomly selected plants were tagged for recording the following biometric observations and the mean values for different characters were subjected to statistical analysis.

3.8.1 Vegetative characters

3.8.1.1 Days taken to sprouting

Days taken from planting of tulip bulbs to sprouting or shoot emergence were recorded in each replication of each treatment and average number of days taken were calculated.

3.8.1.2 Plant height (cm)

Plant height of five representative plants was recorded in centimeters with a metre rod by measuring the scape length from the bottom of the plant (touching soil surface) to the top of the flower.

3.8.1.3 Number of leaves per plant

Number of leaves from each representative plant in each treatment was counted and average was worked out. Data on number of leaves were recorded at the time of maturity of the plant.

3.8.1.4 Leaf area (cm^2)

Fresh leaves were taken treatment-wise from each representative plant, their leaf area was measured and the data were recorded**.**

3.8.1.5 Leaf area index

Leaf area index was calculated by dividing the total leaf area by ground area.

3.8.2 Floral characters

3.8.2.1 Days taken to the appearance of floral bud

Dates of floral bud visibility were noted from five representative plants and days taken to appearance of floral bud were calculated from the date of bulb sprouting.

3.8.2.2 Days taken to colour break

Date of full colouration of the outside of perianth segment was recorded and days taken to colour break were calculated from the date of visibility of floral bud.

3.8.2.3 Days taken to flower opening

Dates of full flower opening were recorded and days taken to flower opening were calculated from the date of colour break.

3.8.2.4 Flower diameter (cm)

The flower diameter from each representative plant was measured with the help of measuring scale when it was fully open in east-west and north-south direction and mean values were worked out.

3.8.2.5 Scape length (cm)

Scape length from five representative plants was measured from just above the base of wrapper leaf to the top of scape and mean value was calculated.

3.8.2.6 Scape thickness (cm)

Scape thickness was measured with the help of Vernier Calliper and the mean values were recorded.

3.8.2.7 Weight of flower scape (g)

The fresh weight of flower scape in each treatment from each replication was recorded on a balance and average was worked out in grams

3.8.2.8 Duration of flowering (day)

The duration of flowering was calculated by recording the number of days taken from full flower opening to flower fading.

3.8.2.9 Vase life (day)

The scapes were harvested from the plants other than those used for recording biometric observations. The uniform cut flowers in terms of developmental stage were harvested from each treatment and were carried fresh to the laboratory. The cut flowers were placed in conical flask containing 200 ml distilled water. Vase life in days was determined at room temperature under natural light conditions. The initial point for recording vase life was chosen when flower bud just opened up. The end of the vase life was depicted when the flower lost its decorative value.

3.8.3 Bulb characters

3.8.3.1 Lifting of bulbs

The bulbs were lifted during the first week of June when most of the foliage had dried up. Bulbs were shade dried, cleaned and then various observations regarding bulb production characters were recorded.

3.8.3.2 Number of bulbs per plant

Total number of bulbs harvested per plant per treatment were counted and recorded from five representative plants.

3.8.3.3 Weight of bulb (g)

Bulbs were picked up from representative plants treatment-wise and their weight was recorded individually on balance.

3.8.3.4 Size of bulb (cm)

Size of the bulb was recorded with the help of vernier caliper across two ends and average value was worked out.

3.8.3.5 Number of bulblets per plant

Number of bulblets other than daughter bulbs were counted per plant and recorded.

3.8.3.6 Weight of bulblets per plant (g)

Bulblets per plant per treatment per replication were weighed with the help of a balance and average weight was recorded.

3.8.3.7 Bulb production ratio

Bulb production ratio was calculated by dividing the number of bulbs harvested by the number of bulbs planted per treatment.

3.9 Statistical analysis

The statistical analysis was carried out in R and S-plus software packages which is the implementation of Box *et al.* (1978). For meteorological data the help was sought from Division of Agronomy of Shalimar Campus SKUAST-K.

CHAPTER – 4

EXPERIMENTAL FINDINGS

4.1 Vegetative characters

Perusal of data (Tables 2-4) on vegetative characters revealed that all vegetative characters were significantly influenced by growth regulators and varieties except number of leaves per plant. However, no significant interaction effect of growth regulators and varieties was observed on all vegetative characters. The corresponding analysis of variance is presented in Appendix-I.

4.1.1 Days taken to bulb sprouting

4.1.1.1 Effect of growth regulators on days taken to bulb sprouting

The data on days taken to bulb sprouting as influenced by plant growth regulators is interpreted in Table-2 and graphically presented in Fig.1. Among various growth regulators, indole acetic acid was most effective in promoting the bulb sprouting as compared to other growth regulators. IAA-500ppm recorded significantly minimum days to bulb sprouting (86.97 days) followed by IAA-750ppm (87.20 days) as compared to other treatments including control. CCC-750 ppm took significantly maximum days to bulb sprouting (90.00 days) followed by CCC-500ppm

(89.27 days) as compared to control (88.30 days). Likewise, TIBA-200ppm was significantly inferior to control in reducing days taken to bulb sprouting (89.23 days). However, TIBA-150ppm and TIBA-100ppm were observed to be ineffective in reducing days taken to bulb sprouting as they were statistically at par with control (88.30 days).

4.1.1.2Effect of varieties on days taken to bulb sprouting

Perusal of the data (Table-3), significant impact of varieties was observed on days taken to bulb sprouting. Apeldoorn (V_1) took significantly minimum days to bulb sprouting (88.00 days) while as Golden oxford (V_2) took relatively maximum days to bulb sprouting (89.06 days).

4.1.1.3 Interaction effect of growth regulators and varieties on days taken to bulb sprouting

The interaction of growth regulators and varieties did not cause any significant variation on days taken to bulb sprouting. However, Apeldoorn (V_1) treated with IAA-500ppm took minimum days to bulb sprouting (86.73 days) followed by treatment with IAA-750ppm (86.93 days) and Golden oxford when treated with IAA-500ppm (87.20 days). Further, maximum days to bulb sprouting (91.47 days) was recorded with Golden oxford (V_2) when treated with CCC-750 ppm followed by treatment with TIBA-200ppm (90.07 days) and CCC-500ppm (89.73 days).

4.1.2 Plant height (cm)

4.1.2.1 Effect of plant growth regulators on plant height

Data on mean plant height of tulip recorded at flowering time as influenced by growth regulators is presented in Table-2 and graphically given in Fig. 2. Among various growth regulators, indole acetic acid (IAA) recorded maximum plant height while as cycocel (CCC) exhibited retarding effect on plant height. IAA-500ppm being statistically at par with IAA-750ppm recorded significantly maximum plant height (40.98 cm) as compared to other treatments. Whereas, CCC-750 ppm recorded significantly minimum plant height (26.00 cm) followed by CCC-500ppm (29.58 cm) and both treatments were significantly inferior to control (33.33 cm) in inducing higher plant height. Like wise, TIBA-200 ppm recorded slight decrease in plant height (32.32 cm) as compared to control (33.33 cm). TIBA-150ppm and TIBA-100 ppm did not cause much impact on plant height (34.37 cm and 35.44 cm, respectively) and were statistically at par with each other as well as with control (33.33 cm).

4.2.2 Effect of varieties on plant height

The data in Table-4 depicted that significant impact of varieties was observed on plant height. Apeldoorn (V_1) recorded significantly maximum plant height (35.43 cm) as compared to Golden oxford (V_2) which recorded relatively minimum plant height (32.64 cm).

4.1.2.3 Interaction effect of growth regulators and varieties on plant height

The difference between the growth regulators and varieties on plant height was not significant. However, Apeldoorn (V_1) treated with IAA-500ppm recorded maximum plant height (41.25 cm) followed by Golden oxford (V_2) treated with IAA-500 ppm (40.70 cm) and Apeldoorn (V_1) treated with IAA-750ppm (39.17 cm). Golden oxford (V_2) treated with CCC-750ppm recorded minimum plant height (25.04 cm) followed by Apeldoorn (V_1) treated with CCC-500 ppm (26.96 cm) and Golden oxford treated with CCC-500 ppm (29.46 cm).

4.1.3 Number of leaves per plant

4.1.3.1 Effect of growth regulators on number of leaves per plant

The data pertaining to number of leaves per plant as influenced by plant growth regulators has been presented in Table-2 and graphically given in Fig. 3. Perusal of data, plant growth regulators did not cause any significant effect on number of leaves per plant. However, indole acetic acid (IAA) was superior in recording higher number of leaves per plant as compared to other growth regulators. IAA-500 ppm recorded maximum number of leaves per plant (4.66) followed by IAA-250 ppm (4.33), CCC-500 ppm (4.33) and TIBA-150 ppm (4.33) as compared to control (3.33).

4.1.3.2 Effect of varieties on number of leaves per plant

Data (Table-3) indicated that the effect of varieties on number of leaves per plant was not significant. However, Apeldoorn (V_1) recorded highest number of leaves per plant (4.13) as compared to Golden oxford which recorded relatively minimum number of leaves per plant (4.09).

4.1.3.3 Interaction effect of growth regulators and varieties on number of leaves per plant

The perusal of data (Table-4) revealed that there was no significant difference between growth regulators and varieties on number of leaves per plant. However, maximum number of leaves per plant (4.66) was recorded in both varieties when treated with IAA-500ppm while as, minimum number of leaves per plant (3.33) were recorded under respective controls of two varieties.

4.1.4 Leaf area (cm^2)

4.1.4.1 Effect of growth regulators on leaf area

The data pertaining to mean leaf area as influenced by growth regulators is interpreted in Table-2 and graphically presented in Fig. 4. An elucidation of the data indicated that effect of growth regulators on leaf area was significant. Indole acetic acid was observed to record maximum leaf area as compared to other growth regulators. IAA-500 ppm being statistically at par with IAA-750ppm and IAA-250 ppm recorded significantly maximum leaf area (93.07, 84.20 and 80.68 cm^2, respectively) as compared to control (66.28 cm^2). Whereas, CCC and TIBA at all doses were observed to be ineffective in recording significantly higher leaf area as compared to control. However, minimum leaf area (66.28 cm^2) was recorded under control.

4.1.4.2 Effect of varieties on leaf area

Perusal of data (Table-3) revealed that there was significant impact of varieties on leaf area. Apeldoorn (V_1) recorded significantly maximum leaf area (88.34 cm^2) as compared to Golden oxford which recorded relatively minimum leaf area (64.29 cm^2).

4.1.4.3 Interaction effect of growth regulators and varieties on leaf area

Perusal of data (Table-4) revealed that the interaction between plant growth regulators and varieties had not caused any significant impact on leaf area. However, Apeldoorn when treated with IAA-500ppm recorded maximum leaf area (103.40 cm^2) followed by treatment with IAA-750ppm and IAA-250ppm which recorded a leaf area of 100.66 cm^2 and 96.94 cm^2, respectively. Further, minimum leaf area (55.51 cm^2) was recorded with Golden oxford when treated with CCC-750ppm followed by treatment with CCC-500ppm (58.27 cm^2) and distilled water (58.47 cm^2).

4.1.5 Leaf area index

4.1.5.1 Effect of growth regulators on leaf area index

An inquisition of data in Table-2 revealed that significant impact of growth regulators was observed on leaf area index. However, indole acetic acid was observed to be most effective in recording significantly maximum leaf area index as compared to other growth regulators. Among various treatments, IAA-500 ppm being statistically at par with IAA-750ppm recorded maximum leaf area index (0.31) as compared in control (0.22) Whereas, CCC and TIBA at all concentrations were ineffective in inducing significantly higher leaf area index and were found to be statistically at par with control (0.22).

4.1.5.2 Effect of varieties on leaf area index

Perusal of data (Table-3) depicted that there was significant impact of varieties on leaf area index. Apeldoorn (V_1) recorded significantly maximum leaf area index (0.29) as compared to Golden oxford which recorded relatively minimum leaf area index (0.21).

4.1.5.3 Interaction effect of growth regulators and varieties on leaf area index

Perusal of data (Table-4), the interaction between growth regulators and varieties on leaf area index had not caused any significant impact on leaf area index. However, Apeldoorn (V_1) when treated with IAA-500ppm recorded maximum leaf area index (0.34) followed by treatment with IAA-750ppm which recorded leaf area index (0.33). Further, minimum leaf area index (0.18) was recorded with Golden oxford (V_2) when treated with CCC-750 ppm followed by treatment with CCC-500ppm (0.19).

4.2 Floral characters

Data (Tables 5-7) revealed that all floral characters were significantly influenced by application of growth regulators except flower diameter and scape weight. Significant effect of varieties was observed on floral characters except days taken to colour break, flower diameter and scape weight

4.2.1 Days taken to appearance of floral bud

4.2.1.1 Effect of growth regulators on days taken to floral bud appearance

Data on days taken to appearance of floral bud as influenced by plant growth regulators is interpreted in Table-5 and graphically presented in Fig. 6. An inquisition of data reveals that days taken to floral bud appearance were observed to be significantly influenced by application of growth regulators. Among various growth regulators, indole acetic acid (IAA) was observed to be superior in recording minimum days to floral bud appearance as compared to other growth regulators. IAA-500 ppm recorded significantly minimum days to floral bud appearance (25.60 days) as compared to other treatments. This was followed by IAA-750 ppm which took 26.50 days to appearance of floral bud as compared to control (27.73 days). Contrary to this, CCC-750ppm recorded significantly maximum days to floral bud appearance (30.50 days) followed by TIBA-200 ppm (29.50 days). Both these treatments were significantly inferior to control (27.73 days) in recording minimum days to floral bud appearance. Although, CCC-500ppm and TIBA-150ppm slightly delayed the floral bud appearance (28.50 and 27.97 days, respectively) but not significantly as they were statistically at par with control.

4.2.1.2 Effect of varieties on days taken to floral bud appearance

Perusal of data (Table-6) revealed that there was significant effect of genotypes on days taken to floral bud appearance. Apeldoorn (V_1) took significantly maximum days to floral bud appearance (28.76 days) than Golden oxford (26.87 days).

4.2.1.3 Interaction effect of growth regulators and varieties on days taken to floral bud appearance

Perusal of data (Table-7), significant impact of interaction between growth regulator treatments and varieties was observed on days taken to appearance of floral bud. Minimum days taken to appearance of floral bud (24.13 days) were significantly recorded with Golden oxford treated with

IAA-500 ppm which is statistically at par with Golden oxford treated with IAA-250ppm (25.33 days). However, maximum days to appearance of floral bud (30.80 days) were significantly recorded with Apeldoorn when treated with CCC-750ppm which is statistically at par with Golden oxford when treated with CCC-750ppm (30.20 days) and Golden oxford treated with TIBA-200ppm (29.66 days).

4.2.2 Days taken to colour break

4.2.2.1 Effect of growth regulators on days taken to colour break

An elucidation of data (Table-5 & Fig. 7) reveals that application of growth regulators had caused a significant impact on days taken to colour break. Indole acetic acid was observed to be significantly superior in recording minimum days to colour break as compared to other growth regulators. Among various treatments, IAA-500 ppm was most effective in recording significantly minimum days to colour break (6.63 days) as compared to rest of the treatments. This was followed by IAA-250 ppm and IAA-750 ppm recording 7.40 and 8.23 days to colour break, respectively as compared to control (8.40 days). On the contrary, CCC-750 ppm recorded significantly maximum days to colour break (10.77 days) followed by CCC-500 ppm (9.53 days) as compared to control (8.40 days). Similarly, TIBA-200 ppm was significantly inferior to control (8.40 days) in recording minimum days to colour break (9.23 days). Although, TIBA-150 ppm and TIBA-100 ppm had slightly extended the days taken to colour break but were not significant and were found to be statistically at par with control.

4.2.2.2 Effect of varieties on days taken to colour break

Perusal of data (Table-6) for days taken to colour break revealed that the two genotypes did not differ significantly. However, Apeldoorn (V_1) took maximum days to colour break (8.66 days) while as Golden oxford (V_2) took relatively minimum days to colour break. (8.59 days).

4.2.2.3 Interaction effect of growth regulators and varieties on days taken to colour break

Perusal of data (Table-7) revealed that, effect of interaction between growth regulators and varieties on days taken to colour break was not significant. However, minimum days to colour break (6.40 days) were recorded with Apeldoorn treated with IAA-500ppm followed by Golden oxford when treated with IAA-500ppm (6.88 days) and IAA-250ppm (7.35 days).Whereas, maximum days to colour break (11.20 days) were recorded with Apeldoorn treated with CCC-750ppm followed by Golden oxford treated with CCC-750ppm (10.33 days) and Apeldoorn treated with CCC-500ppm (9.80 days).

4.2.3 Days taken to flower opening

4.2.3.1 Effect of growth regulators on days taken to flower opening

An inquisition of data (Table-5 & Fig. 8) depicted that significant effect of growth regulators was observed on days taken to flower opening. Indole acetic acid (IAA) at all doses was observed to be significantly superior in accelerating the flower opening process. IAA-500 ppm recorded significantly minimum days to flower opening (3.37 days) followed by IAA-250 ppm (3.93 days) as compared to rest of the treatments. Contrary to this, cycocel (CCC) at all doses significantly delayed the flower opening process. CCC-750 ppm recorded significantly maximum days to flower opening (7.58 days) as compared to control (4.87 days) followed by TIBA-200 ppm (6.67 days). Similarly, CCC-500ppm and TIBA-150 ppm being statistically at par with each other significantly extended the days to flower opening (6.10 and 5.83 days, respectively) as compared to control (4.87 days).

