EFFECT OF CHLORMEQUAT ON GROWTH AND YIELD OF OKRA (*Abelmoschus esculentus* (L.) Moench) cv. Guj. Bhinda -2

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CERTIFICATE

I have pleasure in forwarding this thesis of Mr. Kamlesh R. Bharad M.Sc. (Agri.) entitled **“Effect of Chlormequat on growth and yield of okra (*Abelmoschus esculentus* (L.) Moench) cv. Guj. Bhinda - 2”** for acceptance for the degree of Ph.D. in Plant Science. The results embodied in this thesis are original and have not been submitted for the award of any degree of any University.

Mr. Kamlesh R. Bharad has put in more than six terms of research work in this department under my supervision.

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Associate Professor
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Forwarded through :

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(Kamlesh R. Bharad)

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INTRODUCTION

Okra (*Abelmoschus esculentus* (L.) Moench) is a member of the family malvaceae. Earlier its botanical name was *Hibiscus esculentus* (L.) Moench under the section *Abelmoschus* of *Hibiscus*, established by Linnaeus in 1737.Okra is known by many local names in different parts of the world. For example, it is called lady's finger in England, gumbo in the United States of America and bhindi in India. Okra is one of the most important fruit vegetables grown throughout the tropics and warm temperate zones. It is widely cultivated as a summer season crop in North India and as a kharif and as a summer season crop in Gujarat, Andhra Pradesh, Karnataka and Tamil Nadu. It fails to grow on high hills and the areas, which experience very low temperatures. It grows well in the areas where day temperatures remain between 25^o to 40^o C and that of night are over $22\ ^o$ C. All over India, its immature tender fruits are used as vegetable. The roots and stems of okra are used for clearing the sugar cane juice while preparing jaggery and sugar. Its ripe black or brown white-eyed seeds are sometimes roasted, ground and used as a substitute for coffee in Turkey (Mehta, 1959). Mature fruit waste and stems containing crude fibres are used in the paper industry.

Okra fruit is a good source of vitamin A, B and C. The content of calcium in its fruits is very high (66 mg/100g of edible portion) compared to that in other fruit vegetables. It is an excellent source of iodine. It is also rich in protein and mineral nutrients.

Among fruit vegetables, okra fruits have good demand throughout the year. India is a largest producer of okra (bhindi) in the world. During 1998-99 33.80 lakh tonnes green fruits were produced from 3.26 lakh hectare in the country. The major okra growing states are U.P., Bihar, and West Bengal. The once declining production due to yellow vein mosaic virus (yvmv) is now on rise with release of resistant varieties and hybrids (Thumburaj and Singh, 2003). Okra can be easily grown thrice in a year under tropical climate where winters are mild, twice in subtropical climate (not in winter) and once in a year in a temperate climate during summers.

Plant is an erect herbaceous annual 1-2 meter tall. Stem is green or exhibits reddish tinge. Leaves are alternate, broadly cordate, palmately 3-7 lobed, hirsute and serrate. Flowers are solitary, axillary with about 2 cm long peduncle; epicalyx up to 10. There are narrow hairy bracteoles, which fall before the fruit reaches maturity; calyx split longitudinally as flower opens. Petals 5, yellow with crimson spot on claw, 5-7 cm long. Staminal columns are united to the base of petals with numerous stamens. Ovary superior, stigma 5-9, deep red. Fruit is a capsule, light green, or sometimes red in colour, pyramidal oblong, beaked, longitudinally furrowed, 10-30 cm long, dehiscing longitudinally when ripe. Seeds are green to dark brown and rounded. The greatest increase in fruit weight, length and diameter occurs during 4th to 6th days after pollination (Sistrunk et al.,1960). Generally, the fibre formation in the fruit begins at 5th or 6th day of fruit formation and a sudden increase in fibre content from the 9th day is observed (Nath, 1976).

A flower bud appears in the axil of each leaf above 6th to 8th leaf depending upon the cultivars. There may be a period of 2,3 or more days between the times of development of each flower but never does more than one flower appear on a single stem. The time of anthesis varies with the cultivar, temperature and humidity and it occurs during 8 to 10 am. The dehiscence of anther is transverse and occurs 15 to 20 minutes after anthesis. The dehiscence is complete in 5-10 minutes. It takes 2-6 hours for fertilization after pollination. The flowers remain open for a short time and they wither late in the afternoon. The stigma is receptive at opening of the flower. Experimentally it has been found that there is no significant difference in fruit set under open- pollinated, self-pollinated (by bagging alone) and self-pollinated (hand pollination of bagged flowers), indicating that it is potentially a self-pollinated crop (Purewal and Randhawa, 1947). The pollen fertility is maximum one hour before and after the opening of flower (Srivastava, 1964).

All the varieties of okra grown by farmer are more or less susceptible to yellow vein mosaic (yvm) disease .The Vegetable Research Station of Gujarat Agriculture University has released one new variety of okra in 1999. Name of this variety is Gujarat Bhinda 2. This variety is resistant to yellow vein mosaic virus. Breeding method is pedigree (S-18-20 x Manihot) x S-18-20. Growth and yield of this variety is better than others. However, no work has been carried out on its growth and yield. Because of its acceptability in the market and fetching higher prices, cultivators are eager to know about its scientific management practices and special treatments for obtaining higher yields.

It is known since long back that plants require nutrients for their growth and development. They may grow and survive even if little amount of nutrients is available. But for their reproductive phase, certainly an additional quantum of mineral nutrients is essential which should either be met with the application of nutrients through soil or foliar feed or through the both ways. Further, for augmentation of various physico-biochemical processes, growth regulators also prove beneficial.

Growth and yield potential of okra can be improved with the adoption of scientific cultivation technology including use of growth regulators. As stated earlier growth regulators help in efficient utilization of metabolites (Antony et al., 2003) in certain physiological processes going on in plant systems (Noggle and Fritz, 1992). They play vital role in the regulation of plant growth, formation of pods, seeds etc. in the plants. Among several growth substances, 2-chloroethyl trimethyl ammonium chloride commonly known as in the name of chlormequat is very promising, and it is being used on large scale in a number of fruit vegetables, cereals and flowering crops in developed countries.

Chlormequat brings about retardation in plant height by reducing internodal length. Simultaneously, it also induces the formation of lateral shoots (Chen et al., 2002) thereby plants posses many number of fruit bearing shoots. Some plant species become resistant to water stress. The colour of the leaves changes to dark green, indicating greater concentration of chlorophyll, which in turn stimulates the carbohydrate synthesis and seed production.

There are two methods of application of chlormequat on okra. First is seed treatment prior to sowing and second is foliar spraying. Contradictory reports are available for both the methods under different climatic conditions. Different concentrations of chlormequat exhibit variation in their effect. However, it is necessary to find out method as well as concentration, which provide better yield under agro - climatic and edaphic conditions of Saurashtra region of Gujarat state.

Aim

The present study is an attempt to single out the method and concentration of chlormequat to get maximum yield of newly released variety Gujarat Bhinda 2 (G.O. 2). It is necessary to conduct such studies in Gujarat state because the state is a major producer of fruit and supplier of okra seeds.

Objectives

Considering the importance of immature fruit as vegetable and seed for propagation, the present study was under taken with the following main objectives :

1. To find out the effect of chlormequat on seedling emergence.
2. To find out the effect of chlormequat on vegetative characters.
3. To find out the effect of chlormequat on floral characters
4. To find out the effect of chlormequat on fruit characters.
5. To find out the effect of chlormequat on yield.
6. To find out optimum concentration of chlormequat for better yield.
7. To find out better method of application.
8. To find out the effect of chlormequat on accumulation of macronutrient.

REVIEW OF LITERATURE

The state of knowledge on investigations carried out on okra involving different methods and levels (concentrations) of chlormequat in relation to seedling emergence, plant growth, flowering and fruiting, and fruit and seed yields has been reviewed in this chapter.

Clormequat is one of the most effective growth retardant for plants. It is widely used on a large number of ornamental plants to make them dwarf and decorative. For crop plants, it is used for increasing fruit set and obtaining high yield because it increases the number of effective branches for flowering and fruiting. The use of chlormequat on cotton plant is also very common. Relevant findings on different characteristics of plants are described below.

2.1 Seedling emergence.

A significant increase in seed germination for CO-1 variety of tomato was reported by CCC treatment in an experiment by Irulappan and Muthukrishnan (1973). EL – Beheidi (1979) conducted experiment on okra cv. Balady at Zagazing, Egypt. He recorded the highest average seedling emergence (71.5%) for seeds soaked for 24 hours in an aqueous solution containing 250-ppm CCC plus 100 ppm proline. The total yield was highest on plants grown by seeds treated with 250 ppm CCC plus either proline 100 ppm or sucrose 100 ppm (3.37 – 5.5 kg / 12 m^2 plot). Yield was 2.4 – 4.15 kg / plot under control conditions.

An experiment was conducted on okra cv. Pusa Sawani at Vegetable Research Farm of Haryana Agriculture University Hisar by Mangal et al. during the year 1985 and 1986. Seeds were shown in the artificial salinised soil filled in cement pots. Seeds were soaked in solutions of NAA (10,25 and 50 ppm), chloro choline chloride (CCC) (100,250 and 500 ppm) and in water for 10 hours before sowing. Soil salinity had adverse effect on seed germination of okra under control conditions, while seed soaking in cycocel at 100 ppm and in NAA at 50 ppm exhibited no reduction in germination. The number of branches and umbels per plant, seed yield, test weight, germination percentage and seed vigour index were highest with the application of 100 ppm cycocel 40 days after sowing (Rana et al., 2002).

2.2 Plant growth.

Mehrotra et al. (1970) applied various concentrations of chlormequat to the soil beneath okra plants at the 3rd leaf stage. Also, in another treatment okra seeds were soaked in solutions of chlormequat of same concentrations for 24 hours before sowing. It was recorded that both treatments reduced plant height. Seed soaking was more effective in increasing the number of leaves per plant than soil treatment. Further, chlormequat delayed flowering. When chlormequat was applied at 500 ppm, either in soil or in seed soaking treatment, increased yield and fruit length. Doubling the concentration (1000 ppm) had a deleterious effect on yield.

Increase in the yield of tomatoes by spraying the seedlings with CCC was reported by Shul'-gina and Ledovskii (1978). Tomato seedlings cv. Kievskii 139, were sprayed 3 times at weekly intervals with 0.2 percent chlormequat. Seedling height was reduced, but plant and especially root development was improved. Both total and early yields and returns were markedly increased. Boshnakov et al. (1979) used the retardant chloro choline chloride CCC for producing seedlings of early tomatoes. When CCC was applied at 0.1 percent to the roots of newly pricked out tomato seedlings, it shortened the internodes and thickened stems.

Genchev et al. (1979) studied the effect of growth retardant CCC on tomato growth and production. Chloro choline chloride (CCC) was applied at three concentrations (0.025, 0.05 and 0.1%) to the early outdoor hybrid cvs. Lucy and Apolchi. The best results were obtained with treatment at 0.05-0.1 % if applied 10-12 days before transplanting.

Okra plants spaced at 40 or 60 cm were treated with chlormequat at 1000 or 1500 ppm 20 and 40 days after sowing by Gowda and Gowda (1983). Chlormequat reduced plant height, especially when applied twice at the higher concentration. Further, Gowda et al. (1984) sprayed cycocel (chlormequat) at 1500 ppm on twenty day-old okra plants and sampled leaves 40 days later.

Some chloritc and dark green patches were noted on treated leaves. Dropping of flower buds and young fruits was also observed.

Abdul et al. (1985) carried out experiment on okra cv. Batraa in Iraq. In 2-year trial, chlormequat was applied at 250, 500, 750 or 1000ppm concentrations at 3 to 4 leaf stage and it was observed that there was a remarkable reduction in plant height and shoot dry weight. However, yield was not significantly reduced.

In a field trial with okra cv. Clemson spineless, plants were sprayed with pix at 100,250 or 500 mg/litre, or Terpal [mepiquat – chloride + ethephon] or CCC (chlormequat) at 500, 750 or 1000 mg/litre 5 weeks after planting. All treatments reduced stem height and increased the number and length of branches and the number of leaves / plant. Pix and CCC both reduced the number of days for flowering (Zayed et al., 1985). For high and early yield spraying with pix at 250 mg./ litre or CCC at 1000 mg / litre was recommended.

Adler and Wilcox (1987) conducted experiment on tomato. Root dry weight and leaf number were not affected by stress of thigmic chlormequat chloride. Shoot dry weight, shoot : root dry weight ratio, shoot height, leaf area and root surface area decreased in response to thigmic and chlormequat chloride. However root length decreased and root radius increased in response to chlormequat chloride.

In greenhouse trials, tomatoes cv. Fuhuzyy No. 2, eggplant cv. Hayabusa and sweet paper cv. Shinsakigakemidori, seedlings about one month old were sprayed 3 times with 10 to 20 ppm GA or 500 or 1000 ppm chlormequat at 5 days intervals. Application of GA increased rate of photosynthesis, leaf area, plant dry weight and proportion of dry weight in the stem. Chlormequat increased growth vigour and the extent of root systems, but at 1000 ppm it caused leaf injury. Plant fresh weight increased with application of chlormequat except that higher level of chlormequat decreased fresh weight in eggplants. (Zhong and Kato, 1988).

Seeds of okra cultivars Pusa Sawani were soaked for 24 hours in solutions of cycocel (chlormequat) at 50, 100, 250 or 500 ppm or in NAA at 5,10 or 25 ppm and dried for 2 hours and sown in the rainy seasons (June) of 1985 and 1986. In Some cases the chemicals were also sprayed on the foliage 20 and 40 days after sowing. Chlormequat at 100 ppm used for seed soaking and foliar treatment increased the number of branches and leaves per plant. Chlormequat at 50 ppm as a foliar spray alone hastened the flowering (Arora et al., 1990).

Okra cv. Pusa Sawani plants were grown at 4 planting densities (74070, 55550, 49380 or 37030 plants/ha) and treated with CCC [chlormequat] at 0, 500, 1000 or 1500 ppm applied either as a seed soaking treatment or as a foliar spray 20 and 40 days after sowing. Planting density had no significant effect on plant height or pod number and weight but pod yield increased significantly. Plant height was reduced with increasing CCC concentration (Patel and Singh, 1991).

A field experiment was conducted during 1993 at Gujarat Agricultural University, India to study the effect of irrigation (IW / CPE ratio of 0.5,0.7,0.9 and 1.1) and chlormequat (250,500 and 750 ppm) on growth and yield of summer okra cv. Parbhani Kranti. Plants treated with chlormequat at 750 ppm exhibited lowest height and the highest number of branches, leaves and fruits / plant. Chlormequat treatments were effective in suppressing apical dominance, thus promoting the growth of axillary buds into new stems. There was no significant interaction between the chlormequat and irrigation treatments (Rathod and Patel, 1996)

Jasmine *(Jasminum sambac)* is one of ornamental plants and potentially gives a contribution to farmer's income. In Central Java, particularly in center production area, generally the flower yield of jasmine is low due to inappropriate cultural techniques. A study was conducted to understand the effect of pruning, cycocel application and their combination on flower yield. This study was carried out at the experiment garden of Research Institute for Ornamental Plants at Pasarminggu, from July 1996 to October 1997. A Factorial Randomized Block Design was used with three replications. The first factor was pruning: at four and two months intervals; the second factor was application time of cycocel; one and two weeks after pruning; and the third factor was dosage of cycocel: 0; 500; 1000; and 1500 ppm. The result showed that pruning interval of four months showed significantly higher flower yield than that of two months, where the increases in flower weight and number of flowers were 30.45 percent and 26.6 percent, respectively. Cycocel application tends to enhance flower yield of Jasmine. Results provide a base to set up further investigation on cultural technique to improve plant vigour and flower yield of jasmine (Satsijati et al., 1998).

A field study was conducted at IARI New Delhi in the 1990-91 summer season on groundnut cv. ICGS1 and MH-2. Phosphorus was added at the rate of 0,13 or 26 Kg / ha and sprayed with 0, 500 or 1000 ppm CCC (chlormequat) 40 and 55 days after sowing. Chlormequat caused a lower LAI and dry matter accumulation after 60 days but an increase in both measurements was recorded at harvest. (Kundalam et at. 1999)

A field experiment was conducted at the Research Farm of the Indian Agricultural Research Institute, New Delhi, India during kharif season of 1996 and 1997 to study the influence of nitrogen, bio-fertilizers and growth regulators on growth, yield and quality of cotton (*Gossypium hirsutum*). It was observed that application of 50-ppm chlormequat chloride retarded plant height, leaf area per plant and leaf area index and dry matter production, but increased number of bolls per plant, average weight of boll, and cotton yield (Shriram and Prasad, 2001).

The effects of cyclocel on the growth and the biological and seed yield of safflower cv. Bhima were determined in a field experiment in Solapur, Maharashtra, India during the rabi seasons of 1995-99. The treatments comprised application of 500 or 1000 ppm cyclocel during the flower initiation and 50% flowering stage. Control plants were sprayed with distilled water at flower initiation and 50% flowering. The highest number of capsule per plant (21.12), 1000-seed weight (57.86 g), dry matter at harvest (66.47 g/plant) and chlorophyll content at flowering (1.43 mg/plant) were observed with the application of 1000 ppm cyclocel at the flower initiation stage, whereas the highest number of seed per capsule (26.49) and plant height (69.58 cm) were recorded with the application of 1000 and 500 ppm cyclocel at 50% flowering stage, respectively. The seed yield and harvest index were highest with application of 1000 ppm cycocel at the flower initiation stage, whereas the biological yield was highest (3791 kg/ha) with the application of 500 ppm cyclocel at the flower initiation stage (Kanade et al., 2002).

Studies were conducted to investigate the effects of gibberellic acid (GA) at 50 and 100 ppm, cycocel at 500 and 1000 ppm and NAA at 50 and 100 ppm on growth and flowering of gladiolus cv. Friendship. Foliar application of GA at 100 ppm at 45 days after corm planting resulted in the highest height (104.5 cm), number of leaves (8.5 per plant), spike length (98.3 cm), number of florets (16.7 per spike), size of second florets (10.8 cm) and number of spikes per plant (1.73). The highest floret opening longevity or survival was obtained with cycocel at 1000 ppm (Maurya and Nagda 2002).

Growth hormones, viz., indole butyric acid, gibberellic acid, abscisic acid, kinetin, maleic hydrazide, cycocel [chlormequat], ethrel [ethephon] and alar [daminozide], were used in foliar application to study their effects on the growth of *Albizia lebbek* seedlings. Gibberellic acid at 300 ppm caused the highest shoot length, total chlorophyll and soluble protein content of the seedlings. Cycocel at 3% exhibited the highest leaf area and total dry weight. Alar applied at 300 ppm gave the highest root length (Llango et al., 2003).

A field experiment was conducted during 1995-96 in Sriniketan, West Bengal, India to investigate the effects of P sources and cycocel [chlormequat] sprays on the performance of green gram cv. B-108. The P sources (supplied at 60 kg/ha each) were: Purulia rock phosphate (PRP), single super phosphate (SSP), cattle urine-treated Purulia rock phosphate (CUTPRP) and whey-treated Purulia rock phosphate (WTPRP). The study included a control treatment in which no P was applied. The CCC treatments were: no cycocel (control), single spray of CCC at 100 mg/litre (at 30 days after sowing, DAS); and double sprays of CCC at 100 mg/litre (at 30 and 45 DAS). WTPRP resulted in higher plant height, root length, nodules per plant, primary branches per plant, pods per plant, seeds per pod, 1000-seed weight and seed yield compared to the other P sources. WTPRP showed 75.5% higher seed yield compared to the control. Under the P treatments, seed yield showed highly positive and significant correlation with primary branches per plant, nodules per plant, pods per plant and seeds per pod. Chlormequat reduced the plant height, but increased the number of branches per plant, nodules per plant and other yield-contributing parameters. Two sprays of CCC resulted in 20.2% higher seed yield over the control treatment. The treatment combination WTPRP + CCC (2 sprays) resulted in the highest P uptake (9.82 kg/ha) and the highest benefit: cost ratio (Garai and Datta, 2003).

A field experiment was conducted during 2000-01 in Maharashtra, India, to study the effect of cycocel [chlormequat], ethrel [ethephon] and maleic hydrazide growth regulators spray at 500, 1000, 1500 and 2000 ppm each 15 days before and 15 days after pruning on growth, flowering and flower quality of *Jasminum sambac* cv. Local. The results revealed that among the treatments, cycocel at 500 ppm increased the number of lateral shoot per plant, leaves and leaf area per shoot, internodes per shoot, flower bud quality and flower bud yield, while the plant height, length of secondary shoot and internodal length were inhibited (Muradi et al., 2003).

In order to determine the effect of seed priming and foliar application of growth regulator and chemicals on the growth, seed yield and yield attributes of okra; studies were conducted in Karnataka, India, in two seasons during 1998 and 1999. Cycocel [chlormequat] (CCC; 200 and 400 ppm), TIBA (100 and 200 ppm) and KH2PO4 (5000 and 10000 ppm) were applied via seed soaking (S1), foliar application at 30 DAS (S2) or S1 + S2 combination (S3). Plant height decreased with TIBA application. KH2PO4 increased plant height at all growth stages. Leaf number per plant was highest in 400 ppm CCC which was at par with 200 ppm CCC and KH2PO4. Branch number per plant, leaf number at harvest, processed seed yield and seed recovery were highest with 200 ppm CCC. Chlormequat at 400 ppm took the longest number of days for flower initiation. Seed priming did not affect days to harvest during kharif but significant differences were observed in the rabi season. Seed priming increased the processed seed yield in both seasons. Seed soaking + foliar spray combination resulted the highest leaf number, branch number per plant, and number of days to flower initiation. Further seed soaking + foliar spray combination resulted the highest processed seed yield in kharif and rabi seasons (983.6 and 885.6 kg/ha, respectively). During kharif, seed yield was highest (1242.7 kg/ha) with 200 ppm CCC (seed soaking + foliar application) and lowest in the control (871.3 kg/ha). A similar trend was also observed in the rabi season. It is concluded that higher processed seed yields were obtained by seed soaking for 16 h and spraying at 30 DAS with 200 ppm CCC or 5000 ppm KH2PO4 (Sajjan et al., 2003).

The effects of the foliar application of cycocel [chlormequat] (1000 or 2000 ppm), Alar [daminozide] (100, 200 or 300 ppm) and ABA [abscisic acid] (10, 20 or 30 ppm) on the performance of Indian mustard cv. Varuna under irrigated (two irrigations) and non-irrigated conditions were studied at Kanpur in Uttar Pradesh, India. The number of leaves per plant was higher under irrigated than under non-irrigated conditions. Alar at 300 ppm was more effective in increasing the number of leaves under irrigated conditions, whereas cycocel at 1000 ppm was more effective under non-irrigated conditions. The growth regulators except 20 and 30 ppm ABA increased leaf area. Alar under irrigated and cycocel under non-irrigated conditions resulted in the highest number of branches. The growth regulators reduced the length of the inflorescence, thus, reducing the distance between the source and sink. The reduction in inflorescence length was most pronounced with Alar. The relative growth rate of leaves was generally reduced during the second period due to the application of growth regulators; however, the reduction was less marked with cycocel. Under irrigated conditions, the growth regulators except 20 and 30 ppm ABA significantly enhanced yield and yield components. Alar at 300 ppm resulted in the highest yields. Cycocel at 1000 ppm and Alar at 3000 ppm resulted in the least variation between irrigated and non-irrigated conditions in terms of yield and yield components (Meera-Shrivastava and Shrivastava, 2003).

In an experiment conducted during the rabi season of 1995-96 in Maharashtra, India, with chickpea cv. PG 81-1-1, the effect of the following treatments were evaluated: NPK (kg/ha) at F1 (recommended rate 25:50:0), F2 (fertilizer for targeted yield of 30 q/ha (31.20:60.70:27.00)), F3 35 q/ha (47.45:80.33:33.45) F4 40 q/ha (73.77:99.40:39.90)), F5 45 q/ha (99.95: 118.75: 46.35)) and F6 50 q/ha (126.0:138.0:52.8)) and cycocel [chlormequat] at 0 or 1000 ppm (C0 and C1, respectively). Plant height, plant spread, branch number, dry matter, grain weight per plant, harvest index and grain and stover yields increased with increasing fertilizer rates. Cycocel at 1000 ppm significantly controlled the plant height and diverted the food material towards the reproductive growth instead of vegetative growth. However 1000 ppm cycocel did not affect the plant spread and stover yield. Furthermore, 1000 ppm cycocel increased the branch number, dry matter, pod number per plant, grain number per plant, grain weight per plant, 1000-grain weight, harvest index and grain yield, but decreased the stover: grain ratio. F6 treatment resulted the highest grain number per plant and 1000-grain weight and the lowest stover : grain ratio. The highest pod number was also recorded in F6 treatment but was at par with the F5 treatment (Raut and Sabale 2003).

The interactive effects of nitrogen (0, 40, 60 or 80 kg/ha) and plant growth regulators (cycocel and ethrel both at 200 or 400 ppm) on the photosynthetic biomass production and partitioning in Indian mustard cv. Alankar were studied in a field experiment conducted in Aligarh, Uttar Pradesh, India. Cycocel at 400 ppm + 60 kg N/ha and ethrel at 200 ppm + 80 kg N/ha enhanced leaf photosynthetic rate, water use efficiency, leaf area and leaf dry mass 80 days after sowing. The highest stem, pod and plant dry mass were noted 120 days after sowing. At maturity, pod number and seed yield increased. The effect of plant growth regulators was concentration-dependent. (Khan et al., 2003).

2.3 Fruit yield.

Mehrotra et al. (1970) reported that chlormequat at 500 ppm increased yield and fruit number per plant and decreased fruit length in okra. Doubling the concentration (1000 ppm) had a deleterious effect on yield. Shukla and Tiwari (1973) conducted experiment at laboratory of Tissue Culture and Biochemistry, University of Jodhpur. The pot grown okra plants were sprayed twice, either with chlorphonium at 100 or 1000 ppm or with chlormequat chloride at 1000 to 5000 ppm. The first spray was applied when the seedling had only one fully expanded leaf and two cotyledons, and the second spray a week before anthesis. Fruit length 12 days after anthesis increased in response to both growth substances, the greatest effect was obtained with chlorophenium at 1000 ppm It resulted in fruits 1.4 times longer, and 1.7 times heavier, than those of untreated controls. Fruit maturity was delayed by about a week but fruit flavour was not affected. Seed number and size also increased by growth substance treatment. These effects were accompanied by reduction in shoot weight by 20 –25 percent.