4.2.3.2 Effect of varieties on days taken to flower opening

The data in Table-6 clearly indicated that days taken to flower opening were significantly influenced by varieties. Aprldoorn (V_1) took significantly maximum days to flower opening (5.60 days) while as Golden oxford (V_2) took relatively minimum days to flower opening (4.98 days).

4.2.3.3 Interaction effect of growth regulators and varieties on days taken to flower opening

Data (Table-7) indicated that difference between growth regulators and varieties on days taken to flower opening was observed to be significant. Minimum days to flower opening (2.87 days) were recorded significantly with Golden oxford treated with IAA-500ppm followed by Apeldroon treated with IAA-500ppm (3.87days) and Golden oxford treated with IAA 250 ppm (3.90 days).Whereas, maximum days to flower opening (8.10 days) were significantly recorded with Apleldoorn treated with CCC-750 followed by Golden oxford when treated with TIBA-200ppm (7.20 days). The later two treatments were statistically at par with each other.

4.2.4 Flower diameter (cm)

4.2.4.1 Effect of growth regulators on flower diameter

Perusal of data (Table-5 & Fig. 9) revealed that, flower diameter was not significantly influenced by application of plant growth regulators. However, cycocel recorded maximum flower diameter as compared to other growth regulators. Among various treatments, CCC-500 ppm recorded maximum flower diameter (7.36 cm) followed by CCC-750 ppm (7.30 cm) and IAA-250ppm (7.22 cm) as compared to control (6.11 cm). Similarly, TIBA at all doses induced higher flower diameter as compared to control. The minimum flower diameter (6.11 cm) was recorded under control.

4.2.4.2 Effect of varieties on flower diameter

Perusal of mean value (Table-6) revealed that the two varieties did not differ significantly regarding flower diameter. However, Golden Oxford (V_2) exhibited slightly maximum flower diameter (6.74 cm) while as Apeldoorn (V_1) exhibited relatively lower flower diameter (6.73 cm).

4.2.4.3 Interaction effect of growth regulators and varieties on flower diameter

Data (Table-7) indicated that the effect of growth regulator treatments and varieties on flower diameter did not differ significantly. However, maximum flower diameter (7.44 cm) was recorded with Apeldoorn treated with IAA-250 ppm followed by Golden Oxford when treated with CCC-750 ppm and CCC-500 ppm (7.40 cm, each) where as, minimum flower diameter (5.75 cm) was recorded with Golden Oxford treated with IAA-750ppm followed by control (6.00 cm) within Golden Oxford.

4.2.5 Scape length (cm)

4.2.5.1 Effect of growth regulators on scape length

Data pertaining to mean scape length recorded at flowering time was significantly influenced by application of plant growth regulators (Table-5; Fig.10). Among various growth regulators, indole acetic acid (IAA) was observed to have a promoting effect on scape length while as, cycocel had a retarding effect on scape length. IAA-500 ppm being statistically at par with IAA-750ppm recorded significantly maximum scape length (37.98 cm) as compared to other treatments. On the other hand, CCC-750ppm recorded significantly minimum scape length (23.00 cm) followed by CCC-500ppm (26.58 cm) and both treatments were significantly inferior to control (30.33 cm) in inducing higher scape length. Although, TIBA-200ppm induced a slight decrease in scape length (29.32 cm), it was found to be statistically at par with control (30.33 cm).

4.2.5.2 Effect of varieties on scape length

The data in Table-6 depicted that scape length was significantly affected by varieties. Apeldoorn (V_1) recorded significantly maximum scape length (32.35 cm) as compared to Golden Oxford which recorded relatively minimum scape length (29.97 cm).

4.2.5.3 Interaction effect of growth regulators and varieties on scape length

Perusal of data (Table-7) reveals that interaction effect of growth regulators and varieties on scape length was not significant. However, Apeldoorn treated with IAA-500 ppm recorded maximum scape length (38.25 cm) followed by Golden Oxford treated with IAA-500 ppm (37.71 cm) and Apeldoorn treated with IAA 750 ppm (36.17 cm) whereas, Golden

Oxford treated with CCC-750 ppm recorded minimum scape length (22.04 cm) followed by Apeldoorn treated with CCC-750ppm (23.96 cm) and Golden Oxford treated with CCC-500ppm (26.46 cm).

4.2.6 Scape thickness (mm)

4.2.6.1 Effect of growth regulators on scape thickness

An elucidation of data (Table-5 & Fig. 11) revealed that scape thickness was observed to be significantly influenced by the application of plant growth regulators. Cycocel (CCC) was found to be superior in inducing higher scape thickness as compared to other growth regulators. Among various treatments, CCC-500 ppm followed by CCC-750 ppm and CCC-250 ppm recorded significantly maximum scape thickness (5.70, 5.00 and 4.86 mm, respectively) as compared to other treatments. However IAA and TIBA at all doses were significantly ineffective in increasing the scape thickness as compared to control.

4.2.6.2 Effect of varieties on scape thickness

The data (Table-6) revealed that the two varieties differed significantly regarding scape thickness. Apeldoorn (V_1) recorded significantly maximum scape thickness (4.57 mm) while as, Golden Oxford recorded relatively minimum scape thickness (4.08 mm).

4.2.6.3 Interaction effect of growth regulators and varieties on scape thickness

Perusal of data (Table-7) depicted that the impact of interaction between growth regulators and varieties on scape thickness was not significant. However, maximum scape thickness (6.05 mm) was recorded with Apeldoorn treated with CCC-500ppm followed by Golden oxford treated with CCC-500ppm (5.35 mm) and Apeldoorn when treated with CCC-750ppm (5.27 mm). Minimum scape thickness (3.43 mm) was recorded with Apeldoorn treated with IAA-750ppm followed by Golden oxford treated with TIBA-100ppm (3.44 mm) and distilled water (3.45 mm).

4.2.7 Fresh weight of flower scape (g)

4.2.7.1 Effect of growth regulators on fresh weight of scape

The data on fresh weight of flower scape as influenced by plant growth is interpreted in Table-5 and graphically presented in Fig.12.The statistical analysis of data revealed that, influence of growth regulators on fresh weight per scape of tulip was not significant. However, cycocel (CCC) induced higher weight per scape as compared to other growth regulators. Among various treatments, CCC-500 ppm recorded maximum fresh weight per scape (22.02 g) followed by TIBA-150 ppm (21.02 g) and CCC-250 ppm (20.36 g). While as, lowest fresh weight per scape (16.50 g) was recorded under control followed by TIBA-200ppm and TIBA-150ppm which recorded a scape weight of 17.30 g and 18.77 g, respectively.

4.2.7.2 Effect of varieties on fresh weight per scape

Perusal of data (Table-6) depicted that the effect of varieties on fresh weight of scape was not significant. However, Apeldoorn (V_1) recorded higher weight per scape (20.26 g) as compared to Golden oxford which recorded minimum weight per scape (18.13 g).

4.2.7.3 Interaction effect of growth regulators and varieties on fresh weight per scape

The data (Table-7) indicated that impact of interaction between growth regulators and varieties on fresh weight per scape was not significant. However, maximum fresh weight per scape (25.57g) was recorded with Golden oxford treated with TIBA-150ppm followed by Apeldoorn when treated with IAA-750 ppm (24.93 g) and CCC-250ppm (24.38 g). Whereas, minimum fresh weight per scape (13.30g) was recorded with Golden oxford when treated with IAA-750ppm followed by treatment with IAA-500ppm (14.55 g) and TIBA-200 ppm (15.28 g).

4.2.8 Duration of flowering (day)

4.2.8.1 Effect of growth regulators on duration of flowering

An inquisition of data in Table-5 & Fig. 13 revealed that duration of flowering was significantly influenced by application of growth regulators. Out of the three growth regulators, cycocel (CCC) was most effective in enhancing the duration of flowering as compared to other growth regulators. Among various treatments, CCC-500ppm being statistically at par with CCC-750 ppm significantly prolonged the duration of flowering (13.93 days) as compared to rest of the treatments. Like wise, IAA-250 ppm was significantly superior to control in prolonging the duration of flowering (12.40 days). Further, all doses of TIBA, viz. TIBA-200 ppm, TIBA-150ppm and TIBA-100 ppm were not significant in recording higher duration of flowering (12.60, 12.00 and 12.20 days, respectively) as compared to control (11.30 days).

4.2.8.2 Effect of varieties on duration of flowering

Perusal of data in Table-6 depicted that the two varieties differed significantly regarding duration of flowering. Apeldoorn (V_1) recorded significantly maximum duration of flowering (12.78 days). Comparatively, Golden oxford (V_2) recorded minimum duration of flowering (12.06 days).

4.2.8.3 Interaction effect of growth regulators and varieties on duration of flowering

Data (Table-7) indicated that interaction effect of growth regulators and varieties on duration of flowering was not significant. However, maximum duration of flowering (14.20 days) was recorded with Apeldoorn treated with CCC-500ppm followed by Apeldoorn treated with CCC-250ppm (13.86 days) and Golden oxford treated with CCC-500 ppm (13.66 days). On the other hand, minimum duration of flowering (11.00 days) was recorded under control within Golden oxford (V_2) followed by Apeldoorn treated with IAA-750ppm (11.20 days) and Golden oxford treated with TIBA-100ppm (11.23 days).

4.2.9 Vase life (day) of cut tulips

4.2.9.1 Effect of growth regulators on vase life

The critical analysis of data (Table-5 & Fig.14) for vase life indicated that significant impact of growth regulators was observed on vase life (Plate-2). Cycocel (CCC) at all doses recorded significantly higher vase life as compared to other growth regulator treatments. CCC-500ppm followed by CCC-750ppm recorded significantly maximum vase life (9.08 and 8.33 days, respectively) as compared to rest of treatments. Similarly, TIBA-200ppm induced significantly higher vase life (8.25 days) as compared to control (7.20 days). Although, IAA-250ppm had induced a slight increase in vase life (7.37 days) but not significantly and was statistically at par with control. However, IAA-750 ppm recorded significantly minimum vase life (6.58) as compared to control (7.20 days).

a

b

c

Plate–2 : Study of vase life under laboratory conditions

a) Stage at which scape was cut for vase life study in Apeldoorn.
b) Stage at which scape was cut for vase life study in Golden oxford.
c) Flower opening stage of cut tulip.

4.2.9.2 Effect of varieties on vase life

The data (Table-6) on vase life revealed that the effect of genotypes on vase life was significant. Apeldoorn (V_1) recorded significantly maximum vase life (8.08 days) while as Golden oxford (V_2) recorded relatively minimum vase life (7.16 days).

4.2.9.3 Interaction effect of growth regulators and varieties on vase life of cut tulips

Perusal of data in Table-7 revealed that the difference between growth regulator treatments and varieties on vase life of cut tulips was significant. Longest vase life (9.67, 9.33 and 8.83 days) was recorded with Apeldoorn (V_1) when treated with CCC-500 ppm, CCC-750 ppm and CCC-250 ppm, respectively and all these treatments were statistically at par with each other. Contrary, lowest vase life (6.00, 6.33 and 6.67 days) was recorded significantly with Golden oxford when treated with IAA-750 ppm, and TIBA-100ppm and IAA-500ppm, respectively and were statistically at par with each other.

4.3 Bulb production characters

Data (Tables 8-10) revealed that all bulb characters were significantly influenced by growth regulators. Significant effect of varieties was also observed on all bulb characters except number of bulbs per plant and bulb production ratio. Further, interaction effect of growth regulators and varieties was observed to be significant on number of bulbs per plant and bulb production ratio.

4.3.1 Number of bulbs per plant

4.3.1.1 Effect of plant growth regulators on number of bulbs per plant

The data pertaining to number of bulbs per plant as influenced by the plant growth regulators is presented in Table-8 and graphically presented in Fig.15. Cycocel induced significantly higher number of bulbs per plant as compared to the control and other growth regulators. CCC-500ppm being statistically at par with CCC-750ppm was most effective in recording significantly maximum number of bulbs per plant (1.40). On the other hand, IAA at all doses was not effective in inducing higher number of bulbs per plant as compared to control. Similarly, TIBA-200 ppm and TIBA-150 ppm were significantly ineffective in increasing the number of bulbs per plant as compared to control. However, TIBA-100ppm was observed to be significantly effective in increasing the number of bulbs per plant (1.30) as compared to the control (1.15).

4.3.1.2 Effect of varieties of number of bulbs per plant

The data (Table-9) revealed that there was no significant difference between the two genotypes for number of bulbs per plant. However, Apeldoorn (V_1) exhibited maximum number of bulbs per plant (1.22) as compared to Golden oxford (V_2) which exhibited comparatively lower number of bulbs per plant (1.20).

4.3.1.3 Interaction effect of growth regulators and varieties on number of bulbs per plant

Data (Table-10) revealed that difference between the growth regulator treatments and varieties on number of bulbs per plant was significant. Apeldoorn (V_1) treated with CCC-500ppm and TIBA-100ppm registered a significant increase in the number of bulbs (1.50 each) followed by Golden oxford (V_2) treated with CCC-750 ppm (1.40). On the other hand, Apeldoorn treated with CCC-250 ppm and TIBA-200 ppm registered a significant decrease in the number of bulbs (1.00 each) followed by Apeldoorn (V_1) treated with TIBA-150ppm (1.09).

4.3.2 Weight per bulb (g)

4.3.2.1 Effect of growth regulators on weight per bulb

The data (Table-8 & Fig.16) on weight per bulb indicated that there was significant influence of plant growth regulators on weight per bulb. All the growth regulators were observed to be effective in increasing weight per bulb. IAA was found to be most effective in inducing a significant increase in weight per bulb as compared to other growth regulators. Among various treatments, IAA-500 ppm recorded significantly maximum weight per bulb

(17.83 g) followed by IAA-250 ppm (16.68 g) as compared to rest of the treatments. Similarly, CCC at all doses increased significantly weight per bulb as compared to control (12.17 g). Moreover, TIBA-200ppm and TIBA-150 ppm also induced a significant increase in weight per bulb (16.05 and 15.06 g, respectively) as compared to control (12.17 g).

4.3.2.2 Effect of varieties on weight per bulb

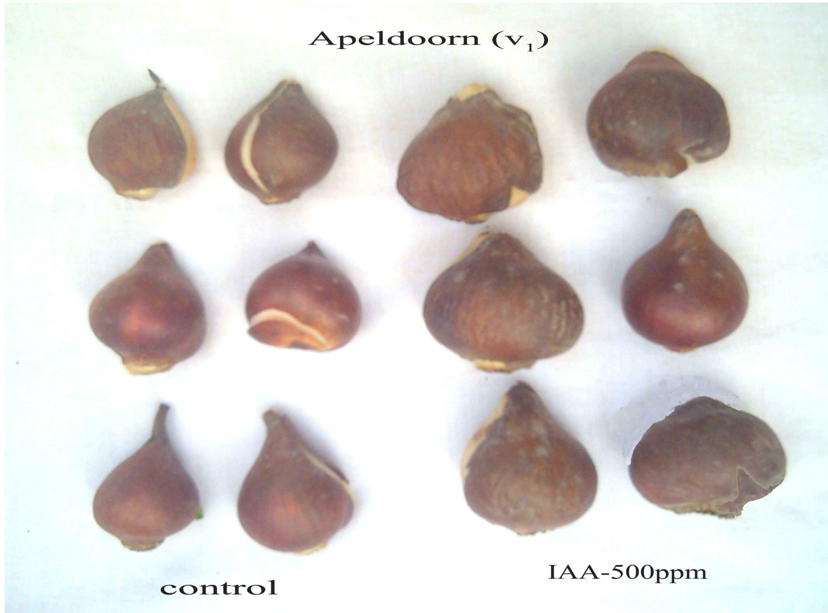
Significant impact of varieties was observed on weight per bulb. Maximum weight per bulb (15.75 g) was recorded significantly by Apeldoorn (V_1) while as minimum weight per bulb (13.95) was recorded by Golden oxford (V_2).

4.3.2.3 Interaction effect of growth regulators and varieties on weight per bulb

Data (Table-10) revealed that interaction effect of growth regulators and varieties on weight per bulb was not significant. However, maximum weight per bulb (18.80 g) was recorded within Apeldoorn (V_1) when treated with IAA-500ppm followed by IAA-250ppm (17.70g) and TIBA-200ppm (17.50g). Golden oxford (V_2) treated with distilled water and TIBA-100ppm recorded minimum weight per bulb (11.95 and 12.07 g, respectively) followed by Apeldoorn (V_1) treated with distilled water (12.40 g).

4.3.3 Size of bulb (cm)
4.3.3.1 Effect of growth regulators on size of bulb

The data pertaining to size of individual bulb as influenced by pant growth regulators is presented in Table-8 and graphically presented in Fig. 17. All growth regulators were observed to be effective in increasing the bulb size. IAA was found to be most effective in increasing the size of bulb as compared to rest of the growth regulators (Plate-3). IAA-500 ppm recorded significantly maximum size of bulb (11.50 cm) followed by IAA-250ppm (11.08 cm) as compared to control (9.05 cm). Like wise, TIBA-200 ppm being statistically at par with TIBA-150 ppm also induced a significant increase in size/circumference of bulb (10.71 cm) as compared to the control (9.05 cm). CCC-250 ppm also recorded significantly higher bulb size (10.37 cm) as compared to the control (9.05 cm). However, CCC-750ppm and CCC-500ppm were significantly ineffective in increasing the bulb size as they were statistically at par with each other as well as with the control (9.05 cm).