Zalewski et al. (1971) reported that the varieties of tomato, Maria, Fireball and Earliest of all showed substantial variation in the changes which occurred in growth, time of flowering, early yield, incidence of disease, nitrate metabolism and peroxides and polyphenol oxidase activity in response to the treatment with the growth regulator CCC.

In a study of effect of CCC on tomato varieties, Lovato et al. (1972) found that all the canning varieties gave increased yields of ripe fruits after foliar spraying. Fruit weight was unaffected in all varieties. Bhujbal and Patil (1973) treated five varieties of tomato with CCC. Average number of fruits per plant was increased in all the varieties except Marglobe. Yield increases were 40% in GS, 20% in ES-58, and 17.7% in ES120 and nil in KY-1.

Chhonkar et al. (1977) studied the effects of ethrel and cycocel on growth and yield of okra at Varansasi (Uttar Pradesh). They treated seeds of okra cultivars Pusa Sawani sown on 14th march 1975, with ethrel (ethepon) at 100, 200, 400 and 800 ppm and 125,250, 500 and 1000 ppm of CCC on 20th April, 1975. At the initial stage, all the plants were of almost similar height and number of branches but at the time of final observation these characters varied markedly due to treatments. At the time of last reading, the ultimate height of plants receiving 1000-ppm cycocel was only 36.56 cm as compared to 64.13 cm of control plants.

In two-season trials, increase in number of pod and weight of pods / okra plant was obtained with wide than with narrow inter row spacing. Cycocel (chlormequat) at 1000 or 1500 ppm applied at early growth stage increased pods/plant. Chlormequat reduced the ascorbic acid content and increased the crude fibre and ash content during one winter season (Gowda, 1983)

Mangal et al., (1988) observed that soaking seeds in 250 ppm cycocel gave the highest average fruit yield /plant. Patel and Singh (1991) conducted experiment on okra cv. Pusa Sawani. Plants were grown at 4 planting densities and treated with CCC (chlormequat) at 0, 500, 1000, or 1500 ppm applied either as seed treatment or as a foliar spray at 20 and 40 days after sowing. Foliar spray with 1000 ppm CCC resulted in highest pod number, weight per pod and yield compared with other CCC treatment. Rathod and Patel (1996) observed that okra plants treated with cycocel at 750 ppm produced highest fruit per plant and total green fruit yield.

In cotton, application of 50-ppm chlormequat chloride increased number of bolls per plant, average weight per boll and seed yield (Shriram and Prasad, 2001).

2.4 Nutrient content

In a field trial conducted a Breznice and klatovy on winter wheat cv. Jubilar with application of 0,30, 60, 90,120 and 150 kg N/ha and with or without 2 kg ccc/ha at feeks stages. Chlormequat increased uptake of N, P and K. Also, chlormequat reduced differences in nutrient uptake between years (Kruskova, 1976).

Plants of *Zinnia elegans* were grown in pots and treated with CCC (chlormequat) at 5000 ppm, GA at 100 ppm and IAA at 100 ppm. Results were recorded for stem and leaf N, P, K, Ca, Mg and S contents. Chlormequat stimulated the accumulation of N, P, K, Ca and Mg compared to that of control (Castro et. al., 1978)

In wheat, seed treatment with 0.1–0.5 % cycocel (chlormequat) solution alone and with foliar spray of 0.1 % chlormequat solution at 700 litre/ha at the tillering or the boot stage increased the relative water content and chlorophyll content of leaves, N and P uptake, and grain protein content. There was no effect on grain yield, however, plant height and dry matter yield decreased (Cheema et al., 1981)

Results of field trial conducted for two years at Research Farm of Institute of Agriculture Science, Varanasi reveals that cycocel application significantly enhanced N, P and K uptake in wheat both the years. Zinc sulphate and ascorbic acid significantly increased the uptake compared with that for control. Nutrient uptake was more with seed treatment than that with foliar sprays during both years. (Misra and Reddy, 1984)

An experiment was conducted on okra to study interaction effect of nitrogen with GA_3 and nitrogen with CCC. The interaction of CCC and nitrogen has decreased phosphorus percentage and increased percentage of protein and potassium. (Husein and Abdul 1985)

Application of foliar spray of 25 and 50 ppm NAA, 40 and 60 ml cytozyme, 10 and 25 ppm GA, 100 and 200 ml miraculon and 500 and 1000 ppm CCC (chlormequat) on peas increased the N and P contents in leaves, stems and seeds. Protein content was highest with 500 ppm chlormequat (Shende et. al., 1987)

A trial was conducted on wheat cv. Sonalica sown on 11 Dec in the rabi (winter) season of 1976-77. Seed treatment with potassium dihydrogen phosphate (PDP) and cycocel was most effective in increasing yield and nutrient uptake (Bhati and Rathore, 1988)

An experiment was conducted on *Brassica juncea* grown in alluvial sandy loam during rabi (winter) seasons of 1982-84. It was found that application of chlormequat increased nutrient uptake in some treatments (Prasad and Shukla, 1992). In mustard also chlormequat application increased seed yield and uptake of N, P and K (Guroo and Patel, 1993). In a field study groundnut cv. I.C.G.S.–1 and MH-2 were treated with P and CCC. Total N and P uptake increased with CCC (Kundalam et al., 1999).

An experiment was conducted during the kharif season of 1994 in Bangalore, Karnataka, India to determine the effect of application of Ca and Mo combined with plant growth regulators on the uptake and recovery of nutrients in groundnut. The highest amount of nutrient was taken up by plants applied with Ca+GA_3. Application of Ca alone resulted 60.2, 16.7 and 125.0 kg/ha uptake of N, P and K, respectively. There was no difference in the uptake of nutrients by plants treated with GA_3 or brassinosteroids or cycocel alone. (Janarjuna et. al., 2001).

MATERIALS AND METHODS

Study Area

The present investigation was carried out at Horticultural Farm of B.R.S. college campus at Dumiyani in Upleta taluka of Rajkot district during Kharif season of the year 2002 and 2003. Experiment was carried out at the same field during both the years. Dumiyani is situated at 21.44’ North latitude and 70.17’ East longitude with an altitude of 67.1’ meter above the mean sea level. The study area is shown in Fig. 3.1

Climate

The climate of this region is typical tropical. In general, winter is moderately cold and dry while the summer is hot and dry. The area is markedly affected by southwestern monsoon. The monsoon is moderately humid. In general, on set of Kharif season extends from mid June to mid July, total annual rainfall is about 554 mm at central area of Saurashtra. Uncertainty of rain and uneven distribution of rain are common phenomena in Saurashtra region. The year is divisible into three seasons : summer (April - mid June), monsoon (mid June - September) and winter (November - February). The month of October and March are transition periods between raining (monsoon) and winter and between winter and summer seasons, respectively.

Physical and Chemical Properties of Soil

Soil sampling

Ten soil samples from 0 -15 and 15-30 cm depth each were collected randomly prior to commencement of the experiment. Soil samples for each depth were thoroughly mixed separately and composite samples were prepared. The soil sample was powdered with wooden pestle and mortar, passed through a 2 mm sieve and stored for chemical analysis.

Analysis of Physical Properties of Soil

The soil was subjected to analysis for physical characteristics. Soil particles such as sand, silt and clay were determined by international pipette method (Piper, 1950).

Analysis of Chemical Properties of Soil

Organic carbon was determined by Walkley and Black's rapid titration method (Jackson, 1967). Nitrogen was determined by using method suggested by Jackson (1967). Phosphorus was determined by the Olsen method (Olsen et. al. 1954). Potassium was determined by flame photometrically following Jackson (1967). Soil pH was determined by pH meter and electrical conductivity (EC) was determined by conductivity meter. Physical and chemical properties of soil are given in Table 1.

Selection of Variety

The okra variety Gujarat okra 2, popularly known as Gujarat Bhinda 2 was selected for this trial. This cultivar of okra was released in 1999 and recommended for Saurashtra region. Breeding objective was to develop high yielding and Y.V.M.V disease resistant variety with tender and green pods. Typical characteristics of the selected variety are shown in Table 2.

Cropping History of the Experimental Field

The cropping history of experimental field for the last three years is given in Table 3.

Table 1. Physical and chemical properties of soil of experimental field

Sr. No.	Parameters	Soil depth	
		0 - 15 cm	15 - 30 cm
	Physical properties		
1	Sand (%)	23.50 ±	22.10 ±
2	Silt (%)	13.40 ±	13.80 ±
3	Clay (%)	63.10 ±	61.10 ±
	Chemical properties		
1	Oraganic carbon (%)	0.78 ±	0.72 ±
2	Total nitrogen (%)	0.070 ±	0.068±
3	Available phosphorus (kg ha^{-1})	54.00 ±	52.00 ±
4	Available potassium (kg ha^{-1})	313.00±	309.00 ±
5	Soil pH (1:2.5 soil : water ratio)	8.30. ±	7.90 ±
6	EC (dS m^{-1}) at 25 ºBC (1:2.5 soil : water ratio)	0.50 ±	0.46 ±

Table 2. Typical characteristic of Okra variety : Gujarat Bhinda 2 (G.O. 2)

Sr.No.	Characteristics	Okra Variety G.O.2
(1)	Plant height (cm)	142.8
(2)	Days to flowering	50.8
(3)	Days to first picking	57.5
(4)	Average number of branches / plant	2.7
(5)	Average number of nodes / plant	27.3
(6)	Average number of fruits / plant	17.2
(7)	Fruit length (cm)	16.9
(8)	Fruit girth (cm)	6.3
(9)	Internodal length (cm)	7.5
(10)	10 fruit weight (g)	194.5

Table 3. Cropping history of the experimental field

Year	Season	Plant	Variety
1999	Kharif	Okra	Varsha
2000	Kharif	Cluster bean	long green
2001	Kharif	Stem cutting of Pomegranate, Teak, Tagri, *Adhatoda sp.*	Local
2002	Kharif	Okra (Present experiment)	G.O.2
2003	Kharif	Okra (Present experiment)	G.O.2

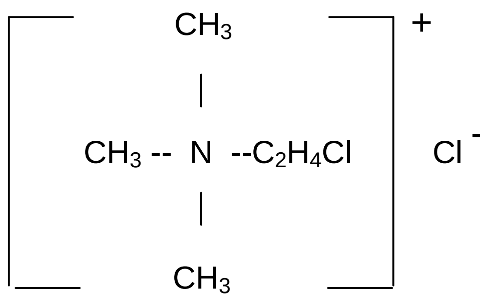
Experimental Details

Design of experiment

In the present study two factors, concentration of chlormequat and method of application were studied simultaneously. Factorial Randomized Block Design was therefore fitted to this experiment.

Treatment

Plants were treated with different concentration of chlormequat. Chemical structure of 2- chloroethyl trimethyl ammonium chloride, commonly named as chlormequat is as below:



This chemical is a plant growth retardant and is used for dwarfing the plants. Chlormequat (CCC) contains a quaternary ammonium group (nitrogen atom to which is attached four chemical groups). Chlormequat is an extremely important biological molecule involved in membrane structure and function. It is not known whether chlormequat antagonises or inhibits choline activity.

Concentrations of chlormequat

Plants were treated with following concentrations of chlormequat.

C0	0 ppm (control, water spray)
C1	500 ppm
C2	1000 ppm
C3	1500 ppm

Methods of application

M1	Presowing seed soaking in chlormequat solutions of four different concentrations for 24 hours.
M2	Foliar spray of chlormequat solutions of four different concentrations at 20 and 40 days after sowing (DAS)
M3	Presowing seed soaking in solutions for 24 hours + Foliar spray at 20 and 40 days after sowing (DAS)

Treatment combination

Treatment combinations are given in Table 4.

Lay out plan of experimental field.

Experiment was laid out in Factorial Randomised Block Design (FRBD) with twelve treatment combinations and three replications. The net plot size was 3 x 2.25 m and the gross plot size was 3.30 x 2.70 m. Required irrigation channel was of 1m width. Lay out plan is given in Fig. 3.2

Presowing preparation of field

The land was prepared by two ploughing followed by one cross harrowing. The experimental plot was divided into flat bed having the dimension of 3.30 m x 2.70 m. Provisions of sufficient number of one

Table 4. Treatment combinations

Sr.No.	Treatment No.	Treatment Symbol	Method of Application	Concentration of Chlormequat
1	T1	M_1 C_0	Seed Soaking	0 ppm (Control)
2	T2	M_1 C_1	Seed Soaking	500 ppm
3	T3	M_1 C_2	Seed Soaking	1000 ppm
4	T4	M_1 C_3	Seed Soaking	1500 ppm
5	T5	M_2 C_0	Foliar Spray	0 ppm (Control)
6	T6	M_2 C_1	Foliar Spray	500 ppm
7	T7	M_2 C_2	Foliar Spray	1000 ppm
8	T8	M_2 C_3	Foliar Spray	1500 ppm
9	T9	M_3 C_0	Seed Soaking + Foliar Spray	0 ppm (Control)
10	T10	M_3 C_1	Seed Soaking + Foliar Spray	500 ppm
11	T11	M_3 C_2	Seed Soaking + Foliar Spray	1000 ppm
12	T12	M_3 C_3	Seed Soaking + Foliar Spray	1500 ppm

meter wide path and irrigation channels were made. The same procedure was repeated during the next year.

Seed soaking treatment and sowing

Certified seed of okra cultivar ‘’Gujarat Bhinda 2‘’ (G.O.2) was purchased from Vegetable Research Station of G.A.U at Junagadh. Preparation of chlormequat solutions of different concentrations is given below.

For making 0 ppm concentration of chlormequat solution, pure water (distilled water) was used that it is called as control treatment. For making 500 ppm concentration of chlormequat solution, 500 mg chlormequat (weighed by digital balance) was dissolved in distilled water and volume was made to 1 litre. Like wise, 1000 mg and 1500 mg chlormequat was dissolved in distilled water and volume was made up to 1 litre for making 1000 ppm and 1500 ppm solutions, respectively.

Seeds were soaked in chlormequat solutions of different concentrations for 24 hours and thereafter air dried for 1 hour. All the seeds were treated with thirum (fungicide). Same procedure was followed during both the years. Planting distance was kept 45 x 30 cm (i.e. 45 cm distance between row to row and 30 cm distance between plant to plant). Seeds were sown on 27 July in the year 2002 and on 23 July in the year 2003.

Other cultural operations

Well rotten farmyard manure and fertilizers were mixed in soil before sowing following recommendation of Vegetable Research Station. Nitrogen was added to the field in the form of urea (46% N), phosphorus in the form of single super phosphate (16% P_20_5) at the rate of 100 and 50 kg / ha. Nitrogen fertilizer was given in two split dose, half dose at the time of sowing and other half at the time of flowering, while total amount of phosphors fertilizers was given at the time of seed sowing. Plant protection measure was taken and weeding was done as and when required. In kharif season plants mostly grow on rainwater, however, crop was irrigated when plants exhibited soil moisture deficit. Same cultural practices were followed during both the years.

Foliar spray of chlormequat

Foliar spray of chlormequat was performed at 20 and 40 days after sowing. In each plot, 1.5 litre solution was used at 20 days and 2.5 litre solution at 40 days.

Parameters Studied

Seedling Emergence

Seedling emergence was recorded daily for 20 days and cumulative percentage seedling emergence was calculated.

Vegetative Characters

Plant height

Plant height (cm) was measured until 90 days at the intervals of 15 days. Plant height was measured with the help of measuring tape. For height measurement five plants under each treatment were randomly selected.

Number of leaves per plant

Number of leaves per plant was noted until 90 days at the intervals of 15 days. Leaves were counted for the same plants, which were selected for height measurement.

Leaf area

Leaf area (cm^2 plant $^{-1}$) was determined until 90 days at the intervals of 15 days. Leaf area was measured by using graph paper. Leaf area was determined for the same plants, which were selected for height measurement.

Number of branches per plant

Numbers of branches per plant were counted at 60,75 and 90 days after sowing. Numbers of branches were counted for the same plants, which were selected for height measurement.

Internodal length

Internodal length (cm) was measured at 60, 75 and 90 days after sowing. It was measured by measuring tape. Internodal length (cm) was recorded for the same plants, which were selected for height measurement.

Root length

Root length was measured until 90 days at the intervals of 15 days. Root elongation was measured with the help of measuring tape. For root length measurement, plants under each treatment were randomly selected.

Stem weight

Dry weight of stem was determined until 90 days at the intervals of 15 days. Dry weight of stem was taken for the same plants, which were selected for the plant dry weight measurement.

Leaf weight

Dry weight of leaf was determined until 90 days at the intervals of 15 days. Dry weight of leaf was taken for the same plants, which were selected for the plant dry weight measurement.

Root weight

Dry weight of root was estimated until 90 days at the intervals of 15 days. Dry weight of root was taken for the same plants, which were selected for the plant dry weight measurement.

Shoot weight

Shoot weight (stem weight + leaf weight) was determined by summing up stem and leaf weight of plants

Whole Plant weight

Shoot weight and root weight were added to calculate the dry weight of the whole plant.

Floral Characters

First flower initiation

Observation of first flower initiation was noted for the plants under each treatment.

Reproductive phase

Observation on first flower initiation to last flower initiation was made for five randomly selected plants under each treatment.

Fruit Characters

Fruit length

Ten fruits from plants under each treatment were taken and their length was measured

Fruit girth

A thin wire was rolled around each selected fruit and length of wire was measured. Ten fruits for each treatment were taken for girth measurement.

Average weight of green fruit

Weight of twenty green fruits for each treatment was taken and average weight was worked out.

Number of green fruits per plant

Five plants were randomly selected and number of green fruits under each treatment, was counted at every picking day. Average number of fruits per plant was calculated.

Number of seeds per fruit

Twenty fruits for each treatment were taken and number of seeds per fruit was counted. Average number of seeds per fruit was calculated.

Test weight (100 seed weight)

For each treatment, 100 seeds were taken from mature fruits and weighed.

Yield

Yield per plant

Average weight of a green fruit and average number of fruits per plant were considered to calculate the weight of green fruits per plants.

Yield

Weight of green fruit per plot was considered to calculate fruit yield per hectare.

Chemical Analysis

Plant samples

Okra fruits for each treatment were collected. The air dried samples of fruit were ground in stainless steel grinder and mixed separately. Powdered samples were used for chemical analysis.

Method for nitrogen estimation

Estimation of nitrogen content in fruit was performed as per method of modified kjeldahl's (Jackson, 1967). Weighed amount of 0.1g plant material was taken in microkjeldahl's flask. Concentrated H_2S0_4 and mixture of catalysts were added to the sample and digested. Ten mL of digest was transferred to micro distillation flask and following it ten mL alkali was added. Boric acid was placed at delivery end and distillation was completed. Boric acid was titrated with 0.2 N H_2S0_4 (Jackson, 1967)

Method for phosphorus estimation

Weighed amount of 0.5 g ground plant material was digested in 100 mL conical flask using a mixture of nitric acid and perchloric acid (3:1) on a hot plate until the contents became colourless. The digest was transferred to 100 mL volumetric flask and the volume was made up to 100 mL by adding distilled water. The extract was filtered through whatman filter paper No. 1 and used for the determination of phosphorus. Phosphorus was estimated by vanadomolybdo phosphoric acid, yellow colour method. Five mL aliquot (extract) was transferred to 50 mL volumetric flask. Five mL of nitro vanadomolybadate reagent was added and volume was made by distilled water. Flask was stirred, allowed to stand for 15 to 30 minutes and thereafter reading was recorded on Klett Summerson photoelectric colorimeter with blue filter.

Method for potassium estimation

Potassium was determined by flame photometrically. (Jackson, 1967)

Soil sampling

After harvest of crop soil samples were collected from plots under each treatment and separately analysed.

Statistical analysis

Statistical analysis of data for various characters in the present study was performed as per factorial randominzed block design. Significance of variance was tested by 'F' test. Two years data were analysed as per method described by Steel and Torriee (1960). CD (LSD) at 5 percent probability level was calculated. Linear model was used for expression of relationship between concentrations of chlormequat and responses of plants.

RESULTS

Seedling Emergence

Effect of Chlormequat on Seedling Emergence

Values of seedling emergence for control and treated seeds were averaged separately on two years data and given in Fig. 4.1 Seedlings began to emerge 5 days after sowing and 82% seed germination was achieved over a period of 11 days under control conditions. Seeds soaked in 500, 1000 and 1500 ppm concentration of chlormequat solution showed emergence after 4 days. The cumulative percentage seed germination was 86, 88 and 90%, respectively under above concentrations of chlormequat. Increasing concentration of chlormequat significantly ($p < 0.05$) enhanced the seed germination. There was a significant positive relationship between percentage seed germination and increasing concentration of chlormequat according to the following expression :

$Y = 80 + 2.6\ x\ (r^2 = 0.966,\ p < 0.05)$

where, Y is cumulative seedling emergence (%) and x is concentration of chlormequat (ppm).

Vegetative Characters.

Effect of Chlormequat on Plant Height

Seed soaking treatment

The average values of plant height for control and treated plants were separately calculated on the data of two years experiment and plotted against time (days)(Fig. 4.2 A). Plant height increased till 90 days under the control conditions. Rate of increase of plant height was initially slow till 30 days, however, it was followed by a rapid rate till 60 days and again it slowed down during ensuing period. Height of control plants was greater than that of treated plants. Moreover, increasing concentration of chlormequat significantly ($p < 0.05$) suppressed the height of plants. There was a negative relationship between plant height and increasing concentration of chlormequat according to the following expression :

$$Y = 108.28 - 4.61\,x \;(r^2 = 0.928,\; p < 0.05)$$

where, Y is the plant height (cm) and x is concentration of chlormequat (ppm).

Foliar spray treatment

Under this treatment the average value of plant height for control and treated plants were separately calculated on two years data and given in Fig. 4.2 B. Change in plant height in response to increasing concentration of chlormequat over time was almost similar to that under seed soaking treatment. There was a decrease in plant height with increase in concentration of chlormequat. The height of control plants was consistently greater than that of treated plants. As a result, increasing concentration of chlormequat significantly ($p < 0.05$) suppressed the height of plants. There was a negative relationship between plant height and increasing concentration of chlormequat according to the following expression :

$$Y = 108.28 - 4.99\,x \;(r^2 = 0.922,\; p < 0.05)$$

where, Y is the plant height (cm) and x is concentration of chlormequat (ppm).

Seed soaking + foliar spray treatment

The values of plant height for control and treated plants were separately averaged on the data of two years experiment and given in Fig. 4.2 C. Under this treatment, the trend of change in plant height in response to increasing concentration of chlormequat over time was almost similar to that of foliar spray treatment. The maximum plant height was recorded under control conditions, whereas plant height was minimum with 1500 ppm concentration of chlormequat. As a result, increasing concentration of chlormequat significantly ($p < 0.05$) suppressed the height of plants. There was a negative relationship between plant height and increasing concentration of chlormequat according to the following expression :

$$Y = 110.15 - 6.63\,x \quad (r^2 = 0.911,\ p < 0.05)$$

where, Y is the plant height (cm) and x is concentration of chlormequat (ppm).

Effect of Application Methods

Methods of application did not differ significantly in retarding the plant height. However, average plant height with seed soaking + foliar spray method was lower than that with other two treatments.

Interaction.

All the interactions involving concentrations of chlormequat and methods of application were found non-significant.

Effect of Chlormequat on Number of Leaves Plant^{-1}

Seed soaking treatment

Number of leaves per plant for control and treated plants was separately averaged on two year data and plotted against time (days) (Fig. 4.3 A.). Number of leaves per plant increased till 60 days and thereafter decreased under the control conditions. However, increasing concentration of chlormequat significantly ($p < 0.05$) enhanced the number of leaves per plant as compared that of control plants. There was a positive relationship between number of leaves per plant and increasing concentration of chlormequat according to the following expression :

$Y = 19.83 + 0.86\ x$ ($r^2 = 0.985$, $p < 0.05$)

where, Y is number of leaves per plant and x is concentration of chlormequat (ppm).

Foliar spray treatment

Number of leaves per plant for control and treated plants was separately averaged on two years data and plotted against time (days) (Fig. 4.3 B). Number of leaves plant^{-1} increased in response to chlormequat concentrations as compared to that of control plants (Fig .4.3 B). All the three concentrations of chlormequat significantly ($p < 0.05$) enhanced the number of leaves per plant. As a result, number of leaves was greater than that on control plants. There was a positive relationship between number of leaves per plant and increasing concentration of chlormequat according to the following expression :

$Y = 19.83 + 0.863\ x$ ($r^2 = 0.985$, $p < 0.05$)

where, Y is number of leaves per plant and x is concentration of chlormequat (ppm).

Seed soaking + foliar spray treatment

Averaged number of leaves per plant for control and treated plants was calculated separately on the data of two years experiment and plotted against time (days) (Fig. 4.3 C). Number of leaves per plant increased till 60 days and thereafter decreased under the control conditions. However, increasing concentration of chlormequat significantly ($p < 0.05$) enhanced the number of leaves per plant. There was a positive relationship between number of leaves per plant and increasing concentration of chlormequat according to the following expression :

$Y = 19.83 + 0.86\,x$ ($r^2 = 0.985$, $p < 0.05$)

where, Y is number of leaves per plant and x is concentration of chlormequat (ppm).

Effect of Application Methods

Methods of application did not exhibit significant difference in affecting number of leaves per plant. Results, further suggested that combination of seed soaking + foliar spray treatment increased number of leaves per plant more than other two treatments.

Interaction.

Interactions between chlormequat concentrations and application methods were found non-significant.

Effect of Chlormequat on Leaf Area $Plant^{-1}$

Seed soaking treatment

The average values of leaf area for control and treated plants were calculated separately on the data of two years experiment and shown in Fig. 4.4 A. Leaf expansion for both control and treated plants was recorded up to 60 days and thereafter, leaf expansion stopped. Consequently leaf area decreased gradually between 60 to 75 days and thereafter it followed a rapid decline. Results suggested that increasing concentration of chlormequat significantly ($p < 0.05$) enhanced leaf expansion. A positive relationship was obtained between leaf area and concentration of chlormequat according to the following expression :

$$Y = 4742.1 + 826.25 x \ (r^2 = 0.99, p < 0.05)$$

where, Y is leaf area (cm^2 $plant^{-1}$) and x is concentration of chlormequat (ppm).