A) Large size attained by bulb after treatment with IAA-500ppm in Apeldoorn

B) Large size attained by bulbs after treatment with IAA-500ppm in Golden oxford

Plate-3 : Effect of growth regulators on bulb size in tulip

4.3.3.2 Effect of varieties on size of bulb

Perusal of data (Table-9) indicated that there was a significant impact of varieties on size or circumference of bulb. Apeldoorn (V_1) was significantly superior to Golden Oxford (V_2) in recording the maximum size of bulb (10.67 cm).

4.3.3.3 Interaction effect of growth regulators and varieties on size of bulb

Perusal of data (Table-10) on the differences due to interaction between growth regulators and varieties on size or circumference of bulb was not significant. However, maximum size of bulb (11.98 cm) was recorded within Apeldoorn (V_1) when treated with IAA-500 ppm followed by treatment with IAA-250 ppm (11.66 cm) and TIBA-200 ppm (11.00). Moreover, minimum size of bulb (8.70 cm) was recorded under control within Golden Oxford (V_2) followed by treatment with TIBA-100ppm (9.00 cm) and CCC-500 ppm (9.23 cm).

4.3.4 Number of bulblets per plant

4.3.4.1 Effect of growth regulators on number of bulblets per plant

The data (Table-8 & Fig. 18) on number of bulblets per plant indicated that there was a significant effect of growth regulators on number of bulblets per plant. Among various growth regulators, cycocel (CCC) was superior in inducing higher number of bulblets per plant as compared to other growth regulators. However, IAA at all doses did not cause any significant effect on number of bulblets per plant as compared to control. CCC-500 ppm induced significantly higher number of bulblets per plant (3.33) followed by CCC-750 ppm (2.94) as compared to control. Similarly, TIBA-200 ppm being statistically at par with TIBA-150ppm registered a significant increase in number of bulblets per plant (2.75) as compared to the control (2.00). Significant decrease in number of bulblets per plant (1.46) was recorded with TIBA-100 ppm as compared to control.

4.3.4.2 Effect of varieties on number of bulblets per plant

Perusal of data (Table-9) indicated that significant impact of varieties was observed on number of bulblets per plant. Apeldoorn (V_1) recorded significantly maximum number of bulblets per plant (2.40) while as, Golden oxford recorded relatively minimum number of bulblets per plant (2.20).

4.3.4.3 Interaction effect of growth regulators and varieties on number of bulblets per plant

Data (Table-10) revealed that interaction effect of growth regulators and varieties on number of bulblets per plant was not significant. However, maximum number of bulblets per plant (3.58) was recorded with Apeldoorn (V_1) treated with CCC-500 ppm followed by Apeldoorn treated with CCC-750 ppm (3.15) and Golden oxford (V_2) treated with CCC-500 ppm (3.08).

On the other hand, Apeldoorn treated with TIBA-100 ppm recorded minimum number of bulblets per plant (1.42) followed by Golden oxford when treated with TIBA-100 ppm (1.50) and IAA-250 ppm (1.75).

4.3.5 Weight of bulblets per plant (g)

4.3.5.1 Effect of growth regulators on weight of bulblets per plant

Perusal of data (Table-8 & Fig. 19) revealed that the growth regulators had a significant impact on weight of bulblets per plant. Among various growth regulators, IAA was most effective in inducing higher weight of bulblets per plant. IAA-500ppm being statistically at par with IAA-750 ppm recorded significantly maximum weight of bulblets per plant (9.44 g) as compared to other treatments. However, CCC and TIBA at all doses were observed to be ineffective in inducing a significant increase in weight of bulblets per plant as compared to control.

4.3.5.2 Effect of varieties on weight of bulblets per plant

The data in Table-9 indicated that the two varieties differed significantly on weight of bulblets per plant. Apeldoorn (V_1) recorded significantly higher weight of bulblets (6.37) while as Golden oxford (V_2) recorded lower weight of bulblets per plant (5.67 g).

4.3.5.3 Interaction effect of growth regulators and varieties on weight of bulblets per plant

Perusal of data (Table-10) revealed that, the difference between growth regulators and varieties on weight of bulblets was not significant. However, maximum weight of bulblets (7.93 g) was recorded within Apeldoorn (V_1) when treated with IAA-500ppm followed by treatment with IAA-750 ppm (7.53 g) and IAA-250ppm (7.47 g). Further, minimum weight of bulblets (5.17 g) was recorded with Golden oxford (V_2) treated with CCC-500 ppm followed by Apeldoorn treated with CCC-500ppm (5.23g) and Golden oxford treated with CCC-250ppm (5.23).

4.3.6 Bulb production ratio

4.3.6.1 Effect of plant growth regulators on bulb production ratio

Perusal of data (Table-8 & Fig. 20), bulb production ratio was observed to be significantly influenced by the application of plant growth regulators. Cycocel induced significantly higher bulb production ratio as compared to the control and other growth regulators. CCC-500ppm being statistically at par with CCC-750 ppm recorded significantly maximum bulb production ratio (1.40). On the other hand, IAA at all doses was ineffective in inducing higher bulb production ratio as compared to control. Similarly, TIBA-200 ppm and TIBA-150 ppm did not have any significant effect on bulb production ratio as compared to control (1.15). However, TIBA-

100ppm recorded a significant increase in bulb production ratio (1.30) as compared to control (1.15).

4.3.6.2 Effect of varieties on bulb production ratio

The data (Table-9) revealed that there was no significant difference between the two genotypes on bulb production ratio. However, Apeldoorn (V_1) exhibited maximum bulb production ratio (1.22) as compared to Golden Oxford (V_2) which exhibited comparatively lower bulb production ratio (1.20).

4.3.6.3 Interaction effect of growth regulators and varieties on bulb production ratio

Perusal of data (Table-10) on the difference due to interaction between growth regulators and varieties on bulb production ratio was significant. Apeldoorn (V_1) treated with CCC-500ppm and TIBA-100ppm registered a significant increase in bulb production ratio (1.50 each) followed by Golden Oxford (V_2) treated with CCC-750 ppm (1.40). On the other hand, Apeldoorn treated with CCC-250 ppm and TIBA-200 ppm induced a significant decrease bulb production ratio (1.00 each) followed by Apeldoorn (V_1) treated with TIBA-150ppm (1.09).

4.4 Economics of production of tulip

Treatment-wise comparative economics of production was worked out for tulip. Perusal of the Table-11 revealed that highest cost benefit ratio of 1.67 was recorded by treatment with IAA-500 ppm followed by C-B ratio of 1.62 in treatment IAA-750 ppm. Similar trend was observed in gross income as well as net income.

Table-2: Effect of growth regulators on vegetative characters in tulip

Treatment	Days taken to bulb sprouting	Plant height (cm)	No. of leaves $plant^{-1}$	Leaf area (cm^2)	Leaf area index
IAA-750ppm	87.20	38.54	4.00	84.20	0.28
IAA-500ppm	86.97	40.98	4.66	93.07	0.31
IAA-250ppm	87.80	35.42	4.33	80.68	0.26
CCC-750ppm	90.00	26.00	4.00	66.27	0.22
CCC-500ppm	89.27	29.58	4.33	72.16	0.24
CCC-250ppm	88.93	33.90	4.00	74.99	0.25
TIBA-200ppm	89.23	32.32	4.00	72.61	0.24
TIBA-150ppm	88.79	34.37	4.33	75.37	0.25
TIBA-100ppm	88.78	35.44	4.33	77.47	0.25
Control	88.30	33.33	3.33	66.28	0.22
LSD at 5%	**0.75**	**2.75**	**NS**	**14.08**	**0.02**
$\pm SE_{diff}$	**0.37**	**1.36**	**NS**	**6.96**	**0.02**

IAA = Indole acetic acid; CCC = Cycocel; TIBA = 2,3,5 triiodobenzoic acid

Table-3: Effect of varieties on vegetative characters in tulip

Variety	Days taken to bulb sprouting	Plant height (cm)	No. of leaves $plant^{-1}$	Leaf area (cm^2)	Leaf area index
Apeldoorn	88.00	35.43	4.13	88.34	0.29
Golden Oxford	89.06	32.64	4.09	64.29	0.21
LSD at 5%	**0.33**	**1.23**	**NS**	**6.30**	**0.02**
$\pm SE_{diff}$	**0.16**	**0.61**	**NS**	**3.11**	**0.01**

Table-4 : Interaction effect of growth regulators and varieties on vegetative characters in tulip

Treatment	Variety	Days taken to bulb sprouting	Plant height (cm)	No. of leaves $plant^{-1}$	Leaf area (cm^2)	Leaf area index
IAA-750ppm	Apeldoorn	86.93	39.17	4.00	100.66	0.33
IAA-500ppm	Apeldoorn	86.73	41.25	4.66	103.40	0.34
IAA-250ppm	Apeldoorn	87.47	38.79	4.66	96.94	0.32
CCC-750ppm	Apeldoorn	88.60	26.96	4.00	77.03	0.26
CCC-500ppm	Apeldoorn	88.80	29.71	4.33	86.05	0.29
CCC-250ppm	Apeldoorn	88.47	35.87	4.00	90.28	0.30
TIBA-200ppm	Apeldoorn	88.40	33.46	4.00	75.13	0.25
TIBA-150ppm	Apeldoorn	88.33	35.67	4.33	88.32	0.29
TIBA-100ppm	Apeldoorn	88.27	37.13	4.00	91.47	0.30
Control	Apeldoorn	88.00	35.08	3.33	74.10	0.25
IAA-750ppm	Golden Oxford	87.47	37.92	4.00	67.74	0.22
IAA-500ppm	Golden Oxford	87.20	40.70	4.66	82.74	0.27
IAA-250ppm	Golden Oxford	88.13	32.04	4.00	64.43	0.21
CCC-750ppm	Golden Oxford	91.47	25.04	4.00	55.51	0.18
CCC-500ppm	Golden Oxford	89.73	29.46	4.33	58.27	0.19
CCC-250ppm	Golden Oxford	89.40	31.92	4.00	59.70	0.20
TIBA-200ppm	Golden Oxford	90.07	31.18	4.00	70.09	0.23
TIBA-150ppm	Golden Oxford	89.25	33.08	4.33	62.43	0.21
TIBA-100ppm	Golden Oxford	89.30	33.46	4.33	63.48	0.21
Control	Golden Oxford	88.60	31.58	3.33	58.47	0.19
LSD at 5%	-	**NS**	**NS**	**NS**	**NS**	**NS**
$\pm SE_{diff}$		**NS**	**NS**	**NS**	**NS**	**NS**

IAA = Indole acetic acid; CCC = Cycocel; TIBA = 2,3,5 triiodobenzoic acid

Table-5: Effect of growth regulators on floral characters in tulip

Treatment	Days to floral bud appearance	Days to colour break	Days to flower opening	Flower diameter (cm)	Scape length (cm)	Scape thickness (mm)	Scape weight (g)	Flower duration (day)	Vase life (day)
IAA-750ppm	26.50	8.23	4.20	6.12	35.54	3.69	19.16	11.30	6.58
IAA-500ppm	25.60	6.63	3.37	6.52	37.98	3.89	18.83	11.83	7.00
IAA-250ppm	26.67	7.40	3.93	7.22	32.50	4.18	19.38	12.40	7.37
CCC-750ppm	30.50	10.77	7.58	7.30	23.00	5.00	18.64	13.63	8.33
CCC-500ppm	28.50	9.53	6.10	7.36	26.58	5.70	22.02	13.93	9.08
CCC-250ppm	28.27	8.70	5.87	6.99	30.90	4.86	20.36	13.06	7.92
TIBA-200ppm	29.50	9.23	6.67	6.77	29.32	4.33	17.30	12.60	8.25
TIBA-150ppm	27.97	8.80	5.83	6.40	31.37	4.09	21.02	12.00	7.50
TIBA-100ppm	27.17	8.57	4.63	6.56	32.44	3.79	18.77	12.20	7.00
Control	27.73	8.40	4.87	6.11	30.33	3.70	16.50	11.30	7.20
LSD at 5% $\pm SE_{diff}$	**0.89 0.44**	**0.76 0.38**	**0.55 0.27**	**NS NS**	**2.76 1.36**	**0.66 0.33**	**NS NS**	**1.02 0.50**	**0.48 0.24**

IAA = Indole acetic acid; CCC = Cycocel; TIBA = 2,3,5 triiodobenzoic acid

Table-6 : Effect of varieties on floral characters in tulip

Variety	Days taken to floral bud appearance	Days taken to colour break	Days taken to flower opening	Flower diameter (cm)	Scape length (cm)	Scape thickness (mm)	Scape weight (g)	Flower duration (day)	Vase life (day)
Apeldoorn	28.76	8.66	5.60	6.74	32.35	4.57	20.26	12.78	8.08
Golden Oxford	26.87	8.59	4.98	6.73	29.97	4.08	18.13	12.06	7.16
LSD at 5%	**0.39**	**NS**	**0.25**	**NS**	**1.24**	**0.30**	**NS**	**0.46**	**0.18**
$\pm SE_{diff}$	**0.19**	**NS**	**0.12**	**NS**	**0.61**	**0.15**	**NS**	**0.23**	**0.21**

Table-7: Interaction effect of growth regulators and varieties on floral characters in tulip

Treatment	Variety	Days taken to floral bud appearance	Days taken to colour break	Days taken to flower opening	Flower diameter (cm)	Scape length (cm)	Scape thickness (mm)	Scape weight (g)	Duration of flowering (day)	Vase life (day)
IAA-750ppm	Apeldoorn	27.58	8.26	4.40	6.50	36.17	3.94	24.93	11.20	7.17
IAA-500ppm	Apeldoorn	27.06	6.40	3.87	6.44	38.25	4.30	23.12	12.23	7.33
IAA-250ppm	Apeldoorn	28.00	7.45	3.97	7.44	35.96	4.60	17.00	12.87	7.33
CCC-750ppm	Apeldoorn	30.80	11.20	8.10	7.20	23.96	5.27	17.57	13.60	9.33
CCC-500ppm	Apeldoorn	29.00	9.80	6.27	7.33	26.71	6.05	24.20	14.20	9.67
CCC-250ppm	Apeldoorn	29.06	8.60	7.13	6.89	32.87	4.72	24.38	13.86	8.83
TIBA-200ppm	Apeldoorn	29.33	9.20	6.13	6.83	30.46	4.67	19.32	13.07	8.50
TIBA-150ppm	Apeldoorn	29.00	8.66	6.07	6.04	32.67	4.45	16.48	12.07	8.00
TIBA-100ppm	Apeldoorn	28.86	8.60	5.07	6.53	34.42	4.13	20.13	13.17	7.67
Control	Apeldoorn	28.93	8.40	5.13	6.22	32.07	3.95	15.50	11.60	7.00
IAA-750ppm	Golden Oxford	25.42	8.20	4.00	5.75	34.92	3.43	13.38	11.40	6.00
IAA-500ppm	Golden Oxford	24.13	6.88	2.87	6.60	37.71	3.49	14.55	11.43	6.67
IAA-250ppm	Golden Oxford	25.33	7.35	3.90	7.00	29.04	3.77	21.77	11.93	7.40
CCC-750ppm	Golden Oxford	30.20	10.33	7.07	7.40	22.04	4.73	19.72	13.66	7.33
CCC-500ppm	Golden Oxford	28.00	9.26	5.93	7.40	26.46	5.35	19.83	13.66	8.50
CCC-250ppm	Golden Oxford	29.66	8.80	4.60	7.11	28.92	5.00	16.33	12.27	7.00
TIBA-200ppm	Golden Oxford	29.66	9.26	7.20	6.72	28.18	3.99	15.28	12.13	8.00
TIBA-150ppm	Golden Oxford	26.93	8.93	5.60	6.77	30.08	3.72	25.57	11.93	7.00
TIBA-100ppm	Golden Oxford	25.46	8.53	4.20	6.60	30.46	3.44	17.40	11.23	6.33
Control	Golden Oxford	26.53	8.40	4.60	6.00	28.58	3.45	17.50	11.00	7.40
LSD at 5%	-	**1.26**	**NS**	**0.78**	**NS**	**NS**	**NS**	**NS**	**NS**	**0.68**
$\pm SE_{diff}$		**0.62**	**NS**	**0.39**	**NS**	**NS**	**NS**	**NS**	**NS**	**0.34**

IAA = Indole acetic acid; CCC = Cycocel; TIBA = 2,3,5 triiodobenzoic acid

Table-8: Effect of growth regulators on bulb characters in tulip

Treatment	No. of bulbs plant^{-1}	Weight per bulb (g)	Size of bulb (cm)	No. of bulblets plant^{-1}	Weight of bulblets plant^{-1}	Bulb production ratio
IAA-750ppm	1.19	14.35	10.10	2.25	6.83	1.19
IAA-500ppm	1.23	17.83	11.50	2.04	7.40	1.15
IAA-250ppm	1.15	16.68	11.08	1.75	6.65	1.15
CCC-750ppm	1.39	14.13	09.82	2.94	5.32	1.39
CCC-500ppm	1.40	13.46	09.65	3.33	5.20	1.40
CCC-250ppm	1.10	15.20	10.37	2.50	5.62	1.10
TIBA-200ppm	1.10	16.05	10.71	2.75	6.02	1.10
TIBA-150ppm	1.10	15.06	10.52	1.87	5.90	1.10
TIBA-100ppm	1.30	12.88	09.45	1.46	5.72	1.30
Control	1.15	12.17	09.05	2.00	5.53	1.23
LSD at 5%	**0.08**	**1.12**	**0.41**	**0.38**	**0.60**	**0.08**
$\pm SE_{diff}$	**0.04**	**0.55**	**0.20**	**0.18**	**0.30**	**0.04**