Foliar spray treatment

The average values of leaf area for control and treated plants were calculated separately on the data of two years experiment and plotted against time as shown in Fig. 4.4 B. Leaf expansion for both control and treated plants was recorded up to 60 days and thereafter, leaf expansion stopped. Consequently leaf area decreased gradually between 60 to 75 days and thereafter it followed a rapid decline. Results suggested that increasing concentration of chlormequat significantly ($p < 0.05$) enhanced leaf expansion. A positive relationship was obtained between leaf area and concentration of chlormequat according to the following expression :

$$Y = 4651.2 + 971.27 x \ (r^2 = 0.99, p < 0.05)$$

where, Y is leaf area (cm^2 $plant^{-1}$) and x is concentration of chlormequat (ppm).

Seed soaking + foliar spray treatment

Values of leaf area for control and treated plants were averaged separately on two years data and shown in Fig. 4.4 C. Trend of leaf expansion in response to increasing concentration of chlormequat over time was almost similar to that recorded for foliar spray. All the three concentrations of chlormequat significantly ($p < 0.05$) enhanced the leaf area $plant^{-1}$ as compared to plants grown under control conditions. A positive relationship was obtained between leaf area and chlormequat concentrations according to the following expression :

$$Y = 4451.6 + 1269.9\ x\ (r^2 = 0.99,\ p < 0.05)$$

where, Y is leaf area (cm^2 $plant^{-1}$) and x is concentration of chlormequat (ppm).

Effect of Application Methods

Leaf area did not differ significantly among different methods of application. Moreover, result suggested that combination of seed soaking + foliar spray treatment increased leaf area per plant greater than other two treatments.

Interaction

Interactions between concentrations of chlormequat and methods of application were found non-significant.

Effect of Chlormequat on Number of Branches $Plant^{-1}$

Seed soaking treatment

Average values of number of branches $plant^{-1}$ for control and treated plants were separately calculated on the data of two years experiment and plotted against time (Fig. 4.5 A). Number of branches on controlled as well as treated plants, increased till 90 days and thereafter it was maintained constant. Plants treated with 1000 and 1500 ppm chlormequat exhibited maximum number of branches, while minimum number of branches was obtained on control plants. As a result chlormequat significantly ($p < 0.05$) promoted branches of plants and the optimum concentrations of chlormequat was 1000 or 1500 ppm according to the following expression:

$$Y = 1.7 + 0.47\ x\ (r^2 = 0.939,\ p < 0.05)$$

where, Y is number of branches $plant^{-1}$ and x is concentration of chlormequat (ppm).

Foliar spray treatment

Values of number of branches for control and treated plants were separately averaged on the data of two years experiment and given in Fig. 4.5 B. Number of branches on the control and treated plants increased with age of the plants till 90 days. Also, number of branches $plant^{-1}$ significantly ($p < 0.05$) increased with the increasing concentration of chlormequat. The optimum concentration of chlormequat to promote number of branches was 1500 ppm according to the following expression :

$Y = 1.7 + 0.5 x$ ($r^2 = 0.953$, $p < 0.05$)

where, Y is number of branches $plant^{-1}$ and x is concentration of chlormequat (ppm).

Seed soaking + foliar spray treatment

Values of number of branches for control and treated plants recorded for two years experiment were averaged separately and given in Fig. 4.5.C. Number of branches on the control and treated plants exhibited a trend similar to that recorded for plants treated with foliar spray. However, the optimum concentration of chlormequat was 1500 ppm for significantly ($p < 0.05$) promoting number of branches according to the following expression :

$Y = 1.78 + 0.55 x$ ($r^2 = 0.969$, $p < 0.05$)

where, Y is number of branches $plant^{-1}$ and x is concentration of chlormequat (ppm).

Effect of Application Methods

There was no significant different in methods of application for increasing number of branches per plant. Nevertheless, result suggested that combination of seed soaking + foliar spray treatment exhibited greater number of branches per plant compared to other two treatments.

Interaction

All the interactions involving concentrations of chlormequat and methods of application were found non-significant.

Effect of Chlormequat on Internodal Length

Seed soaking treatment

Average values of internodal length for control and treated plants were calculated separately on the data of two years experiment and plotted against time (Fig. 4.6 A) Internodal length for control and treated plants increased till 90 days and thereafter it was maintained constant. Moreover, internodal length plant^{-1} decreased with increasing concentration of chlormequat. As a result, chlormequat significantly ($p < 0.05$) reduced plant height by reducing internodal length. Internodal length was minimum for plant treated with 1500-ppm chlormequat and maximum for control plants according to the following expression :

$$Y = 14.03 - 1.01\,x \quad (r^2 = 0.909,\ p < 0.05)$$

where, Y is internodal length (cm) and x is concentration of chlormequat (ppm).

Foliar spray treatment

Average values of internodal length for control and treated plants were separately averaged on the data of two years experiment and shown in Fig. 4.6 B. Internodal length for both control and treated plants increased with the increase of age of plants till 90 days. There was no increase of internodal length after 90 days growth period. However increasing concentration of chlormequat significantly ($p < 0.05$) reduced the internodal length of plants. As a result, plants treated with 1500 ppm chlormequat were shortest, whereas control plants were tallest according to the following expression :

$Y = 14.01 - 0.99\,x$ ($r^2 = 0.94$, $p < 0.05$)

where, Y is internodal length (cm) and x is concentration of chlormequat (ppm).

Seed soaking + foliar spray treatment

Average values of internodal length $plant^{-1}$ for control and treated plants were separately calculated on the data of two years experiment and given in Fig. 4.6 C. Internodal length for control and treated plants increased over time till 90 days. Moreover, a significant ($p < 0.05$) decrease in internodal length $plant^{-1}$ was obtained with increasing concentration of chlormequat. The maximum reduction in internodal length of plants was obtained with 1500 ppm concentration of chlormequat as compared to the internodal length of control plants according to the following expression :

$Y = 14.39 - 1.55\,x$ ($r^2 = 0.922$, $p < 0.05$)

where, Y is internodal length (cm) and x is concentration of chlormequat (ppm).

Effect of Application Methods

There was significant ($p < 0.05$) difference among methods of application in reducing the internodal length. Results, further suggested that combination of seed soaking + foliar spray treatment decreased internodal length more than other two treatments.

Interaction

All the interactions involving concentrations of chlormequat and methods of application were found non-significant.

Effect of Chlormequat on Root Elongation

Seed soaking treatment

Values of root length of control and treated plants were averaged separately on the data of two years experiment and plotted against time and given in Fig 4.7 A. Root length of control and treated plants increased as the age of plants progressed till 90 days. Root length of control plants was consistently greater that that of treated plants. Increasing concentration of chlormequat resulted in significant ($p < 0.05$) reduction of root length. As a result, root length was maximum for control plants and minimum for plants treated with chlormequat at 1500 ppm concentration. There was a negative relationship between root elongation and increasing concentration of chlormequat according to the following expression :

$Y = 24.13 - 1.83\,x$ ($r^2 = 0.99$, $p < 0.05$)

where, Y is root elongation (cm) and x is concentration of chlormequat (ppm).

Foliar spray treatment

Values of root length of control and treated plants were averaged separately on the data of two years experiment and plotted against time and given in Fig 4.7 B. Both control and treated plants exhibited increase in root length with increase in age. Root elongation continued till 90 days after sowing. Root length of control plants was consistently greater than that of treated plants. Moreover, increasing concentration of chlormequat significantly ($p < 0.05$) retarded root elongation. Root length was maximum for control plants, whereas it was minimum for plants treated with chlormequat at 1500 ppm concentration There was a negative relationship between root elongation and increasing concentration of chlormequat according to the following expression :

$Y = 23.25 - 1.52\ x\ (r^2 = 0.98,\ p < 0.05)$

where, Y is root elongation (cm) and x is concentration of chlormequat (ppm).

Seed soaking + foliar spray treatment

Values of root length of control and treated plants were averaged separately on the data of two years experiment and plotted against time and given in Fig 4.7 C. Root length of both control and treated plants increased as the age of plants progressed till 90 days. Root length of control plants was consistently greater than that of treated plants. Increasing concentration of chlormequat significantly ($p < 0.05$) suppressed root elongation. Consequently, root length was maximum for control plants and minimum for plants treated with chlormequat at 1500 ppm concentration. There was a negative relationship between root elongation and increasing concentration of chlormequat according to the following expression :

$Y = 22.6 - 1.61\ x\ (r^2 = 0.88,\ p < 0.05)$

where, Y is root elongation (cm) and x is concentration of chlormequat (ppm).

Effect of Application Methods

Methods of application did not differ significantly in retarding the root elongation. However, average root elongation with seed soaking + foliar spray method was lower than that with other two treatments.

. Interaction

All the interactions involving concentrations of chlormequat and methods of application were found non-significant.

Effect of Chlormequat on Dry Weight of Stem

Seed soaking treatment

Values of weight of stem for control and treated plants were averaged separately on the data of two years experiment and plotted against time (Fig. 4.8 A). Dry weight of stem of both control and treated plants increased with increase in age of the plants till 90 days. However, dry weight of stem of control plants was consistently lower than that of control plants. Dry weight of stem of treated plants increased with the increase in the concentration of chlormequat. As a result, chlormequat significantly ($p < 0.05$) promoted dry weight of stem. There was a positive relationship between dry weight of stem and increasing concentration of chlormequat according to the following expression :

$Y = 40.7 + 7.31\,x$ ($r^2 = 0.9$, $p < 0.05$)

where, Y is dry weight of stem (g) and x is concentration of chlormequat (ppm).

Foliar spray treatment

Values of weight of stem for control and treated plants were averaged separately on the data of two years experiment and plotted against time (Fig. 4.8 B). Increase in dry weight of stem for control as well as treated plants was recorded with the increase in age of plants. Dry weight of stem of treated plants increased as the concentration of chlormequat increased. As a result, maximum dry weight of stem was obtained for plants treated with 1500 ppm chlormequat, while minimum was for control plants. The data suggested that chlormequat significantly ($p < 0.05$) promoted the dry weight of stem. There was a positive relationship between dry weight of stem and increasing concentration of chlormequat according to the following expression :

$Y = 40.62 + 7.08\ x$ ($r^2 = 0.89$, $p < 0.05$)

where, Y is dry weight of stem (g) and x is concentration of chlormequat (ppm).

Seed soaking + foliar spray treatment

Values of weight of stem for control and treated plants were averaged separately on the data of two years experiment and plotted against time (Fig. 4.8 C). Dry weight of stem for both control and treated plants increased with the increase in age of plants till 90 days. Dry weight of stem for treated plants was consistently greater than that of control plants. Moreover, dry weight of stem for treated plants significantly ($p < 0.05$) increased with increase in concentration of chlormequat. The data suggested that chlormequat stimulated the growth (dry weight) of plants. There was a positive relationship between dry weight of stem and increasing concentration of chlormequat according to the following expression :

$Y = 38.32 + 9.9\ x$ ($r^2 = 0.86$, $p < 0.05$)

where, Y is dry weight of stem (g) and x is concentration of chlormequat (ppm).

Effect of Application Methods

There was no significant difference in methods of application for increasing dry weight of stem. Nevertheless, result suggested that combination of seed soaking + foliar spray treatment exhibited heavier dry weight of stem compared to other two treatments.

Interaction

All the interactions involving concentrations of chlormequat and methods of application were found non-significant.

Effect of Chlormequat on Dry Weight of Leaf

Seed soaking treatment

Values of weight of leaves for control and treated plants were averaged separately on the data of two years experiment and plotted against time (Fig. 4.9 A). Dry weight of leaves for both control and treated plants increased till 60 days. Following this period, dry weight of leaves gradually declined. Results suggest that increasing concentration of chlormequat significantly ($p < 0.05$) stimulated dry matter accumulation in leaves. Consequently, leaf dry weight was maximum for plants treated with chlormequat at 1500 ppm concentration and minimum for control plants. The optimum concentration of chlormequat for leaf growth was 1500 ppm. There was a positive relationship between dry weight of leaves and increasing concentration of chlormequat according to the following expression :

$$Y = 6.14 + 0.29 x \; (r^2 = 0.98, p < 0.05)$$

where, Y is dry weight of leaves (g) and x is concentration of chlormequat (ppm).

Foliar spray treatment

Values of weight of leaves for control and treated plants were averaged separately on the data of two years experiment and plotted against time (Fig. 4.9 B). There was consistent increase in dry weight of leaves for both control and treated plants till 60 days and thereafter it showed gradual decline. Increasing concentration of chlormequat significantly ($p < 0.05$) stimulated dry matter accumulation in leaves. As a result, maximum dry weight of leaves was obtained for plants treated with chlormequat at 1500 ppm concentration and minimum for control plants. The optimum concentration of chlormequat for leaf growth was 1500 ppm. There was a positive relationship between dry weight of leaves and increasing concentration of chlormequat according to the following expression :

$Y = 6.05 + 0.39x$ ($r^2 = 0.97$, $p < 0.05$)

where, Y is dry weight of leaves (g) and x is concentration of chlormequat (ppm).

Seed soaking + foliar spray treatment

Values of weight of leaves for control and treated plants were averaged separately on the data of two years experiment and plotted against time (Fig. 4.9 C). Dry weight of leaves for both control and treated plants increased with increase in age of plants till 60 days. Following this period, dry weight of leaves gradually decreased. Increasing concentration of chlormequat significantly ($p < 0.05$) promoted dry matter accumulation in leaves. As a result, maximum dry weight of leaves was recorded for plants treated with chlormequat at 1500 ppm concentration and minimum was recorded for control plants. The optimum concentration of chlormequat for leaf growth was 1500 ppm. There was a positive relationship between dry weight of leaves and increasing concentration of chlormequat according to the following expression :

$Y = 5.92 + 0.54x$ ($r^2 = 0.99$, $p < 0.05$)

where, Y is dry weight of leaves (g) and x is concentration of chlormequat (ppm).