IAA = Indole acetic acid; CCC = Cycocel; TIBA = 2,3,5 triiodobenzoic acid

Table-9 : Effect of varieties on bulb characters in tulip

Variety	No. of bulbs plant^{-1}	Weight per bulb (g)	Size of bulb (cm)	No. of bulblets plant^{-1}	Weight of bulblets plant^{-1}	Bulb production ratio
Apeldoorn	1.22	15.75	10.67	2.40	6.37	1.22
Golden oxford	1.20	13.95	9.77	2.20	5.67	1.20
LSD at 5%	**NS**	**0.25**	**0.18**	**0.17**	**0.25**	**NS**
$\pm SE_{diff}$	**NS**	**0.50**	**0.09**	**0.08**	**0.12**	**NS**

Table-10 : Interaction effect of growth regulators and varieties on bulb characters in tulip

Treatment	Variety	No. of bulbs plant^{-1}	Weight per bulb (g)	Size of bulb (cm)	No. of bulblets plant^{-1}	Weight of bulblets plant^{-1}	Bulb production ratio
IAA-750ppm	Apeldoorn	1.23	15.17	10.56	2.25	7.53	1.23
IAA-500ppm	Apeldoorn	1.22	18.80	11.98	2.08	7.93	1.15
IAA-250ppm	Apeldoorn	1.17	17.70	11.66	1.75	7.47	1.17
CCC-750ppm	Apeldoorn	1.38	14.90	10.26	3.15	5.33	1.38
CCC-500ppm	Apeldoorn	1.50	14.07	10.07	3.58	5.23	1.50
CCC-250ppm	Apeldoorn	1.00	16.27	10.93	2.75	6.00	1.00
TIBA-200ppm	Apeldoorn	1.00	17.50	11.00	3.00	6.38	1.00
TIBA-150ppm	Apeldoorn	1.09	16.97	10.97	1.92	6.20	1.09
TIBA-100ppm	Apeldoorn	1.50	13.70	09.90	1.42	5.83	1.50
Control	Apeldoorn	1.15	12.40	09.40	2.08	5.77	1.22
IAA-750ppm	Golden Oxford	1.15	13.53	09.63	2.25	6.13	1.15
IAA-500ppm	Golden Oxford	1.24	16.87	10.02	2.00	6.87	1.15
IAA-250ppm	Golden Oxford	1.14	15.67	10.50	1.75	5.83	1.14
CCC-750ppm	Golden Oxford	1.40	13.36	09.36	2.73	5.30	1.40
CCC-500ppm	Golden Oxford	1.30	12.87	09.23	3.08	5.17	1.30
CCC-250ppm	Golden Oxford	1.20	14.13	09.80	2.25	5.23	1.20
TIBA-200ppm	Golden Oxford	1.20	14.60	10.43	2.50	5.67	1.20
TIBA-150ppm	Golden Oxford	1.12	14.35	10.07	1.83	5.60	1.12
TIBA-100ppm	Golden Oxford	1.10	12.07	09.00	1.50	5.60	1.10
Control	Golden Oxford	1.15	11.95	08.70	1.92	5.30	1.24
LSD at 5%	-	**0.11**	**NS**	**NS**	**NS**	**NS**	**0.11**
±SE$_{diff}$		**0.05**	**NS**	**NS**	**NS**	**NS**	**0.05**

Table-11: Economics of production in tulip using plant growth regulators (per 500 m^2 basis)

Treatment	Gross expenditure (Rs.)	Scape income (Rs.)	Bulb income (Rs.)	Bulblet income (Rs.)	Gross income (Rs.)	Net income (Rs.)	B:C ratio
IAA-750ppm	990663.60	46665.50	95197.62	5008.54	146871.66	56208.06	1.62
IAA-500ppm	89999.20	46665.50	98397.54	5426.53	150489.57	60490.37	1.67
IAA-250ppm	89334.79	46665.50	91997.70	4876.54	143539.74	54204.95	1.61
CCC-750ppm	89467.67	46665.50	92664.35	3901.23	143231.08	53763.41	1.60
CCC-500ppm	89201.91	46665.50	93331.00	4121.23	144117.73	54915.82	1.61
CCC-250ppm	88936.15	46665.50	87997.80	3813.24	138476.54	49540.39	1.56
TIBA-200ppm	89916.01	46665.50	87997.80	4414.56	139077.86	49161.79	1.55
TIBA-150ppm	89603.34	46665.50	87997.80	4326.56	138989.86	49386.52	1.55
TIBA-100ppm	89292.36	46665.50	86664.50	4194.56	137524.56	48232.20	1.54
Control	88670.39	46665.50	76664.75	4055.23	127385.48	38715.09	1.43

Scapes sold @ Rs.3.5/scape; bulblets @ Rs.55/kg.

Bulbs above 10cm size were sold @ Rs.6/bulb and bulbs below 10cm size were sold @ Rs.5/bulb

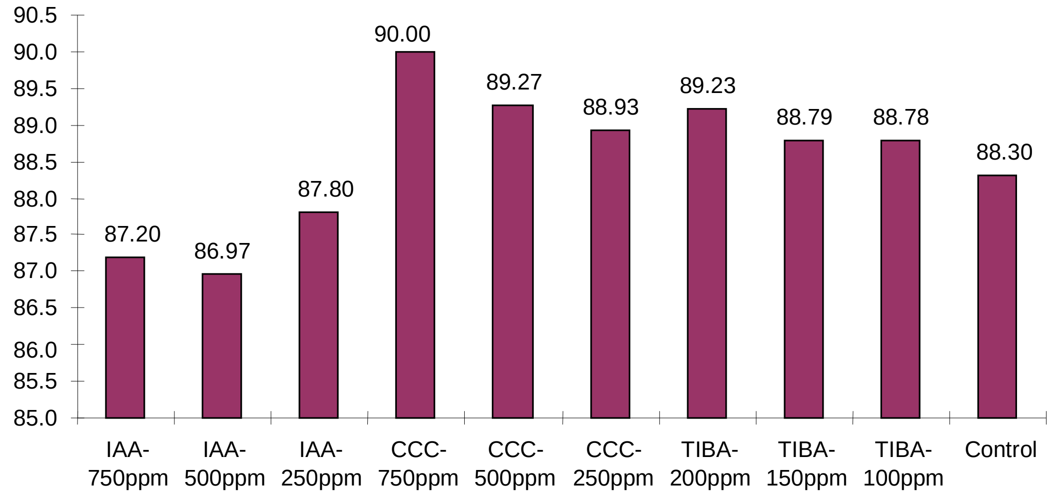


Fig-1 Days taken to bulb sprouting

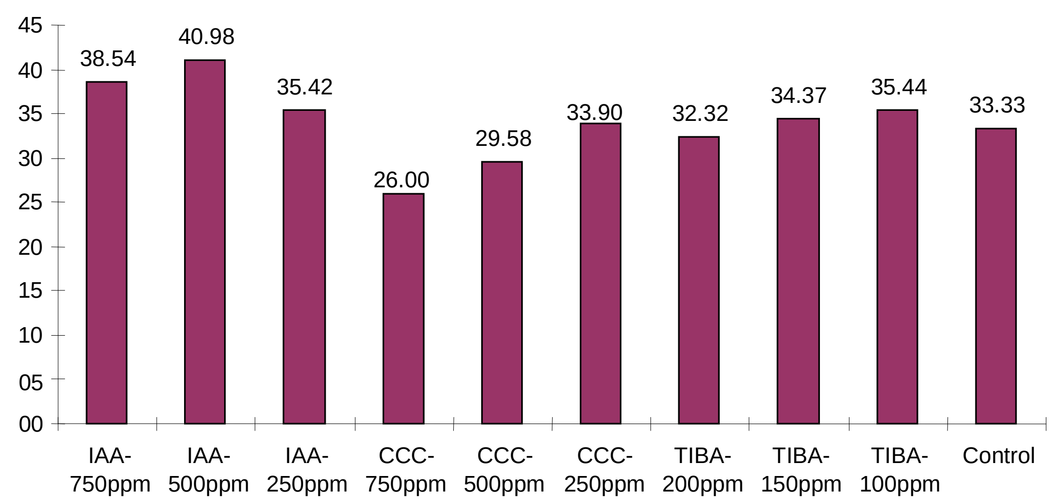


Fig-2 Plant height (cm)

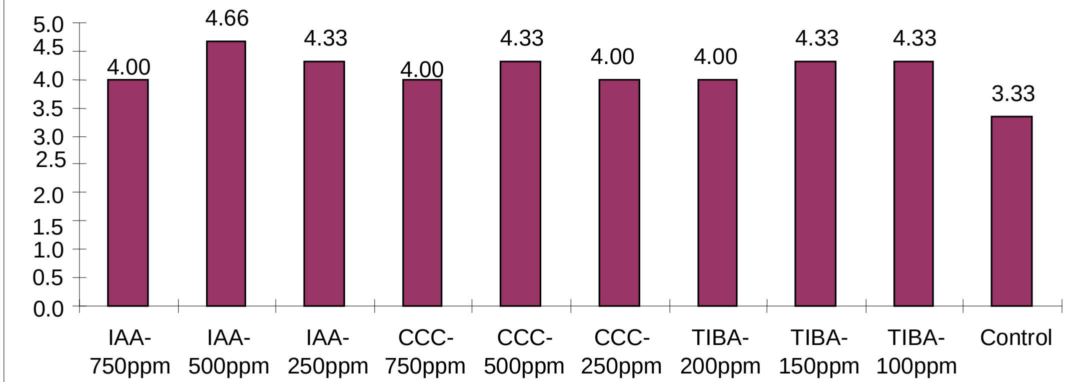


Fig-3 Number of leaves per plant

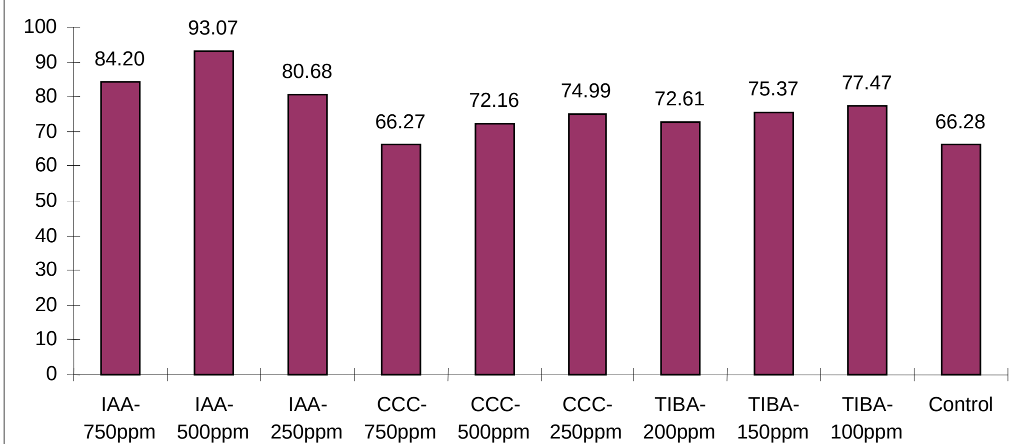


Fig-4 Leaf area (cm^2)

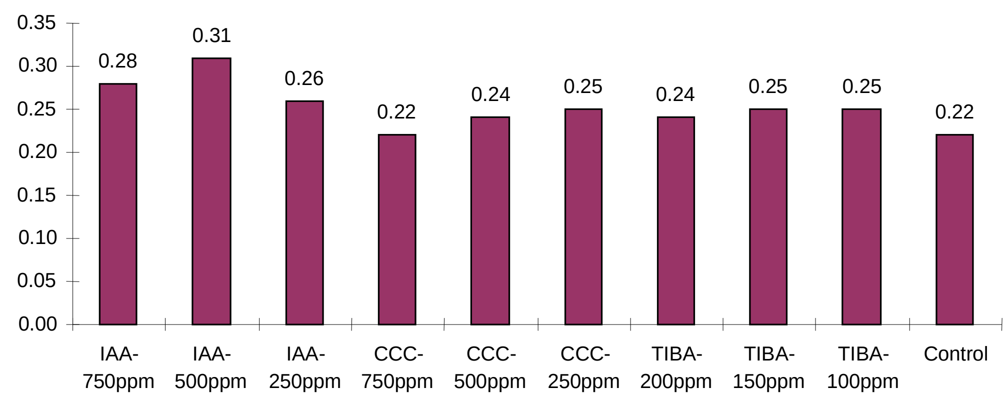


Fig-5 Leaf area index

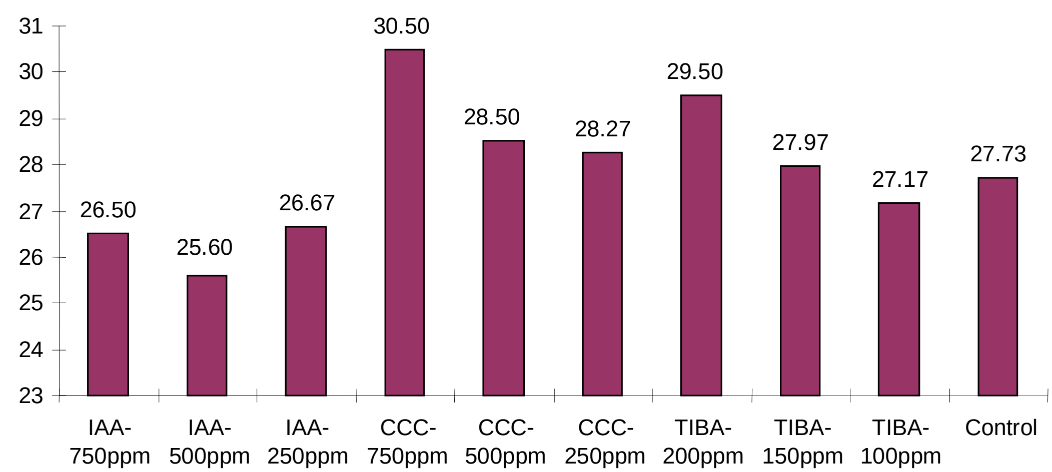
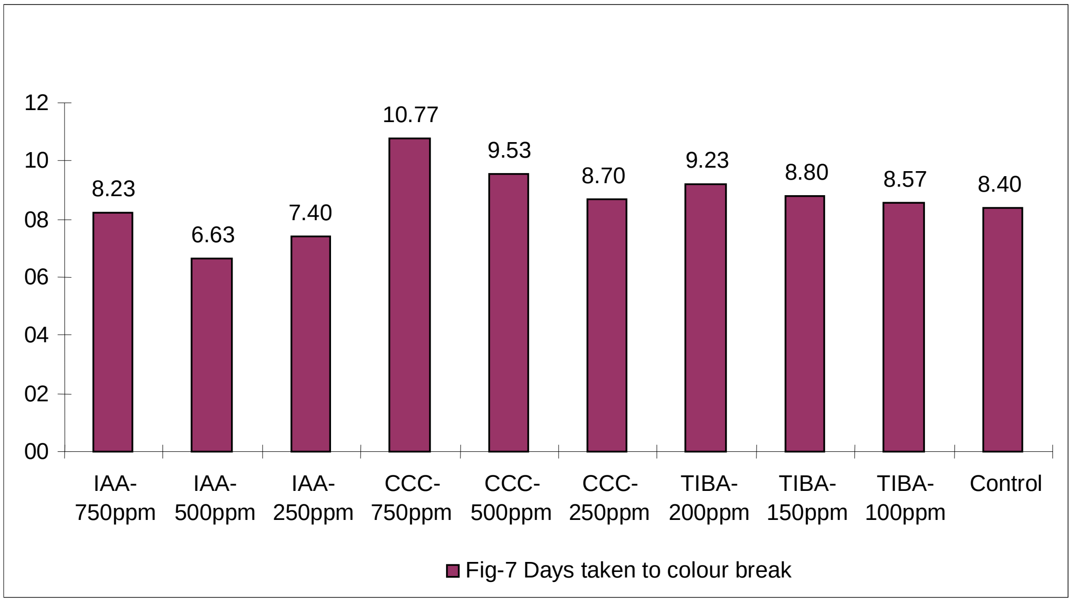