Effect of Application Methods

There was no significant difference in methods of application for increasing dry weight of leaves. Nevertheless, result suggested that combination of seed soaking + foliar spray treatment exhibited heavier dry weight of leaves compared to other two treatments.

Interaction

All the interactions involving concentrations of chlormequat and methods of application were found non-significant.

Effect of Chlormequat on Dry Weight of Root

Seed soaking treatment

Values of dry weight of root for control and treated plants were averaged separately on the data of two years experiment and plotted against time (Fig. 4.10 A). Dry weight of root for control and treated plants increased with increase in age of plants till 90 days. Dry weight of root for control plants was lower than that for treated plants. Moreover, dry weight of roots increased as the concentration of chlormequat increased. The data suggested that chlormequat significantly ($p < 0.05$) stimulates growth of roots. There was a positive relationship between dry weight of root and increasing concentration of chlormequat according to the following expression :

$$Y = 19.66 + 2.38\,x \quad (r^2 = 0.94,\ p < 0.05)$$

where, Y is dry weight of root (g) and x is concentration of chlormequat (ppm).

Foliar spray treatment

Values of dry weight of root for control and treated plants were averaged separately on the data of two years experiment and plotted against time (Fig. 4.10 B). Root weight of control and treated plants increased with the increase in age of plants. Dry weight of root was greater for treated plants than that for control plants. Moreover, root weight for treated plants increased with increase in the concentration of chlormequat. As a result, maximum dry weight was obtained for the roots of plants treated with 1500 ppm chlormequat and minimum for roots of control plants. Results also suggest that chlormequat significantly ($p < 0.05$) promotes root growth. There was a positive relationship between dry weight of root and increasing concentration of chlormequat according to the following expression :

$Y = 20.16 + 2.3\,x$ ($r^2 = 0.94$, $p < 0.05$)

where, Y is dry weight of root (g) and x is concentration of chlormequat (ppm).

Seed soaking + foliar spray treatment

Values of dry weight of root for control and treated plants were averaged separately on the data of two years experiment and plotted against time (Fig. 4.10 C). There was an increase in dry weight of roots for control and treated plants with the increase in age of plants. Dry weight of roots for treated plants was greater than that for control plants. Moreover, dry weight of roots for treated plants increased with increase in the concentration of chlormequat. The data suggested that chlormequat significantly ($p < 0.05$) promoted dry weight of roots. There was a positive relationship between dry weight of root and increasing concentration of chlormequat according to the following expression :

$Y = 19.43 + 2.94\,x$ ($r^2 = 0.94$, $p < 0.05$)

where, Y is dry weight of root (g) and x is concentration of chlormequat (ppm).

Effect of Application Methods

There was no significant difference in methods of application for increasing dry weight of root. Nevertheless, result suggested that combination of seed soaking + foliar spray treatment exhibited heavier dry weight of root compared to other two treatments.

Interaction

All the interactions involving concentrations of chlormequat and methods of application were found non-significant.

Effect of Chlormequat on Dry Weight of Shoot (Stem + Leaves)

Seed soaking treatment

Values of dry weight of shoot for control and treated plants were averaged separately on the data of two years experiment and plotted against time (Fig. 4.11 A). Dry weight of shoot of both control and treated plants increased with increase in age of the plants till 90 days. However, dry weight of shoot of control plants was consistently lower than that of control plants. Dry weight of shoot of treated plants significantly ($p < 0.05$) increased with the increase in the concentration of chlormequat. As a result, chlormequat promoted the dry weight of shoot. There was a positive relationship between dry weight of shoot and increasing concentration of chlormequat according to the following expression :

$Y = 46.84 + 7.6\,x$ ($r^2 = 0.91$, $p < 0.05$)

where, Y is dry weight of shoot (g) and x is concentration of chlormequat (ppm).

Foliar spray treatment

Values of dry weight of shoot for control and treated plants were averaged separately on the data of two years experiment and plotted against time (Fig. 4.11 B). Increase in dry weight of shoot for control as well as treated plants was obtained with the increase in age of plants. Dry weight of shoot of treated plants increased as the concentration of chlormequat increased. As a result, maximum dry weight of shoot was obtained for plants treated with 1500 ppm chlormequat, while minimum was for control plants. The data suggested that chlormequat significantly ($p < 0.05$) promoted the dry weight of shoot. There was a positive relationship between dry weight of shoot and increasing concentration of chlormequat according to the following expression :

$$Y = 46.68 + 7.47\,x \quad (r^2 = 0.89,\ p < 0.05)$$

where, Y is dry weight of shoot (g) and x is concentration of chlormequat (ppm).

Seed soaking + foliar spray treatment

Values of dry weight of shoot for control and treated plants were averaged separately on the data of two years experiment and plotted against time (Fig. 4.11 C). Dry weight of shoot for both control and treated plants increased with the increase in age of plants till 90 days. Dry weight of shoot for treated plants was consistently greater than that of control plants. Moreover, dry weight of shoot for treated plants increased with increase in concentration of chlormequat. The data suggested that chlormequat significantly ($p < 0.05$) stimulated the growth (dry weight) of plants. There was a positive relationship between dry weight of shoot and increasing concentration of chlormequat according to the following expression :

$Y = 44.24 + 10.44\,x$ ($r^2 = 0.87$, $p < 0.05$)

where, Y is dry weight of shoot (g) and x is concentration of chlormequat (ppm).

Effect of Application Methods

There was no significant difference in methods of application for increasing dry weight of shoot. Moreover, result suggested that combination of seed soaking + foliar spray treatment increased dry weight of shoot than other two treatments.

Interaction

All the interactions involving concentrations of chlormequat and methods of application were found non-significant.

Effect of Chlormequat on Dry Weight of Whole Plant

Seed soaking treatment

Average dry weight values for the whole plant (leaf + stem + root) for control and treated plants were calculated separately on the data of two years experiment and plotted against time and given in Fig 4.12 A. Dry weight of the whole plant for control and treated plants increased with increase in age of the plants. However, dry weight of treated plants was consistently greater than that for control plants. Results, further suggested that dry weight of the whole plant for treated plants increased with increasing concentration of chlormequat. As a result, chlormequat significantly ($p < 0.05$) promoted the growth of the whole plant. There was a positive relationship between dry weight of the whole plant and increasing concentration of chlormequat according to the following expression :

$Y = 66.5 + 9.99 x$ ($r^2 = 0.91$, $p < 0.05$)

where, Y is dry weight of the whole plant (g) and x is concentration of chlormequat (ppm).

Foliar spray treatment

Average dry weight values for the whole plant (leaf + stem + root) for control and treated plants were calculated separately on the data of two years experiment and plotted against time and given in Fig 4.12 B. Weight of both control and treated plants increased with increase in age of plant. Dry weight of treated plants was greater than that of control plants. Moreover, dry weight of treated plants increased with increase in concentration of chlormequat. As a result, chlormequat significantly ($p < 0.05$) promoted plant growth. There was a positive relationship between dry weight of the whole plant and increasing concentration of chlormequat according to the following expression :

$Y = 66.78 + 9.75 x$ ($r^2 = 0.9$, $p < 0.05$)

where, Y is dry weight of the whole plant (g) and x is concentration of chlormequat (ppm).

Seed soaking + foliar spray treatment

Average dry weight values for the whole plant (leaf + stem + root) for control and treated plants were calculated separately on the data of two years experiment and plotted against time and given in Fig 4.12 C. Dry weight of the whole plant for both control and treated plants increased with increase in age of plants till 90 days. Dry weight of the whole plant, for treated plants was consistently greater than that of control plants. Moreover, dry weight of the whole plant for treated plants increased with increase in concentration of chlormequat. The data suggested that chlormequat significantly ($p < 0.05$) promoted the growth (dry weight) of the whole plant. There was a positive relationship between dry weight of the whole plant and increasing concentration of chlormequat according to the following expression :

$Y = 63.35 + 13.47\ x\ (r^2 = 0.88,\ p < 0.05)$

where, Y is dry weight of the whole plant (g) and x is concentration of chlormequat (ppm).

Effect of Application Methods

There was no significant difference in methods of application for increasing dry weight of whole plant. Moreover, result suggested that combination of seed soaking + foliar spray treatment increased dry weight of whole plant than other two treatments.

Interaction

All the interactions involving concentrations of chlormequat and methods of application were found non-significant.

Floral Characters

Effect of Chlormequat on First Flower Initiation

Seed soaking treatment

Number of days required for initiation of flowering for control and treated plants was averaged separately on two years data and given in Fig 4.13 A. Flowering started on 47 days after sowing on control plants, while flowering was hastened on treated plants. First flower emerged on 42, 39 and 37 days after sowing on plants treated with 500, 1000 and 1500 ppm chlormequat, respectively. As a result, increasing concentration of chlormequat significantly ($p < 0.05$) reduced number of days required for flowering. A negative relationship was obtained between number of days for first flower initiation and increasing concentration of chlormequat according to the following expression:

$Y = 49.83 - 3.33 x$ ($r^2 = 0.953$, $p < 0.05$)

where, Y is number of days for first flower initiation and x is concentration of chlormequat (ppm).

Foliar spray treatment

Average number of days required for flowering in control and treated plants was calculated on two years data and given in Fig 4.13 B. First flower emerged on control plants on 46 day after sowing. Flowering was hastened on plants treated with chlormequat. Flowering was recorded on 41, 38 and 36 days after sowing on plants treated with 500, 1000 and 1500 ppm chlormequat, respectively. As a result, increasing concentration of chlormequat significantly ($p < 0.05$) reduced the number of days required for flowering. A negative relationship was obtained between number of days for first flower initiation and increasing concentration of chlormequat according to the following expression:

$$Y = 48.83 - 3.333x \quad (r^2 = 0.953, p < 0.05)$$

where, Y is number of days for first flower initiation and x is concentration of chlormequat (ppm).

Seed soaking + foliar spray treatment

Numbers of days required for flowering for control and treated plants was averaged separately on two years data and given in Fig 4.13 C. First flower emerged on control plants on 48 days after sowing. However, flowering was advanced on treated plants. First flower was recorded on 39, 36 and 35 days after sowing on plants treated with 500, 1000 and 1500 ppm chlormequat, respectively. The data suggested that increasing concentration of chlormequat significantly ($p < 0.05$) reduced number of days required for flowering. A negative relationship was obtained between number of days for first flower initiation and increasing concentration of chlormequat according to the following expression:

$$Y = 49.41 - 3.898x \quad (r^2 = 0.828, p < 0.05)$$

Where, Y is first flower initiation and x is concentration of chlormequat (ppm).

Effect of Application Methods

There was no significant difference in methods of application for decreasing days of first flower initiation. However, result suggested that combination of seed soaking + foliar spray treatment reduced number of days required for flowering than other two treatments.

Interaction

All the interactions involving concentrations of chlormequat and methods of application were found non-significant.

Effect of Chlormequat on Longevity of Reproductive Phase

Seed soaking treatment

Numbers of days in reproductive phase for control and treated plants were separately averaged on the results of two years experiment and given in Fig 4.14 A Reproductive period lasted for 51 days for control plants, while it prolonged for treated plants. Reproductive period lasted for 55, 58 and 59 days for plants treated with 500, 1000 and 1500 ppm chlormequat, respectively. As a result, reproductive period of plants was significantly ($p < 0.05$) prolonged by increasing concentration of chlormequat. A positive relationship was obtained between number of days in reproductive phase and increasing concentration of chlormequat according to the following expression:

$$Y = 49.833 + 2.349\ x \quad (r^2 = 0.932, p < 0.05)$$

where, Y is number of days in reproductive phase (days) and x is concentration of chlormequat (ppm).

Foliar spray treatment

Average numbers of days in reproductive phase for control and treated plants were separately calculated on the data recorded for two years experiment and given in Fig. 4.14 B There was a reproductive period of 51 days for control plants, whereas it was extended for treated plants. Reproductive period continued for 58, 59 and 60 days for plants treated with 500, 1000 and 1500ppm chlormequat, respectively. The data suggested that increasing concentration of chlormequat significantly ($p < 0.05$) extended reproductive period of plants. A positive relationship was obtained between number of day in reproductive phase and increasing concentration of chlormequat according to the following expression:

$Y = 49.419 + 3.049x$ ($r^2 = 0.811$, $p < 0.05$)

where, Y is number of days in reproductive phase (days) and x is concentration of chlormequat (ppm).

Seed soaking + foliar spray treatment

Average numbers of days in reproductive phase for control and treated plants were separately calculated on the data recorded for two years experiment and given in Fig 4.14.C Reproductive period for control plants continued for 50 days. Treated plants exhibited a prolonged period in reproduction. Reproductive period continued for 58, 60 and 61 days for plants treated with 500, 1000 and 1500 ppm chlormequat, respectively. Results suggested that increasing concentration of chlormequat significantly ($p < 0.05$) extended the reproductive period of plants. A positive relationship was obtained between number of days in reproductive phase and increasing concentration of chlormequat according to the following expression:

$Y = 48.583 + 3.615x$ ($r^2 = 0.848$, $p < 0.05$)

Where, Y is number of days in reproductive phase (days) and x is concentration of chlormequat (ppm).

Effect of Application Methods

There was no significant difference in methods of application for increasing days of reproductive phase. However, result suggested that combination of seed soaking + foliar spray treatment increased longevity of reproductive phase than other two methods.

Interaction

All the interactions involving concentrations of chlormequat and methods of application were found non-significant.

Fruit Characters

Effect of Chlormequat on Fruit Length

Seed soaking treatment

Values of fruit length for control and treated plants were separately averaged on two years data and plotted against concentration of chlormequat (Fig. 4.15 A). Fruit length increased as the concentration of chlormequat increased. As a result, fruit length was maximum on the plants treated with 1500 ppm chlormequat and minimum on the control plants. For fruit length, the optimum concentration of chlormequat was 1500 ppm. The data suggested that chlormequat significantly ($p < 0.05$) promoted the fruit length. A positive relationship was obtained between fruit length and increasing concentration of chlormequat according to the following expression:

$Y = 14.25 + 1.05\,x$ ($r^2 = 0.963$, $p < 0.05$)

where, Y is fruit length (cm) and x is concentration of chlormequat (ppm).

Foliar spray treatment

Values of fruit length for control and treated plants were separately averaged on two years data and plotted against the concentration of chlormequat (Fig. 4.15 B). Fruit length consistently increased with the increase in concentration of chlormequat. There was maximum fruit length on the plants treated with 1500 ppm chlormequat, while minimum fruit length was recorded on the control plants. Therefore, optimum concentration of chlormequat for increase of fruit length was 1500 ppm. The data suggested that spraying of chlormequat significantly ($p < 0.05$) promoted fruit length. A positive relationship was obtained between fruit length and increasing concentration of chlormequat according to the following expression:

$$Y = 14.25 + 1.34\,x \quad (r^2 = 0.937,\ p < 0.05)$$

where, Y is fruit length (cm) and x is concentration of chlormequat (ppm).

Seed soaking + foliar spray treatment

Values of fruit length for control and treated plants were separately averaged on two years data and plotted against concentration of chlormequat (Fig. 4.15 C). Fruit length regularly increased with increase in concentration of chlormequat. As a result, maximum fruit length was recorded on plants treated with 1500 ppm chlormequat, while minimum on control plants. The data suggested that chlormequat significantly ($p < 0.05$) promoted fruit length and optimum concentration of chlormequat was 1500 ppm. A positive relationship was obtained between fruit length and increasing concentration of chlormequat according to the following expression:

$$Y = 14.3 + 1.39\,x \quad (r^2 = 0.945,\ p < 0.05)$$

where, Y is fruit length (cm) and x is concentration of chlormequat (ppm).

Effect of Application Methods

There was a significant ($p < 0.05$) difference among the Methods of application for increasing fruit length. Results further suggested that combination of seed soaking + foliar spray treatment increasing fruit length more than other two treatments.

Interaction

All the interactions involving concentrations of chlormequat and methods of application were found non-significant.

Effect of Chlormequat on Fruit Girth

Seed soaking treatment

Values of fruit girth for the control and treated plants were averaged separately on the data of two years experiment and plotted against the concentration of chlormequat (Fig 4.16 A). Fruit girth (thickness) increased with increase in the concentration of chlormequat. Consequently, fruit girth was maximum on plants treated with 1500 ppm chlormequat, while it was minimum on control plants. The optimum concentration of chlormequat was obtained to be 1500 ppm. The data suggested that chlormequat significantly ($p < 0.05$) promotes the thickness of fruit. A positive relationship was obtained between fruit girth and increasing concentration of chlormequat according to the following expression:

$Y = 5.015 + 0.395\ x\ (r^2 = 0.896,\ p < 0.05)$

where, Y is fruit girth (cm) and x is concentration of chlormequat (ppm).

Foliar spray treatment

Values of fruit girth for the control and treated plants were averaged separately on the data of two years experiment and plotted against the concentration of chlormequat (Fig 4.16 B). Fruit girth consistently increased with increase in the concentration of chlormequat. Results suggest that optimum concentration of chlormequat for increase in fruit girth was 1500 ppm. Also, it is apparent that chlormequat significantly ($p < 0.05$) promoted the fruit thickness. A positive relationship was obtained between fruit girth and increasing concentration of chlormequat according to the following expression:

$$Y = 4.985 + 0.483\,x \quad (r^2 = 0.997,\ p < 0.05)$$

where, Y is fruit girth (cm) and x is concentration of chlormequat (ppm).

Seed soaking + foliar spray treatment

Values of fruit girth for the control and treated plants were averaged separately on the data of two years experiment and plotted against the concentration of chlormequat (Fig 4.16 C). There was a consistent increase in fruit length with increase in concentration of chlormequat. Fruit girth was maximum on plants treated with 1500 ppm chlormequat, while minimum was on the control plants. The optimum concentration of chlormequat was 1500 ppm. It is apparent from the results that chlormequat significantly ($p < 0.05$) promoted the fruit thickness. A positive relationship was obtained between fruit girth and increasing concentration of chlormequat according to the following expression:

$$Y = 4.945 + 0.573\,x \quad (r^2 = 0.965,\ p < 0.05)$$

where, Y is fruit girth (cm) and x is concentration of chlormequat (ppm).

Effect of Application Methods

There was a significant ($p < 0.05$) difference among the Methods of application for increasing fruit girth. Results further suggested that combination of seed soaking + foliar spray treatment increasing fruit girth more than other two treatments.

Interaction

All the interactions involving concentrations of chlormequat and methods of application were found non-significant.

Effect of Chlormequat on Fruit Weight

Seed soaking treatment

Average values of fruit weight for control and treated plants were separately calculated on two years data and plotted against the concentration of chlormequat (Fig. 4.17.A). Fruit weight increased as the concentration of chlormequat increased. The maximum fruit weight was obtained on plants treated with 1500 ppm chlormequat, while minimum was on control plants. As a result, optimum concentration of chlormequat was 1500 ppm. Results suggested that chlormequat significantly ($p < 0.05$) promoted fruit weight. A positive relationship was obtained between average fruit weight and increasing concentration of chlormequat according to the following expression:

$$Y = 13.45 + 1.17\,x \quad (r^2 = 0.971,\ p < 0.05)$$

where, Y is average fruit weight (g) and x is concentration of chlormequat (ppm).

Foliar spray treatment

Average values of fruit weight for control and treated plants were separately calculated on two years data and plotted against the concentration of chlormequat (Fig. 4.17.B). There was a consistent increase in fruit weight as the concentration of chlormequat increased. The maximum fruit weight was obtained on the plants treated with 1500 ppm chlormequat and minimum on control plants. The optimum concentration of chlormequat was 1500 ppm. The data suggested that chlormequat promoted fruit weight. As a result, optimum concentration of chlormequat was 1500 ppm. Results suggested that chlormequat significantly ($p < 0.05$) promoted fruit weight. A positive relationship was obtained between average fruit weight and increasing concentration of chlormequat according to the following expression:

$Y = 13.355 + 1.269\ x\ (r^2 = 0.961,\ p < 0.05)$

where, Y is average fruit weight (g) and x is concentration of chlormequat (ppm).

Seed soaking + foliar spray treatment

Average values of fruit weight for control and treated plants were separately calculated on two years data and plotted against the concentration of chlormequat (Fig. 4.17.C). There was a consistent increase in fruit weight as the concentration of chlormequat increased. The maximum fruit weight was obtained on the plants treated with 1500 ppm chlormequat and minimum fruit weight was recorded on the control plants. The optimum concentration of chlormequat was 1500 ppm. The data suggested that chlormequat significantly ($p < 0.05$) promoted the fruit weight. As a result, optimum concentration of chlormequat was 1500 ppm. A positive relationship was obtained between average fruit weight and increasing concentration of chlormequat according to the following expression:

$Y = 13.43 + 1.391\ x\ (r^2 = 0.873,\ p < 0.05)$

where, Y is average fruit weight (g) and x is concentration of chlormequat (ppm).

Effect of Application Methods

There was no significant difference among the Methods of application for increasing average fruit weight. Results further suggested that combination of seed soaking + foliar spray treatment increasing average fruit weight more than other two treatments.

Interaction

All the interactions involving concentrations of chlormequat and methods of application were found non-significant.

Effect of Chlormequat on Number of fruits

Seed soaking treatment

Number of okra fruits per plant for control and treated plants was separately averaged on the results of two years experiment and given in Fig. 4.18 A. Average number of fruits on control plants was minimum, while it increased on treated plants. Number of fruits was maximum for plants treated with 1500 ppm chlormequat. As a result, number of fruits significantly ($p < 0.05$) increased by increasing concentration of chlormequat. A positive relationship was obtained between number of fruits per plant and increasing concentration of chlormequat according to the following expression:

$$Y = 15.63 + 0.85\,x \quad (r^2 = 0.89,\ p < 0.05)$$

where, Y is number of fruits $plant^{-1}$ and x is concentration of chlormequat (ppm)

Foliar spray treatment

Number of okra fruits per plant for control and treated plants was separately averaged on the results of two years experiment and given in Fig. 4.18 B. Average number of fruits on control plants was minimum, while it increased on treated plants. Number of fruits was maximum for plant treated with 1500 ppm chlormequat. As a result, number of fruits significantly ($p < 0.05$) increased by increasing concentration of chlormequat. A positive relationship was obtained between number of fruits per plant and increasing concentration of chlormequat according to the following expression:

$$Y = 15.5 + 1.26\, x \quad (r^2 = 0.92,\ p < 0.05)$$

where, Y is number of fruits $plant^{-1}$ and x is concentration of chlormequat (ppm)

Seed soaking + foliar spray

Number of okra fruits per plant for control and treated plants was separately averaged on the results of two years experiment and given in Fig. 4.18 C. Average number of fruits on control plants was minimum, while it increased on treated plants. Number of fruits was found to be maximum for plants treated with 1500 ppm chlormequat. As a result, number of fruits significantly ($p < 0.05$) increased by increasing concentration of chlormequat. A positive relationship was obtained between number of fruits per plant and increasing concentration of chlormequat according to the following expression :

$$y = 15.45 + 1.32\, x \quad (r^2 = 0.895,\ p < 0.05)$$

where, Y is number of fruits $plant^{-1}$ and x is concentration of chlormequat (ppm)

Effect of Application Methods

There was a significant ($p < 0.05$) difference among the Methods of application for increasing number of fruits per plant. Results further suggested that combination of seed soaking + foliar spray treatment increasing number of fruits plant more than other two treatments.

Interaction

All the interactions involving concentrations of chlormequat and methods of application were found non-significant.

Effect of Chlormequat on Number of Seeds Fruit $^{-1}$

Seed soaking treatment

Number of seeds per okra fruit for control and treated plants was separately averaged on the results of two years experiment and given in Fig. 4.19 A. Average number of seeds per fruit for control plants was minimum, while number of seeds increased for the treated plants. Number of seeds was maximum for plants treated with 1500 ppm chlormequat. As a result, seeds of okra fruits significantly ($p < 0.05$) increased by increasing concentration of chlormequat. A positive relationship was obtained between number of seeds per fruit and increasing concentration of chlormequat according to the following expression :

$Y = 53.55 + 3.36\ x$ ($r^2 = 0.819$, $p < 0.05$)

where, Y is number of seeds fruit $^{-1}$ and x is concentration of chlormequat (ppm)

Foliar spray treatment

Number of seeds per okra fruit for control and treated plants was separately averaged on the results of two years experiment and are given in Fig. 4.19 B. Average value of number of seeds per fruit in control plants was recorded minimum while number of seeds increased for the treated plants. Numbers of seeds was maximum for plants treated with 1500 ppm chlormequat. As a result, seeds of okra fruits significantly ($p < 0.05$) increased by increasing concentration of chlormequat. A positive relationship was obtained between number of seeds fruit^{-1} and increasing concentration of chlormequat according to the following expression :

$$Y = 55.1 + 2.98\,x \quad (r^2 = 0.909,\ p < 0.05)$$

where, Y is number of seeds fruit $^{-1}$ and x is concentration of chlormequat (ppm)

Seed soaking + foliar spray treatment

Number of seeds per okra fruit for control and treated plants was separately averaged on the results of two years experiment and given in Fig. 4.19 C Average number of seeds per fruit in control plants was recorded minimum while number of seeds increased in the fruits of the treated plants. Number of seeds was maximum for plants treated with1500 ppm chlormequat. As a result, seeds of okra fruit significantly ($p < 0.05$) increased by increasing concentration of chlormequat. A positive relationship was obtained between number of seeds per fruit^{-1} and increasing concentration of chlormequat according to the following expression:

$$Y = 49.85 + 4.69\,x \quad (r^2 = 0.929,\ p < 0.05)$$

where, Y is number of seeds fruit $^{-1}$ and x is concentration of chlormequat (ppm)

Effect of Application Methods

There was no significant difference among the Methods of application for increasing number of seed per fruit. Results further suggested that combination of seed soaking + foliar spray treatment increasing number of seed per fruit more than other two treatments.

Interaction

All the interactions involving concentrations of chlormequat and methods of application were found non-significant.