Fig-6 Days taken to floral bud appearance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08
06
04
02
00
8.23
6.63
7.40
10.77
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8.70
9.23
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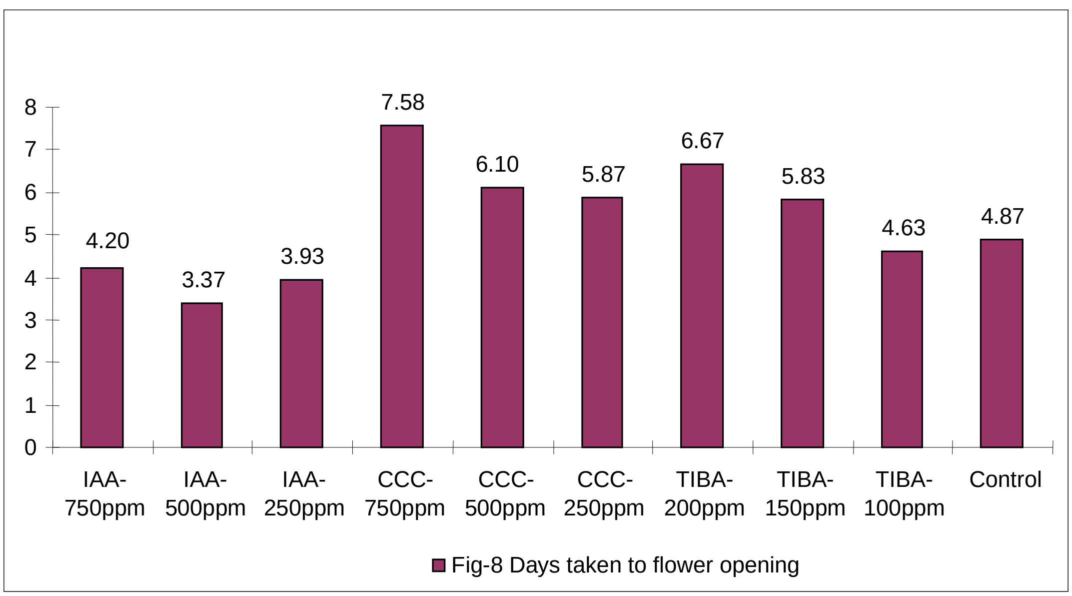
8.57
8.40
IAA-750ppm
IAA-500ppm
IAA-250ppm
CCC-750ppm
CCC-500ppm
CCC-250ppm
TIBA-200ppm
TIBA-150ppm
TIBA-100ppm
Control
Fig-7 Days taken to colour break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7
6
5
4
3
2
1
0
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3.37
3.93
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6.10
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6.67
5.83
4.63
4.87
IAA-750ppm
IAA-500ppm
IAA-250ppm
CCC-750ppm
CCC-500ppm
CCC-250ppm
TIBA-200ppm
TIBA-150ppm
TIBA-100ppm
Control
Fig-8 Days taken to flower opening

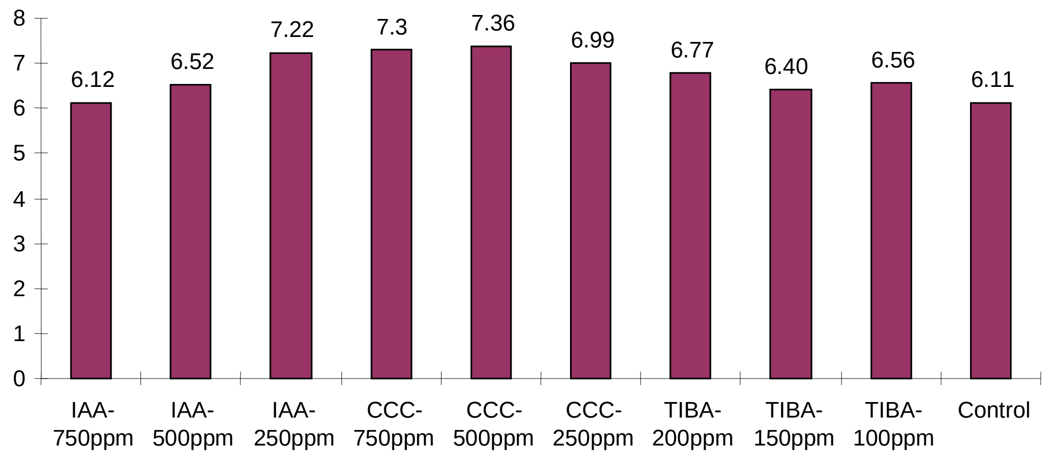


Fig-9 Flower diameter (cm)

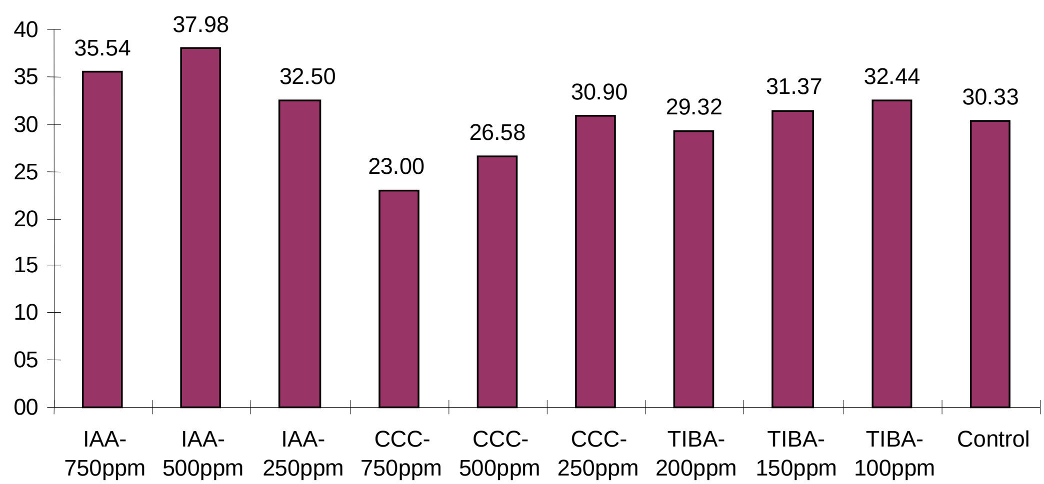
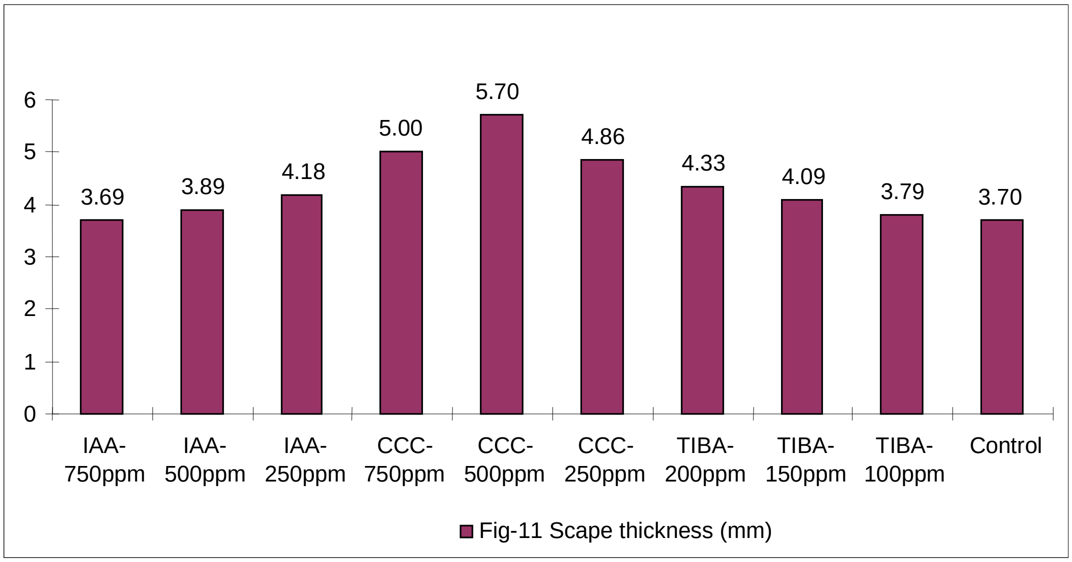


Fig-10 Scape length (cm)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5.00
5.70
4.86
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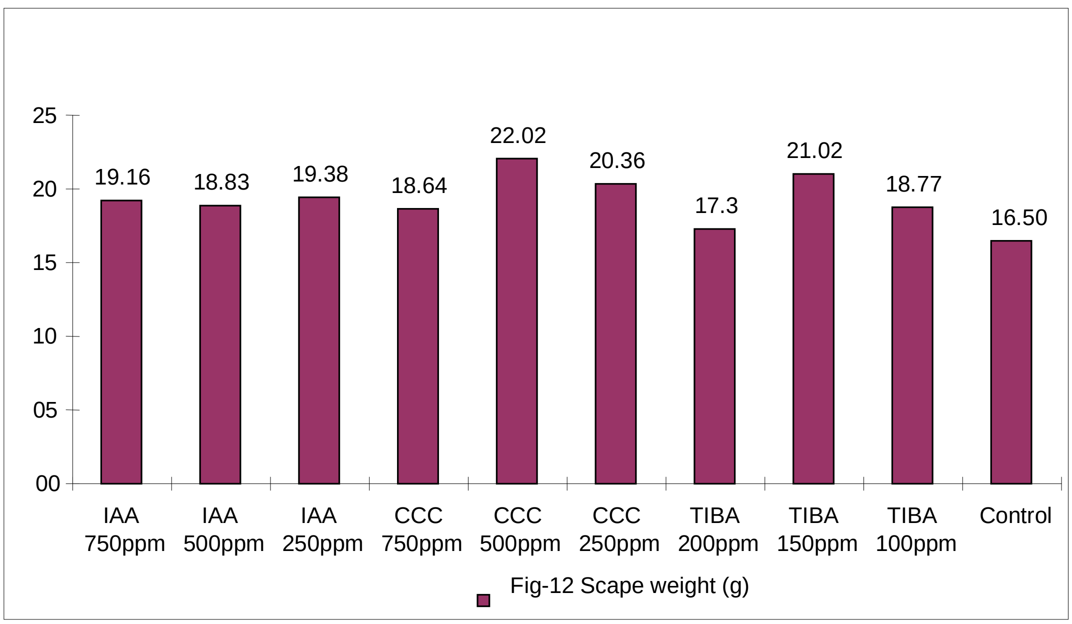
4.09
3.79
3.70
IAA-750ppm
IAA-500ppm
IAA-250ppm
CCC-750ppm
CCC-500ppm
CCC-250ppm
TIBA-200ppm
TIBA-150ppm
TIBA-100ppm
Control
Fig-11 Scape thickness (mm)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20
15
10
05
00
19.16
18.83
19.38
18.64
22.02
20.36
17.3
21.02
18.77
16.50
IAA 750ppm
IAA 500ppm
IAA 250ppm
CCC 750ppm
CCC 500ppm
CCC 250ppm
TIBA 200ppm
TIBA 150ppm
TIBA 100ppm
Control
Fig-12 Scape weight (g)

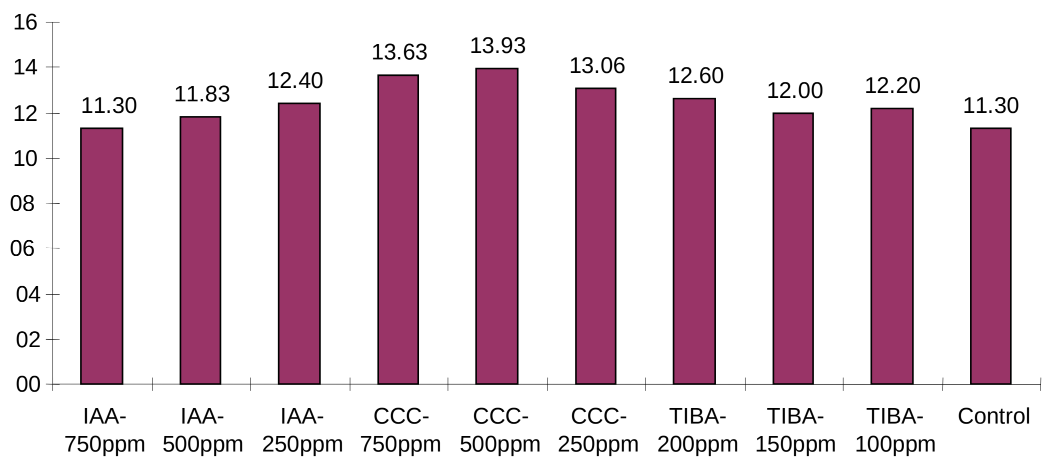


Fig-13 Flower duration (day)

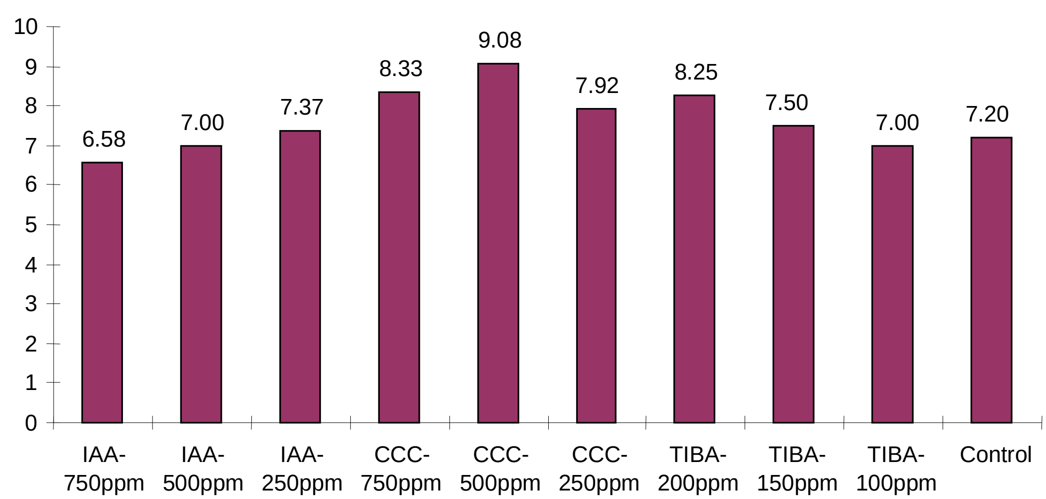
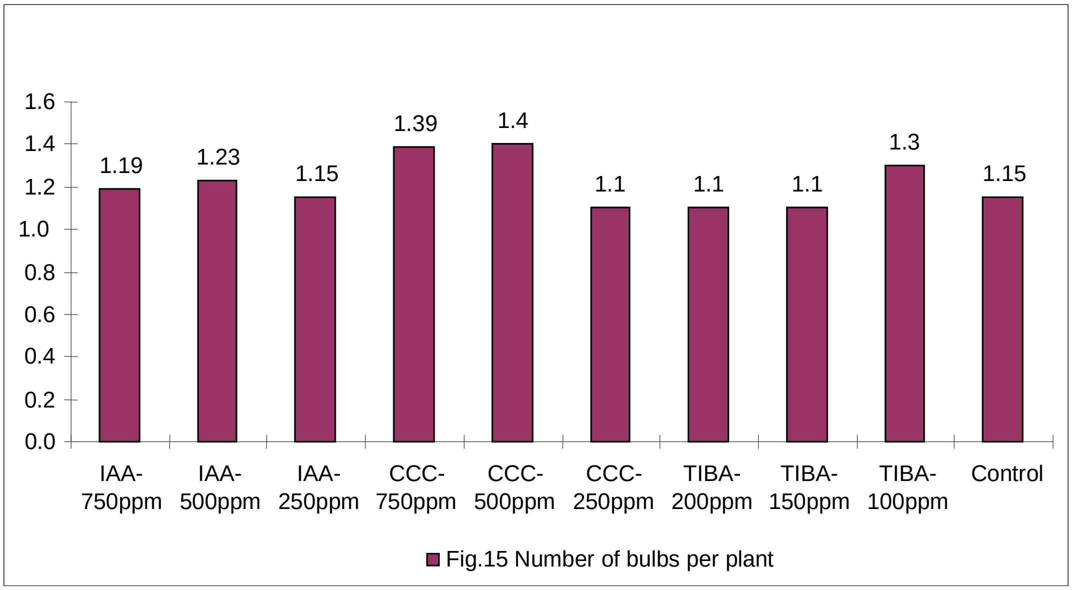


Fig-14 Vase life (day)



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1.0
0.8
0.6
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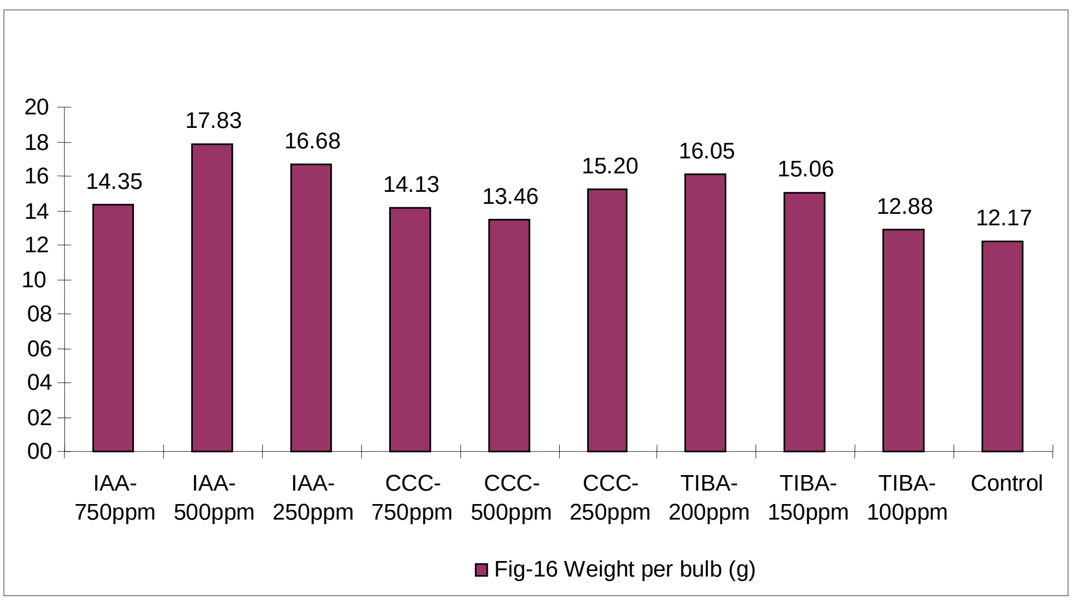
0.2
0.0
1.19
1.23
1.15
1.39
1.4
1.1
1.1
1.1
1.3
1.15
IAA-750ppm
IAA-500ppm
IAA-250ppm
CCC-750ppm
CCC-500ppm
CCC-250ppm
TIBA-200ppm
TIBA-150ppm
TIBA-100ppm
Control
Fig.15 Number of bulbs per plant



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10
08
06
04
02
00
14.35
17.83
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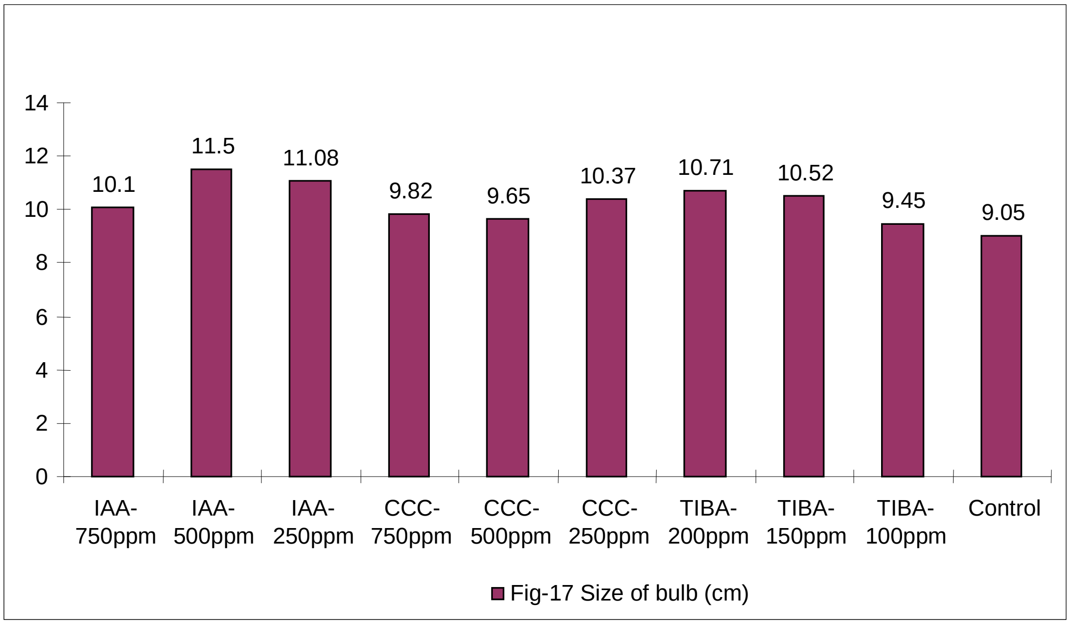
13.46
15.20
16.05
15.06
12.88
12.17
IAA-750ppm
IAA-500ppm
IAA-250ppm
CCC-750ppm
CCC-500ppm
CCC-250ppm
TIBA-200ppm
TIBA-150ppm
TIBA-100ppm
Control
Fig-16 Weight per bulb (g)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6
4
2
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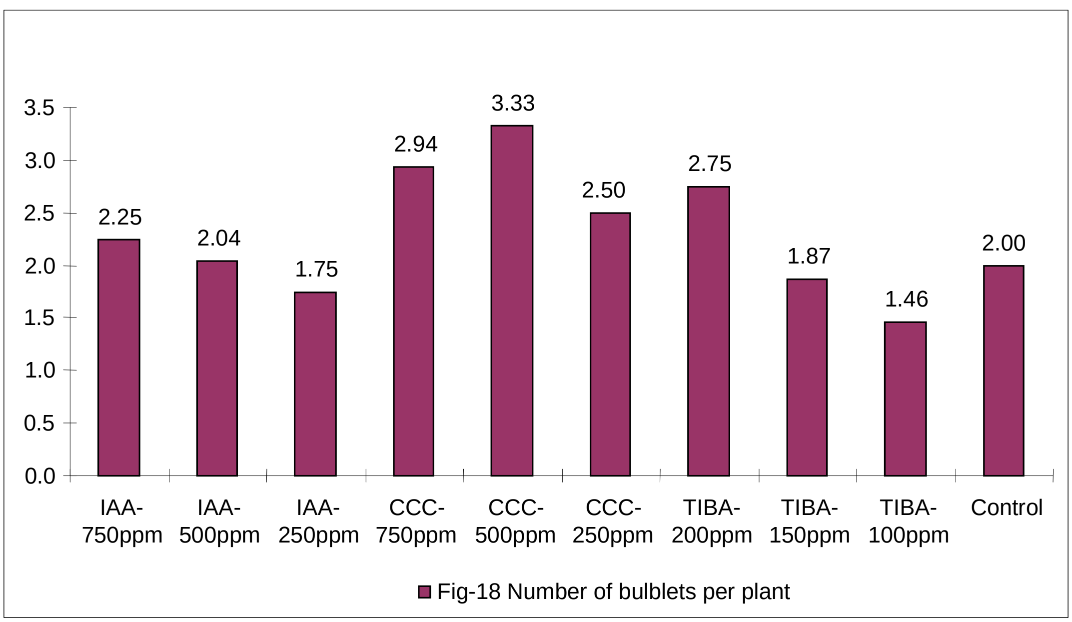
10.37
10.71
10.52
9.45
9.05
IAA-750ppm
IAA-500ppm
IAA-250ppm
CCC-750ppm
CCC-500ppm
CCC-250ppm
TIBA-200ppm
TIBA-150ppm
TIBA-100ppm
Control
Fig-17 Size of bulb (cm)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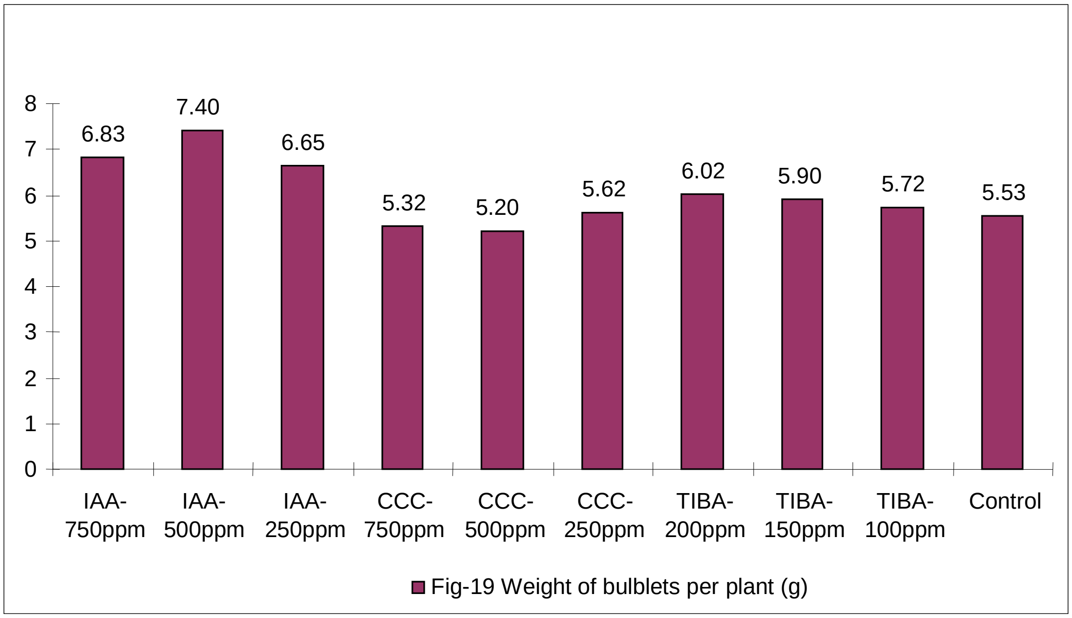
2.5
2.0
1.5
1.0
0.5
0.0
2.25
2.04
1.75
2.94
3.33
2.50
2.75
1.87
1.46
2.00
IAA-750ppm
IAA-500ppm
IAA-250ppm
CCC-750ppm
CCC-500ppm
CCC-250ppm
TIBA-200ppm
TIBA-150ppm
TIBA-100ppm
Control
Fig-18 Number of bulblets per plant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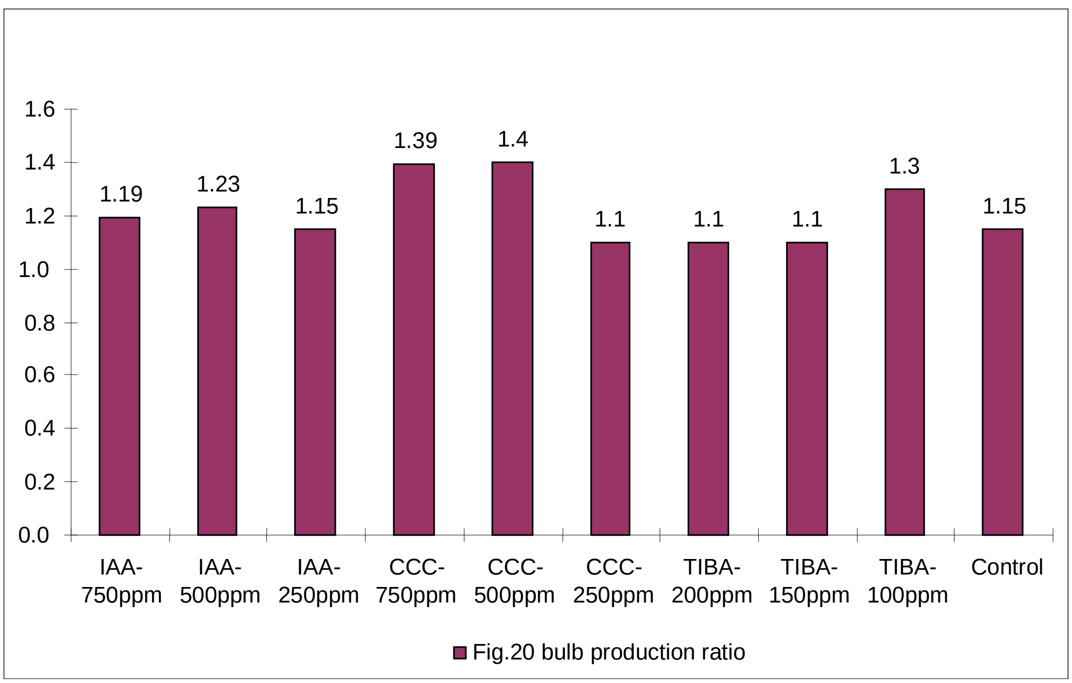
7
6
5
4
3
2
1
0
6.83
7.40
6.65
5.32
5.20
5.62
6.02
5.90
5.72
5.53
IAA-750ppm
IAA-500ppm
IAA-250ppm
CCC-750ppm
CCC-500ppm
CCC-250ppm
TIBA-200ppm
TIBA-150ppm
TIBA-100ppm
Control
Fig-19 Weight of bulblets per plant (g)


1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
1.19
1.23
1.15
1.39
1.4
1.1
1.1
1.1
1.3
1.15
IAA-750ppm
IAA-500ppm
IAA-250ppm
CCC-750ppm
CCC-500ppm
CCC-250ppm
TIBA-200ppm
TIBA-150ppm
TIBA-100ppm
Control
Fig.20 bulb production ratio

CHAPTER – 5

DISCUSSION

Among various ornamental crops, tulips are one of the most researched genera in the world. Research has been conducted on tulip by several workers to obtain higher economic benefits by manipulating growth and flowering. In the recent past, plant growth regulators have revolutionised various garden practices and have been successfully employed for improving growth and yield. However, the information on precise use of plant growth regulators is limited with regard to vegetative, floral and bulb production of tulip. As such the present investigation was undertaken to study the effect of plant growth regulators on vegetative, floral and bulb production of tulip. The results obtained are discussed in this chapter.

5.1 Vegetative characters

The results obtained in the present study on tulip reveals that the vegetative characters under investigation, *viz.* days taken to bulb sprouting, plant height, leaf area and leaf area index were significantly influenced by plant growth regulators. However, number of leaves per plant remained unaffected by the application of plant growth regulators.

Out of the three chemicals, *viz.* indole acetic acid (IAA), cycocel (CCC) and 2,3,5 triiodobenzoic acid (TIBA) tested in the present study, IAA was most effective in improving plant growth as compared to other chemicals. Among various treatments, IAA-500 ppm being statistically at par with IAA-750 ppm took significantly minimum days to bulb sprouting (86.97 days) as compared to other treatments including control.

Auxin increases the activity of apical bud meristem thereby, promotes metabolism and has an inhibitory effect on abscissic acid which causes bud dormancy. Moreover, auxins have been involved in elongation of apical bud also. These factors might be the probable cause for early sprouting. Similar results were reported in gladiolus (Sharga, 1979 and Chauhan and Chauhan, 2002). Besides, induction of early sprouting by the application of IAA in narcissus was reported by Hanks and Rees (1977b). In contrast to IAA, CCC delayed bulb sprouting; and CCC-750 ppm took significantly maximum days to bulb sprouting (90.00 days) as compared to other treatment including control. Similarly, TIBA also delayed bulb sprouting at higher concentrations but was observed to be ineffective at lower concentration as compared to control. The inhibition of the cyclization of Geranylgeranyl pyrophosphate to copallyl pyrophosphate is the primary mode of action of cycocel leading to inhibition of gibberellin formation which is an important bud dormancy breaking factor (Arteca, 1997). This could be the possible reason for reduced plant growth by application of cycocel. Similar results were reported by Kirad *et al.* (2001) in gladiolus.

Data presented in Table-2 reveal that IAA recorded maximum plant height as compared to other growth regulators. Among various concentrations, IAA-500 ppm being statistically at par with IAA-750 ppm recording significantly maximum plant height (40.98 cm) as compared to control. IAA promotes the elongation of cells in the apical region of shoot. Besides, it exhibits the phenomenon of apical dominance also. This may be the probable reason for excessive elongation of shoot by IAA application. Similar results were obtained by Banasik and Saniewski (1985), Kawa and Saniewski (1989), Saniewski *et al.* (1990) and Saniewski *et al.* (1999), who reported elongation of stem by application of IAA in tulip.

In comparison to IAA, CCC has a retarding effect on plant height and it was observed that CCC-750 ppm recorded significantly minimum plant height (26.00 cm) as compared to control. However, TIBA at all doses did not cause much impact on plant height as compared to control. Cycocel, a gibberellin biosynthesis inhibitor, decreases the concentration of gibberellins in plants and inhibit cell expansion by lowering the gibberellindependant cell wall relaxation (Cosgrove and Sovonick Dunford, 1989). These results were in agreement with Bragt and Dekker (1973), Laskowska *et al*. (1998) and Saniewski and Okubo (1998) in tulip.

Data in present study reveals that, IAA was superior in inducing all growth parameters as compared to other growth regulators. The best results among various treatments were obtained with IAA-500 ppm which recorded maximum number of leaves per plant (4.66) followed by IAA-250ppm. Minimum number of leaves (3.00) per plant was recorded under control. IAA-500ppm being statistically at par with IAA-750ppm registered maximum leaf area (93.07 cm^2) and leaf area index (0.31) as compared to control. However, CCC and TIBA at all doses were ineffective in recording higher leaf area and leaf area index as compared to control. Minimum leaf area (66.28 cm^2) and leaf area index (0.22) was recorded under control. These results were in close agreement with various workers in various bulbous crops (Mahesh and Misra, 1993; Dantuluri *et al.*, 2002 and Gaur *et al.*, 2003)

Perusal of data (Table-3) on vegetative characters revealed significant impact of varieties on bulb sprouting, plant height, leaf area and leaf area index. However, number of leaves was not significantly affected by varieties. Apeldoorn (V_1) recorded significantly minimum days to bulb sprouting (88.00 days), maximum plant height (35.43 cm), maximum leaf area (88.34 cm^2) and leaf area index (0.29). Comparatively, Golden Oxford recorded maximum days to bulb sprouting (89.06 days), minimum plant height (32.64 cm), leaf area (64.29 cm^2) and leaf area index (0.21).

Further perusal of data (Table-4) reveals that the interaction between growth regulators and varieties did not cause any significant impact on all vegetative characters. However, Apeldoorn treated with IAA-500 ppm recorded minimum days to bulb sprouting (86.73 days), maximum plant height (41.25 cm), number of leaves (4.66), leaf area (103.40 cm^2) and leaf area index (0.34) whereas, Golden Oxford treated with CCC-750 ppm recorded maximum days to bulb sprouting (91.47 days), minimum plant height (25.04 cm), leaf area (55.51 cm^2) and leaf area index (0.18).

5.2 Floral characters

The data on floral characters in the present study reveals that the floral characters under investigation, *viz.* days taken to appearance of floral bud, days taken to colour break, days taken to flower opening, scape length, scape thickness, flower duration and vase life were significantly influenced by application of plant growth regulators. However, flower diameter and scape weight remained unaffected by the application of plant growth regulators.

Perusal of data (Table-5) depicted that IAA was most effective in reducing days taken to floral bud appearance, days to colour break and days to flower opening as compared to other growth regulators. The best results among various treatments were obtained with IAA-500 ppm which took significantly minimum days to floral bud appearance (25.60 days), colour break (6.63 days) and flower opening (3.37 days) as compared to rest of the treatments. The improvement in floral characters in response to indole acetic acid is due to its favourable effects on vegetative growth. These results are in agreement with several workers in various flower crops (Sharma *et al.*, 1978; Meher *et al.*, 1999; Chauhan and Chauhan, 2002 and Gaur *et al.*, 2003).

In contrast to IAA, CCC-750ppm took significantly maximum days to floral bud appearance (30.50 days), colour break (10.77 days) and flower opening (7.58 days) as compared to control. The results in the present study are supported by the finding of Al-Humaid (2001) and Dantuluri *et al.* (2002), who reported that application of cycocel caused delayed flowering in gladiolus and Asiatic lily, respectively. Similarly, TIBA at a higher dose of 200 ppm significantly delayed flowering by exhibiting 29.50 days to floral bud appearance, 9.23 days to colour break and 6.67 days to flower opening. Delayed flowering due to growth retardants is apparently the result of growth inhibition rather than direct effect upon flowering stimulus. These results were in consonance with the findings of several workers who worked on various bulbous crops (Mohariya *et al.*, 2003 and Geng *et al.*, 2005).

Plant growth regulators were observed to be ineffective in causing a significant effect on flower diameter. However, CCC-500 ppm recorded maximum flower diameter (7.36 cm) followed by CCC-750 ppm (7.30 cm) as compared to control. Minimum flower diameter (6.11cm) was recorded under control. These results are in conformity with the findings of Nair *et al.* (2002) who reported that application of CCC gave largest flower diameter in gerbera.

Perusal of data in present study reveals that, IAA was observed to be superior in recording highest scape length as compared to other growth regulators. Among various treatments tested, IAA-500 ppm being statistically at par with IAA-750 ppm recorded significantly maximum scape length (37.98cm) as compared to rest of the treatments including control. These results are in close conformity with the findings of Banasik and Saniewski (1985), Kawa and Saniewski (1989), Saniewski *et al.* (1990) and Saniewski *et al.* (1999), all of whom reported increased shoot length by application of IAA in tulip. On the contrary, cycocel effectively retarded the scape length and CCC-750 ppm recorded significantly minimum scape length (23.00 cm) as compared to control. However, TIBA at all doses did not exhibit any significant impact on scape length. Similar results were reported by Bragt and Dekker (1973) and Laskowska *et al.* (1998) in tulip. The results get further support with the similar findings of Devendra *et al.* (1999) in tuberose.

Data depicted that CCC was observed to be most effective in increasing the scape thickness. Among various treatments, CCC-500 ppm recorded significantly maximum scape thickness (5.70 mm) as compared to other treatments and control. The increase in scape thickness may be attributed by the decreased scape length induced by cycocel. Besides, cycocel may enhance the activity of 6-benzyladenine but do not behave like cytokinin alone (Werbouck and Debergh, 1996) which in turn may promote the cell division. The results obtained are in close confirmation with those reported by Weryszko *et al.* (1997) in tulip. Similar results were also obtained by several workers in other ornamental crops (Sharma *et al.*, 1978; Al-Humaid, 2001 and Data *et al.*, 2001). IAA and TIBA at all doses were observed to be ineffective in influencing the scape thickness as compared to control. However, IAA at low concentration was observed to have a favourable effect on scape thickness.

The data reveals that fresh weight of scape was not affected significantly by the application of growth regulators. However, all growth regulator treatments gave higher scape weight as compared to control. Maximum fresh weight of scape (22.02 g) was recorded by CCC-500 ppm followed by TIBA-150 ppm and CCC-250 ppm which recorded 21.02 g and 20.36 g of fresh scape weight, respectively. Whereas, minimum fresh weight of scape (16.50 g) was recorded under control.

Maximum duration of flowering was recorded by CCC followed by TIBA and IAA. Among various treatments, CCC-500 ppm being statistically at par with CCC-750 ppm and CCC-250 ppm recorded significantly maximum duration of flowering (13.93 days) as compared to other treatments. Similarly, IAA-250 ppm recorded significantly higher flower duration (12.40 days) as compared to control. However, TIBA at all doses was ineffective in inducing higher flower duration as compared to control. The results in present study are in consonance with the findings of Sharma *et al.* (1978), Sharga (1979) and Mahesh and Misra (1993) all of whom reported increased flower duration by auxins in various flower crops. These results are further supported by the findings of Hassan and Agina (1980), Kirad *et al.* (2001) and Maurya and Nagada (2002) in bulbous crops, who reported increased flowering duration by application of cycocel.

Cycocel was superior in recording maximum vase life as compared to other growth regulators. The best result among various treatments was obtained with CCC-500 ppm which recorded maximum vase life (9.08 days) as compared control. Similarly, TIBA at highest concentration of 200 ppm induced significantly higher vase life (8.25 days) as compared to control while as, it was ineffective at lower concentrations. This may be attributed due to their ability to alter the sensitivity of plants to a number of environmental stresses. These have an ability to decrease the transpiration loss either due to their ability to induce smaller leaves or fewer or smaller stomata in the leaves (Steinberg *et al.*, 1991). Besides these also inhibit ethylene production by blocking the conversion of 1-aminocylopropane-1-carboxylic acid (ACC) to ethylene which is considered as an important senescence factor (Kraus *et al.*, 1991). These factors might have attributed for the increased vase life of cut tulips by application of growth retardants. Similar results were obtained by several workers in bulbous crops (Aswath *et al.*, 1995; Devendra *et al.*, 1999; Nair *et al.*, 2002 and Dantuluri *et al.*, 2002). On the contrary, IAA-750 ppm recorded minimum vase life of 6.58 days as compared to control. This inhibitory effect of auxins on vase life is due to auxin-induced ethylene production. Similar results were reported by Guo Wei Ming *et al.* (2003) in chrysanthemum.

Perusal of data (Table-6) reveals that varieties differed significantly with respect to days taken to floral bud appearance, days taken to flower opening, scape length, scape thickness, duration of flowering and vase life. Apeldoorn (V_1) was significantly superior to Golden oxford in recording maximum days to floral bud appearance (28.76), flower opening (5.60 days), scape length (32.35 cm), scape thickness (4.57 mm), flower duration (12.78 days) and vase life (8.08 days). Comparatively, Golden oxford recorded minimum days to floral bud appearance (26.87 days), flower opening (4.98 days), scape length (29.97 cm), scape thickness (4.08 mm), flower duration (12.06 days) and vase life (7.16 days). However, no significant impact of varieties was observed on days taken to colour break, flower diameter and fresh weight of scape. The results in present study were supported by Sujatha and Shiva (2003) and Sheela *et al.* (2005) in gerbera and heliconia, respectively.

Further, perusal of data (Table-7) on floral characters depicted that significant impact of interaction between growth regulators and varieties was observed on days taken to floral bud appearance, days to flower opening and vase life. However, no significant impact of interaction between growth regulators and varieties was observed on days taken to colour break, flower diameter, scape length, scape thickness, fresh weight of scape and duration of flowering. Apeldoorn treated with CCC-750 ppm recorded significantly maximum days to floral bud appearance (30.80 days) and flower opening (8.10 days) whereas, Golden oxford treated with IAA-500 ppm took significantly minimum days to floral bud appearance (24.13 days) and flower opening (2.87 days). However, Apeldoorn treated with CCC-750 ppm and IAA 500 ppm took maximum days to colour break (11.20 days) and minimum days to colour break (6.40 days), respectively. Maximum flower diameter (7.44 cm) was recorded with Apeldoorn treated with IAA-250 ppm and minimum flower diameter (5.75 cm) was recorded with Golden oxford treated with IAA-750 ppm. Maximum scape length (38.25 cm) was recorded with Apeldoorn treated with IAA-500 ppm while as minimum scape length (22.04 cm) was recorded with Golden oxford treated with CCC-750 ppm. Maximum scape thickness (6.05 mm) was recorded with Apeldoorn treated with CCC-500 ppm and minimum scape thickness (3.43 mm) was recorded with Golden oxford treated with IAA-750 ppm. Moreover, maximum fresh weight of scape (24.93 g) was recorded with Apeldoorn treated with IAA-750 ppm and minimum fresh weight of scape (13.38 g) was recorded with Golden oxford treated with IAA-750 ppm. Apeldoorn when treated with CCC-500 ppm recorded maximum flowering duration (14.20 days) and vase life (9.67 days). Whereas, minimum flowering duration (11.00 days) and vase life (6.00 days) was recorded with Golden Oxford when treated with distilled water and IAA-750 ppm, respectively.

5.3 Bulb production characters

The studies on bulb production characters (Table-8) reveal that all bulb characters, *viz.* number of bulbs per plant, weight per bulb, size of bulb, bulb production ratio, number of bulblets per plant and weight of bulblets per plant were significantly influenced by the application of plant growth regulators.

Data indicated that CCC was most effective in increasing the number of bulbs per plant and bulb production ratio as compared to other plant growth regulators. Among various treatments tested, CCC-500 ppm being statistically at par with CCC-750 ppm recorded significantly maximum number of bulbs per plant (1.40) and bulb production ratio (1.40) as compared to rest of the treatments. The plants treated with growth retardants might have used less carbohydrate for shoot growth and as such stored more starch, although the starch degrading activity was not altered (Yim *et al.*, 1997). This starch accumulation may probably enhanced the realization of yield potential by improving partitioning of dry matter into harvestable yield. Similar results were obtained by Mukherjee *et al.* (1999), Laskowska *et al.* (1998) and Hetman *et al.* (1992) in tulip. These results get further support from the findings of Al-Humaid (2001) and Swain (2006) in gladiolus. On the contrary, TIBA and IAA at all doses were significantly ineffective in increasing the number of bulbs per plant and bulb production ratio except TIBA-100ppm which recorded a significant increase in number of bulbs (1.30) and bulb production ratio (1.30) as compared to control. These results were in contradiction with Kurtar and Ayan (2005) who reported increased bulb yield by IAA when tried at higher concentrations.

Perusal of data revealed that all plant growth regulators were effective in increasing weight per bulb and bulb size. IAA recorded maximum weight per bulb and bulb size followed by TIBA and CCC. Among various treatments tested, IAA-500 ppm recorded significantly highest weight per bulb (17.83 g) and bulb size (11.50 cm) as compared to rest of the treatments. Increase in weight per bulb and bulb size may be attributed by cell enlargement caused by auxins, as they are known to be involved in cell extension and may also be due to its favourable effects on vegetative growth. The results obtained in present study are in consonance with Mahesh and Misra (1993) and Kurtar and Ayan (2005) in gladiolus and tulip, respectively. Similarly, CCC at all concentrations induced significantly higher weight per bulb and bulb size as compared to control. Moreover, TIBA induced significant increase in weight per bulb and bulb size at higher dose of 200 ppm recording 16.05 g weight per bulb and 10.71 cm bulb size as compared to control. Minimum weight per bulb (12.17 g) and bulb size (9.05 cm) was recorded under control. The positive effects of TIBA and CCC might be as a result of modification of source-sink relationship. At the end of crop season the photosynthates are diverted towards the sink *i.e.* bulbs due to the strong source-sink relationship thereby improving bulb weight and size. These results were in close agreement with Mohamed and Fawzi (1980), Hetman *et al.* (1992), Laskowska *et al.* (1998) and Mukherjee *et al.* (1999), who reported improvement in bulb production characters by application of CCC in tulip.

It can be easily inferenced from the results in present study that a concomitant increase in number of bulbs induced an almost concomitant decrease in weight and size of bulb. This may be due to antagonistic effect of bulb number on bulb weight and size, which may be the characteristic of crop under study.

The data indicated that CCC was most effective in increasing the number of bulblets per plant as compared to other growth regulators. However, IAA at all doses was ineffective in increasing the number of bulblets per plant as compared to control. The best result among various treatments was obtained with CCC-500 ppm which recorded significantly maximum number of bulblets per plant (3.33) as compared to other treatments including control. TIBA-100 ppm recorded significantly lowest number of bulblets per plant (1.46) as compared to control. These results are in consonance with Mohamed and Fawzi (1980) and Mukherjee *et al.* (1999) who reported increased bulblet production by application of cycocel in tulip.

IAA was most effective in inducing higher weight of bulblets per plant as compared to other growth regulators. Among various treatments, IAA-500 ppm being statistically at par with IAA-750 ppm recorded significantly maximum weight of bulblets per plant (7.40 g) as compared to rest of the treatments. However, CCC and TIBA were ineffective in inducing higher weight of bulblets. Minimum weight of bulblets (5.20 g) per plant was recorded with CCC-500 ppm. Similar findings were obtained by Hanks and Rees (1977b) in narcissus. An increase in number of bulblets induced an antagonistic effect on weight of bulblets which may be due to genetic make up of the crop under study.

Perusal of data (Table-9) revealed that the two varieties differed significantly regarding weight per bulb, bulb size, number of bulblets per pant and weight per bulblet. Apeldoorn (V_1) recorded significantly higher weight per bulb (15.75 g), bulb size (10.67 cm), bulblet number (2.40) and weight of bulblets (6.37 g) per plant. Comparatively, Golden oxford recorded significantly minimum weight per bulb (13.95 g), bulb size (9.77 cm), bulblet number (2.20) and weight of bulblets (5.67 g) per plant. However, the two varieties did not differ significantly with respect to number of bulbs per plant and bulb production ratio. Although, Apeldoorn (V_1) recorded maximum number of bulbs (1.22) and bulb production ratio (1.22) as compared to Golden oxford which recorded minimum bulb number of bulbs (1.20) and bulb production ratio (1.20). These results were supported by the findings of Bichoo *et al.* (2002) and Sheikh and Mushtaq (2006) in gladiolus.

Further, perusal of data (Table-10) reveals that significant effect of interaction between growth regulators and varieties was observed on number of bulbs per plant and bulb production ratio. However, no significant impact of interaction between growth regulators and varieties was observed on weight per bulb, bulb size, number of bulblets per plant and weight of bulblets. Apeldoorn treated with CCC-500 ppm recorded significantly maximum number of bulbs per plant (1.50) and bulb production ratio (1.50) and when treated with TIBA-200 ppm, minimum number of bulbs per plant (1.00) and bulb production ratio (1.00) were recorded significantly. Maximum weight per bulb (18.80 g) and bulb size (11.98 cm) was recorded with Apeldoorn when treated with IAA-500 ppm while as, minimum weight per bulb (11.95 g) and bulb size (8.70 cm) was recorded under control within Golden Oxford. Maximum bulblet number (3.58) and weight of bulblets (7.93 g) per plant was recorded with Apeldoorn treated with CCC-500 ppm and IAA-500 ppm, respectively. Minimum number of bulblets (1.42) and weight of bulblets (5.17 g) per plant was recorded with Apeldoorn treated with TIBA-100 ppm and Golden Oxford treated with CCC-500 ppm, respectively.

5.4 Economics of PGRs application

Benefit cost ratio were estimated in order to identify an economically viable treatment among various treatments in tulip under common management. While the total costs employed in this analysis include costs on various components like bulbs, chemicals etc. (Appendix-III). The gross benefit includes returns from the sale of scapes, bulbs and bulblets. The cost, returns and the estimates of B-C ratio for various treatments is presented in Table-11. The data revealed that higher gross expenditure (Rs.90663.60) was recorded by using IAA-750ppm followed by Rs.89999.20 with IAA-500ppm and Rs.89916.01 with TIBA-200ppm. Minimum gross expenditure of Rs.88670.39 was recorded with control.

The benefit ratio was found to show variation for different treatments with highest B-C ratio (1.67) obtained in plots treated with IAA-500ppm followed by IAA-750 ppm (1.62) and CCC-500ppm (1.61). Similar trend was observed in gross returns and net returns.

CHAPTER – 6

SUMMARY AND CONCLUSION

The present investigation on "Effect of plant growth regulators on vegetative, floral and bulb production in tulip" was carried out in the experimental plots of Division of Floriculture, Medicinal and Aromatic Plants, SKUAST-K, Shalimar.

The salient features of investigation are summarized as under:

1. Days taken to bulb sprouting was significantly decreased by application of indole acetic acid. IAA-500 ppm recorded significantly minimum days to bulb sprouting (86.99 days) where as, CCC-750 took significantly maximum days to bulb sprouting (90.00 days).

2. Plant height was increased by indole acetic acid and retarded by cycocel. IAA-500 ppm recorded significantly maximum plant height (40.98 cm) while CCC-750 ppm recorded minimum plant height (26.00 cm).

3. Number of leaves per plant remained unaffected by application of growth regulators.

4. Leaf area and leaf area index were significantly increased by application of IAA. However, CCC and TIBA at all doses were observed to be ineffective in increasing the leaf area and leaf area index. IAA-500 ppm was observed to record maximum leaf area (93.07 cm^2) and leaf area index (0.31).

5. Early flowering was induced by application of indole acetic acid and delayed flowering was observed by application of cycocel and TIBA. IAA-500 ppm took significantly minimum days to floral bud appearance (25.60 days), colour break (6.63 days) and flower opening (3.37 days). While as, CCC-750 ppm took significantly maximum days to floral bud appearance (30.50 days), colour break (10.77 days) and flower opening (7.58 days).

6. Flower diameter remained unaffected by the application of growth regulators in present study.

7. Scape length was increased by application of indole acetic acid and was retarded by cycocel application. However, TIBA did not show any significant effect on scape length as compared to control. IAA-500 ppm recorded significantly maximum scape length of 37.98 cm and CCC-750ppm recorded significantly minimum scape length of 23.00 cm.

8. Scape thickness was also observed to have increased by application of cycocel. However IAA and TIBA did not show any significant effect on scape thickness as compared to control. CCC-500 ppm recorded significantly maximum scape thickness of 5.70 cm. whereas IAA-750 ppm recorded minimum scape thickness of 3.69 mm.

9. Fresh weight of flower scape remained unaffected by application of growth regulators in the present study.

10. Flowering duration and vase life was recorded to have increased by application of cycocel. CCC-500 ppm recorded maximum flowering duration and vase life of 13.93 days and 9.08 days, respectively. Although, IAA and TIBA were observed to be ineffective except TIBA at 200 ppm concentration which recorded increase in flower duration and vase life as compared to control.

11. Number of bulbs per plant and bulb production ratio was significantly increased by application of cycocel. CCC-500 ppm recorded significantly maximum number of bulbs and bulb production ratio (1.40 each). However, IAA and TIBA were observed to be ineffective except TIBA-100ppm which recorded

increased number of bulbs and bulb production ratio as compared to control.

12. Weight per bulb and bulb size were observed to have increased significantly by application of all growth regulators. However, maximum weight per bulb (17.83 g) and bulb size (11.50 cm) was recorded by IAA 500 ppm and minimum weight per bulb and bulb size was recorded under control.

13. Number of bulblets per plant were significantly increased by application of cycocel but remained unaffected by application of IAA and TIBA. CCC-500 ppm recorded significantly maximum number of bulblets per plant (3.33).

14. Weight of bulblets per plant was significantly increased by application of indole acetic acid but remained unaffected by application of CCC and TIBA as compared to control. IAA-500 ppm recorded significantly maximum weight of bulblets (7.40 g) per plant.

15. Apeldoorn was observed to be superior over Golden Oxford in enhancing most of the characters.

From the results of present findings, it can be concluded that IAA at a concentration of 500ppm was observed to be most suitable for vegetative and floral production whereas, CCC at a concentration of 500ppm was observed to be most effective for bulb production as compared to control. However, highest benefit-cost ratio was recorded by using IAA-500ppm.

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* Original not seen.

APPENDIX-I

Analysis of variance for various characters in tulip (*Tulipa gesneriana*)

```
1. Days taken to bulb sprouting
> fit2<-aov(sprouting~Replication+GR*variety,data=tulip)
> summary(fit2)
            Df  Sum Sq  Mean Sq  F value    Pr(>F)
Replication  2  0.355   0.177    0.4351     0.65040
GR           9  52.313  5.813    14.2613    1.055e-09 ***
variety      1  16.896  16.896   41.4563    1.427e-07 ***
GR:variety   9  7.023   0.780    1.9146     0.07931
Residuals    38 15.488  0.408
```

```
2. Plant height
> fit2<-aov(height~Replication+GR*variety,data=tulip)
> summary(fit2)
            Df  Sum Sq   Mean Sq  F value   Pr(>F)
Replication  2  12.82    6.41     1.1583    0.3249
GR           9  962.01   106.89   19.3161   1.307e-11 ***
variety      1  109.15   109.15   19.7240   7.474e-05 ***
GR:variety   9  50.65    5.63     1.0170    0.4441
Residuals   38 210.28    5.53
```

```
3. Number of leaves per plant
> fit2<-aov(leafnumber~Replication+GR*variety,data=tulip)
> summary(fit2)
            Df   Sum Sq  Mean Sq F value Pr(>F)
Replication  2   5.556   2.778   0.9154  0.4090
GR           9   16.622  1.847   0.6085  0.7819
variety      1   2.773   2.773   0.9139  0.3451
GR:variety   9   17.695  1.966   0.6478  0.7492
Residuals   38   115.3   3.035
```

```
4. Leaf area
> fit2<-aov(leafarea~Replication+GR*variety,data=tulip)
> summary(fit2)
             Df Sum Sq  Mean Sq  F value    Pr(>F)
Replication  2  125.4   62.7     0.4321     0.65228
GR           9  3590.8  399.0    2.7489     0.01407  *
variety      1  9413.5  9413.5   64.8595    9.692e-10***
GR:variety   9  1433.1  159.2    1.0971     0.38790
Residuals   38  5515.2  145.1
```

```
5. Leaf area index
> fit2<-aov (lai~Replication+GR*variety, data=tulip)
> summary(fit2)
            Df   Sum Sq   Mean Sq  F value   Pr(>F)
Replication  2  0.001023 0.000512  0.2681    0.76623
GR           9  0.033375 0.003708  1.9434    0.05474  *
variety      1  0.111802 0.111802  58.591    3.258e-09***
```

```
GR:variety   9  0.016548 0.001839  0.9636   0.48438
Residuals   38  0.072510 0.001908
```

6. Days taken to appearance of floral bud

```
> fit2<-aov(budappearance~Replication+GR*variety,data=tulip)
> summary(fit2)
            Df   Sum Sq   Mean Sq F value   Pr(>F)
Replication  2   1.601    0.801   1.3698    0.266429
GR           9   120.677  13.409  22.9392   9.462e-13 ***
variety      1   53.771   53.771  91.9902   1.075e-11 ***
GR:variety   9   18.376   2.042   3.4930    0.003123  **
Residuals   38   22.212   0.585
```

7. Days taken to colour break

```
> fit2<-aov(colourbreak~Replication+GR*variety,data=tulip)
> summary(fit2)
             Df  Sum Sq  Mean Sq F value    Pr(>F)
Replication  2   0.217   0.109   0.2527    0.7780
GR           9   71.016  7.891   18.3474   2.816e-11 ***
variety      1   0.067   0.067   0.1550    0.6960
GR:variety   9   2.027   0.225   0.5236    0.8482
Residuals   38   16.343  0.430
```

8. Days taken to flower opening.

```
> fit2<-aov(floweropening~Replication+GR*variety,data=tulip)
> summary(fit2)
             Df  Sum Sq  Mean Sq F value   Pr(>F)
Replication  2   1.101   0.551   2.4517    0.09966
GR           9   96.347  10.705  47.6772   2.2e-16   ***
variety      1   5.704   5.704   25.4043   1.171e-05 ***
GR:variety   9   11.024  1.225   5.4553    8.378e-05 ***
Residuals    38  8.532   0.225
```

9. Flower diameter.

```
> fit2<-aov(flowerdiameter~Replication+GR*variety,data=tulip)
> summary(fit2)
             Df  Sum Sq   Mean Sq F value  Pr(>F)
Replication  2   0.6262   0.3131  0.4450   0.64415
GR           9   15.526   1.7251  2.4514   0.26030
variety      1   0.0073   0.0073  0.0103   0.91963
GR:variety   9   2.5537   0.2837  0.4032   0.92555
Residuals    38  26.7412  0.7037
```

10. Scape length.

```
> fit2<-aov(scapelength~Replication+GR*variety,data=tulip)
> summary(fit2)
             Df  Sum Sq  Mean Sq F value   Pr(>F)
Replication  2   12.92   6.46    1.1552    0.3258
GR           9   963.48  107.05  19.1388   1.501e-11 ***
variety      1   110.50  110.50  19.7551   7.394e-05 ***
GR:variety   9   52.71   5.86    1.0471    0.4224
```

```
Residuals    38  212.55  5.59
```

11. Scape thickness

```
> fit2<-aov(scapethickness~Replication+GR*variety,data=tulip)
> summary(fit2)
             Df  Sum Sq  Mean Sq F value   Pr(>F)
Replication  2   1.393   0.696   2.1597    0.129306
GR           9   43.799  4.867   15.0947   4.759e-10 ***
variety      1   3.543   3.543   10.9893   0.002022  **
GR:variety   9   5.416   0.602   1.8666    0.087548 .
Residuals   38   12.251  0.322
```

12. Fresh weight of flower scape

```
> fit2<-aov(scapeweight~Replication+GR*variety,data=tulip)
> summary(fit2)
            Df Sum Sq Mean Sq F value  Pr(>F)
Replication  2  31.11   15.55  0.6692  0.5180
GR           9 145.04   16.12  0.6934  0.7104
variety      1  68.07   68.07  2.9290  0.0951
GR:variety   9 574.28   63.81  2.7454  0.417
Residuals   38 883.19   23.24
```

13. Duration of flowering.

```
> fit2<-aov(flowerduration~Replication+GR*variety,data=tulip)
> summary(fit2)
            Df Sum Sq   Mean Sq F value   Pr(>F)
Replication  2  0.858   0.429   0.5567    0.577723
GR           9 54.458   6.051   7.8525    1.975e-06 ***
variety      1  7.392   7.392   9.5931    0.003662  **
GR:variety   9 11.034   1.226   1.5910    0.153079
Residuals   38 29.281   0.771
```

14. Vase life

```
> fit2<-aov(vaselife~Replication+GR*variety,data=tulip)
> summary(fit2)
            Df  Sum Sq   Mean Sq  F value   Pr(>F)
Replication  2  0.4853   0.2427   1.4360    0.2504827
GR           9  31.4007  3.4890   20.6469   4.776e-12 ***
variety      1  14.6027  14.6027  86.4153   2.494e-11 ***
GR:variety   9  7.9773   0.8864   5.2453    0.0001203 ***
Residuals   38  6.4213   0.1690
```

15. Number of bulbs per plant

```
> fit2<-aov(bulbnumber~Replication+GR*variety,data=tulip)
> summary(fit2)
            Df  Sum Sq  Mean Sq  F value   Pr(>F)
Replication  2  0.00014 0.00007  0.0143    0.9858
GR           9  0.72107 0.08012  15.9741   2.125e-10 ***
variety      1  0.00913 0.00913  1.8197    0.1853
GR:variety   9  0.42501 0.04722  9.4154    2.372e-07 ***
Residuals   38  0.19059 0.00502
```

16. Size of bulb

```
> fit2<-aov(bulbsize~Replication+GR*variety,data=tulip)
> summary(fit2)
            Df  Sum Sq   Mean Sq  F value   Pr(>F)
Replication  2  0.5760   0.2880   2.3045    0.1136
```

```
GR           9  30.0021  3.3336   26.6728   8.803e-14 ***
variety      1  13.0014  13.0014  104.0280  1.967e-12 ***
GR:variety   9  0.3737   0.0415   0.3323    0.9587
Residuals   38  4.7492   0.1250
```

17. Weight per bulb.

```
> fit2<-aov(bulbweight~Replication+GR*variety,data=bulb3)
> summary(fit2)
            Df   Sum Sq   Mean Sq F value   Pr(>F)
Replication  2   0.305    0.153   0.1648    0.8486
GR           9   176.175  19.575  21.1333   3.348e-12 ***
variety      1   48.961   48.961  52.8583   1.062e-08 ***
GR:variety   9   6.554    0.728   0.7861    0.6304
Residuals   38   35.198   0.926
```

18. Number of bulblets per plant

```
> fit2<-aov(bulbletnumber~Replication+GR*variety,data=tulip)
> summary(fit2)
            Df  Sum Sq Mean Sq  F value   Pr(>F)
Replication  2  0.6771  0.3385  3.1912   0.5235
GR           9  18.562  2.0625  19.442   1.186e-11 ***
variety      1  0.5042  0.5042  4.7525   0.03552   *
GR:variety   9  0.6208  0.0690  0.6502   0.74717
Residuals   38  4.0312  0.1061
```

19. Weight of bulblets per plant

```
> fit2<-aov(bulbletweight~Replication+GR*variety,data=tulip)
> summary(fit2)
            Df Sum Sq Mean Sq F value    Pr(>F)
Replication  2  1.300   0.650  0.7039 0.5010054
GR           9 33.997   3.777  4.0912 0.0009795 ***
variety      1 11.284  11.284 12.2210 0.0012192 **
GR:variety   9  1.294   0.144  0.1557 0.9971494
Residuals   38 35.086   0.923
```

20. Bulb production ratio

```
> fit2<-aov(bulbproduction~Replication+GR*variety,data=tulip)
> summary(fit2)
            Df  Sum Sq  Mean Sq  F value   Pr(>F)
Replication  2  0.00014 0.00007  0.0143    0.9858
GR           9  0.72107 0.08012  15.9741   2.125e-10 ***
variety      1  0.00913 0.00913  1.8197    0.1853
GR:variety   9  0.42501 0.04722  9.4154    2.372e-07 ***
Residuals   38  0.19059 0.00502
```

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
GR = Growth regulator

Appendix-II

Climatological data showing weather parameters from May, 2007 to June, 2008

Station: Shalimar, Srinagar, Altitude: 1587 m amsl

Month	Weather Parameters			
	Max. Temp (°C)	**Min. Temp (°C)**	**Relative humidity (%)**	**Rainfall (mm)**
May, 2007	25.10	10.52	65.31	44.50
June, 2007	28.54	14.55	65.53	49.70
July, 2007	29.90	16.86	69.29	57.60
Aug., 2007	29.79	16.53	69.63	46.40
Sept., 2007	26.88	12.35	72.20	23.20
Oct., 2007	24.02	02.71	63.92	00.00
Nov., 2007	17.20	-1.83	65.13	00.00
Dec., 2007	09.60	-2.29	81.47	13.20
Jan., 2008	04.83	-2.61	85.63	85.90
Feb., 2008	08.15	-1.87	92.60	102.5
March, 2008	19.02	03.77	57.53	07.90
April, 2008	19.41	06.32	65.30	108.0
May, 2008	24.97	09.73	65.61	39.10
June, 2008	29.48	16.64	67.20	29.70

Source: Experimental Agromet Advisory Service Annual Report, 2007 & 2008; Division of Agronomy, SKUAST-K, Shalimar, Srinagar.

Appendix-III

Cost of inputs of different Agro-techniques

A	**Fixed cost**		
1	Rental value of land @ 10000/ha	=	250.00
2	Depreciation of farm implements	=	41.00
	Interest on fixed cost	=	7.27
	Total fixed cost	**=**	**291.00**
B	**Variable cost**		
1	Tractor labour (2 ploughings)	=	300.00
2	Preparation of beds (3 Mandays)	=	300.00
3	Cost of bulbs (13333 bulbs @ Rs.8/bulb)	=	79998.00
4	Cost of planting bulbs (2 Mandays)	=	200.00
5	Cost of manures and fertilizers		
	Cowdung 6q @ 100/q	=	600.00
	Urea 32.60 kg @ 5.50/kg	=	179.30
	SSP 46kg @ 6.80/kg	=	312.80
	MOP 20kg @ 8/kg	=	160
6	Cost of weeding cum hoeing (4 Mandays)	=	400.00
7	Irrigation (4 Mandays)	=	400.00
8	Plant protection chemicals	=	200.00
9	Cost of harvesting flower scapes, packing and transport @ Rs.0.20/flower scape	=	2666.60
10	Cost of digging out, cleaning and treatment of bulbs with fungicides (5 Mandays)	=	500.00
	Variable cost	=	86216.70

Contd…

Appendix-III contd…

Total cost of cultivation (Rs.) of various treatments

Treatment	Cost of chemical	variable cost (VC)	Interest on variable cost	Total variable cost	Gross expenditure (VC=FC)
IAA-750ppm	1944.60	88161.30	2204.03	90365.33	990663.60
IAA-500ppm	1296.40	87513.10	2187.83	89700.93	89999.20
IAA-250ppm	648.20	86864.90	2171.62	89036.52	89334.79
CCC-750ppm	777.84	86994.54	2174.86	89169.40	89467.67
CCC-500ppm	518.56	86735.26	2168.38	88903.64	89201.91
CCC-250ppm	259.28	86475.98	2161.90	88637.88	88936.15
TIBA-200ppm	1215.24	87431.94	2185.80	89617.74	89916.01
TIBA-150ppm	910.20	87126.90	2178.17	89305.07	89603.34
TIBA-100ppm	606.80	86823.50	2170.59	88994.09	89292.36
Control	---	86216.70	2155.42	88372.12	88670.39

1g IAA = Rs.70.00; 1g CCC = Rs.28.00; 1g TIBA = Rs.164

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CERTIFICATE

This is to certify that all the corrections/modifications suggested by External Examiner in the thesis manuscript entitled "**Effect of plant growth regulators on vegetative, floral and bulb production in tulip (*Tulipa gesneriana* L.)"** by **Mr. Zahoor Ahmed Rather (Regd. No. 2006-A-791-M)** have been taken care of before final binding of the same.

Dr. M.Q. Sheikh
Major Advisor