Effect of chlormequat on weight of seeds

Seed soaking treatment

Values of seed test weight (100 seed weight) for control and treated plants were separately averaged on the results of two years experiment and given in Fig. 4.20 A. Average value of hundred seeds weight on the control plants was minimum, while it increased for the treated plants. Seed weight was recorded maximum for the plants treated with 1500 ppm chlormequat. Seed weight significantly ($p < 0.05$) increased as the concentration of chlormequat increased. A positive relationship was obtained between seed weight and increasing concentration of chlormequat according to the following expression :

$Y = 5.675 + 0.119\,x$ ($r^2 = 0.956$, $p < 0.05$)

where, Y is seed test weight (g) and x is concentration of chlormequat (ppm)

Foliar spray treatment

Values of seed test weight (100 seed weight) for control and treated plants were separately averaged on the results of two years experiment and given in Fig. 4.20 B. Average value of hundred seed weight on the control plants was minimum, while it increased for the treated plants. Seed weight was recorded maximum for the plants treated with 1500 ppm chlormequat. Seed weight significantly ($p < 0.05$) increased as the concentration of chlormequat increased. A positive relationship was obtained between seed weight and increasing concentration of chlormequat according to the following expression :

$Y = 5.455 + 0.26x$ ($r^2 = 0.96$, $p < 0.05$)

Where, Y is seed test weight (g) and x is concentration of chlormequat (ppm)

Seed soaking + foliar spray

Values of seed test weight (100 seed weight) for control and treated plants were separately averaged on the results of two years experiment and are given in Fig. 4.20 C. Average value of hundred seed weight on the control plants was minimum, while it increased for the treated plants. Seed weight was recorded maximum for the plants treated with 1500 ppm chlormequat, respectively. Seed weight significantly ($p < 0.05$) increased as the concentration of chlormequat increased. A positive relationship was obtained between seed weight and increasing concentration of chlormequat according to the following expression :

$Y = 5.35 + 0.319x$ ($r^2 = 0.912$, $p < 0.05$)

where, Y is seed test weight (g) and x is concentration of chlormequat (ppm)

Effect of Application Methods

There was no significant difference among the Methods of application for increasing seed weight. Results further suggested that combination of seed soaking + foliar spray treatment increasing seed weight more than other two treatments.

Interaction

All the interactions involving concentrations of chlormequat and methods of application were found non-significant.

Yield

Effect of Chlormequat on Weight of Fruits plant $^{-1}$

Seed soaking treatment

Weight of okra fruits plant^{-1} for the control and treated plants was separately averaged for two years data and given in Fig. 4.21 A. Average fruit yield per plant was minimum for the control plants, while it increased for the treated plants. Maximum fruit yield was recorded for the plants treated with 1500 ppm chlormequat. As a result, fruit yield per plants significantly ($p < 0.05$) increased with the increase in the concentration of chlormequat. A positive relationship was obtained between fruit weight per plant and increasing concentration of chlormequat according to the following expression :

$$Y = 205.3 + 39.934\,x \quad (r^2 = 0.937,\ p < 0.05)$$

where, Y is fruit yield (g $plant^{-1}$) and x is concentration of chlormequat (ppm)

Foliar spray treatment

Weight of okra fruits $plant^{-1}$ for the control and treated plants was separately averaged for two years data and given in Fig. 4.21 B. Average fruit yield per plant was minimum for the control plants, while it increased for the treated plants. Maximum fruit yield was recorded for the plants treated with 1500 ppm chlormequat. As a result, fruit yield per plant significantly ($p < 0.05$) increased with the increase in the concentration of chlormequat. A positive relationship was obtained between fruit weight per plant and increasing concentration of chlormequat according to the following expression :

$$Y = 200.83 + 43.808\,x \quad (r^2 = 0.955,\ p < 0.05)$$

where, Y is fruit yield (g $plant^{-1}$) and x is concentration of chlormequat (ppm)

Seed soaking + foliar spray treatment

Weight of okra fruits $plant^{-1}$ for the control and treated plants was separately averaged on two years data and given in Fig. 4.21 C. Average fruit yield per plant was minimum for the control plants, while it increased for the treated plants. Maximum fruit yield was recorded for the plants treated with 1500 ppm chlormequat. As a result, fruit yield per plant significantly ($p < 0.05$) increased with the increase in the concentration of chlormequat. A positive relationship was obtained between fruit weight per plant and increasing concentration of chlormequat according to the following expression :

$Y = 201.5 + 47.239\,x \quad (r^2 = 0.896, p < 0.05)$

where, Y is fruit yield (g $plant^{-1}$) and x is concentration of chlormequat (ppm)

Effect of Application Methods

There was significant ($p < 0.05$) difference among the Methods of application for increasing fruits yield per plant. Results further suggested that combination of seed soaking + foliar spray treatment increasing fruit yield per plant more than other two treatments.

Interaction

All the interactions involving concentrations of chlormequat and methods of application were found non-significant.

Effect of Chlormequat on Yield of Okra Fruits ha^{-1}

Seed soaking treatment

Green fruit yield ha^{-1} for the control and treated plants was separately averaged on the results of two years experiment and given in Fig. 4.22 A. Average fruit yield per hectare was lowest for the control plants, while it increased for the plants treated with chlormequat. Maximum yield was recorded for the plants treated with 1500 ppm chlormequat. As a result, yield of okra fruits significantly ($p < 0.05$) increased with the increase in the concentration of chlormequat. A positive relationship was obtained between green fruit yield and increasing concentration of chlormequat according to the following expression :

$Y = 111.87 + 29.58\,x \quad (r^2 = 0.937, p < 0.05)$

where, Y is green fruit yield (q ha^{-1}) and x is concentration of chlormequat (ppm)

Foliar spray treatment

Green fruit yield ha^{-1} for the control and treated plants was separately averaged on the results of two years experiment and given in Fig. 4.22 B. Average fruit yield per hectare was lowest for the control plants, while it increased for the plants treated with chlormequat. Maximum yield was recorded for the plants treated with 1500 ppm chlormequat. As a result, yield of okra fruits significantly ($p < 0.05$) increased with the increase in the concentration of chlormequat. A positive relationship was obtained between green fruit yield and increasing concentration of chlormequat according to the following expression :

$$Y = 108.77 + 32.449 x \ (r^2 = 0.955, p < 0.05)$$

where, Y is green fruit yield (q ha^{-1}) and x is concentration of chlormequat (ppm)

Seed soaking + foliar spray treatment

Green fruit yield ha^{-1} for the control and treated plants was separately averaged on the results of two years experiment and given in Fig. 4.22 C. Average fruit yield per hectare was lowest for the control plants, while it increased for the plants treated with chlormequat. Maximum fruit yield was recorded for the plants treated with 1500 ppm chlormequat. As a result, yield of okra fruits significantly ($p < 0.05$) increased with the increase in the concentration of chlormequat. A positive relationship was obtained between green fruit yield and increasing concentration of chlormequat according to the following expression :

$$Y = 109.26 + 34.994 x \ (r^2 = 0.897, p < 0.05)$$

where, Y is green fruit yield (q ha^{-1}) and x is concentration of chlormequat (ppm)

Effect of Application Methods

There was significant ($p < 0.05$) difference among the Methods of application for increasing fruits yield per hectare. Results further suggested that combination of seed soaking + foliar spray treatment increasing fruit yield per hectare more than other two treatments.

Interaction

All the interactions involving concentrations of chlormequat and methods of application were found non-significant.

Macro-Nutrient Content

Effect of Chlormequat on Nitrogen Content in Okra Fruit

Seed soaking treatment

Nitrogen content in okra fruit for the control and treated plants was separately averaged on two years data and given in Fig. 4.23 A. Nitrogen content in fruits of control plants was consistently lower than that in fruits of treated plants. The concentration of nitrogen was maximum in fruits of the plants treated with 1500 ppm chlormequat. As a result, nitrogen content in the fruits significantly ($p < 0.05$) increased with the increasing concentration of chlormequat. A positive relationship was obtained between nitrogen content in fruits and increasing concentration of chlormequat according to the following expression :

$Y = 3.35 + 0.44\,x$ ($r^2 = 0.77$, $p < 0.05$)

where, Y is nitrogen content (mg g^{-1}) in fruits and x is concentration of chlormequat (ppm)

Foliar spray treatment

The concentration of nitrogen in fruits for the control and treated plants was separately averaged on the data of two years experiment and given in Fig. 4.23 B. Nitrogen content in fruits of control plants was lower than that in fruits of the treated plants. There was maximum nitrogen content in fruits of plants treated with 1500 ppm chlormequat. As a result, nitrogen content in the fruits significantly ($p < 0.05$) increased with the increasing concentration of chlormequat. A positive relationship was obtained between nitrogen content in fruits and increasing concentration of chlormequat according to the following expression :

$$Y = 3.3 + 0.46\,x \quad (r^2 = 0.71,\ p < 0.05)$$

where, Y is nitrogen content (mg g^{-1}) in fruits and x is concentration of chlormequat (ppm)

Seed soaking + foliar spray treatment

Nitrogen content in okra fruits for the control and treated plants was separately averaged on the result of two years experiment and given in Fig. 4.23 C. The concentration of nitrogen in fruits of control plants was lower than that in fruits of treated plants. There was maximum nitrogen content in fruits of plants treated with 1500 ppm chlormequat. Results suggested that nitrogen content significantly ($p < 0.05$) increased in the fruits with the increasing concentration of chlormequat. A positive relationship was obtained between nitrogen content in fruits and increasing concentration of chlormequat according to the following expression :

$$Y = 3.22 + 0.51\,x \quad (r^2 = 0.674,\ p < 0.05)$$

where, Y is nitrogen content (mg g^{-1}) in fruits and x is concentration of chlormequat (ppm).

Effect of Application Methods

There was no significant difference among the Methods of application for increasing nitrogen content in fruit. Results further suggested that combination of seed soaking + foliar spray treatment increasing nitrogen content in fruit more than other two treatments.

Interaction

All the interactions involving concentrations of chlormequat and methods of applications were found non-significant.

Effect of Chlormequat on Phosphorus Content in Okra Fruit

Seed soaking treatment

Phosphorus content in okra fruits for the control and treated plants was separately averaged on the results of two years experiment and given in Fig. 4.24 A. Phosphorus content in fruits of control plants was lower than that in fruits of treated plants. Moreover phosphorus content in fruits significantly ($p < 0.05$) increased with increase in chlormequat concentration. Maximum phosphorus content was recorded in fruits of plants treated with 1500 ppm chlormequat. A positive relationship was obtained between concentration of phosphorus in fruits and increasing concentration of chlormequat according to the following expression :

$$Y = 0.535 + 0.09\,x \quad (r^2 = 0.978,\ p < 0.05)$$

where, Y is phosphorus content (mg g^{-1}) in fruits and x is concentration of chlormequat (ppm).

Foliar spray treatment

Phosphorus content in fruits for the control and treated plants was separately averaged on the results of two years experiment and given in Fig. 4.24 B. Concentration of phosphorus in control fruits was minimum, while it was maximum in fruits of plants treated with 1500 ppm chlormequat. As a result, phosphorus in fruits significantly ($p < 0.05$) increased with increase in concentration of chlormequat. A positive relationship was obtained between phosphorus content in fruits and increasing concentration of chlormequat according to the following expression :

$Y = 0.555 + 0.089\,x$ ($r^2 = 0.924$, $p < 0.05$)

where, Y is phosphorus content (mg g^{-1}) in fruits and x is concentration of chlormequat (ppm).

Seed soaking + foliar spray treatment

Phosphorus content in fruits for the control and treated plants was separately averaged on the results of two years experiment and given in Fig. 4.24 C. Phosphorus content was lower in fruits of control plants than that in fruits of plants treated with chlormequat. Results suggested that phosphorus content in fruit significantly ($p < 0.05$) increased with increasing concentration of chlormequat. A positive relationship was obtained between phosphorus content in fruits and increasing concentration of chlormequat according to the following expression :

$Y = 0.525 + 0.097\,x$ ($r^2 = 0.959$, $p < 0.05$)

where, Y is phosphorus content (mg g^{-1}) in fruits and x is concentration of chlormequat (ppm).

Effect of Application Methods

There was no significant difference among the Methods of application for increasing phosphorus content in fruit. Results further suggested that combination of seed soaking + foliar spray treatment increasing phosphorus content in fruit more than other two treatments.

Interaction

All the interactions involving concentrations of chlormequat and methods of application were found non-significant.

Effect of Chlormequat on Potassium Content in Okra Fruits

Seed soaking treatment

Potassium content in okra fruits for the control and treated plants was separately averaged on the results of two years experiment and given in Fig. 4.25 A. Potassium content in fruits of control plants was lower than that in fruits of treated plants. Moreover, potassium content in fruits significantly ($p < 0.05$) increased with increasing concentration of chlormequat. Maximum potassium content was recorded in fruits of plants treated with 1500 ppm chlormequat. There was a positive relationship between potassium content in fruits and increasing concentration of chlormequat according to the following expression :

$$Y = 0.95 + 0.2\,x \quad (r^2 = 0.952,\ p < 0.05)$$

where, Y is potassium content (mg g^{-1}) in fruits and x is concentration of chlormequat (ppm).

Foliar spray treatment

Potassium content in fruits for the control and treated plants was separately averaged on the results of two years experiment and given in Fig. 4.25 B. Potassium content in fruits of control plants was lower than that in fruits of treated plants. As a result, potassium in fruits significantly ($p < 0.05$) increased with increasing concentration of chlormequat. There was a positive relationship between potassium content in fruits and increasing concentration of chlormequat according to the following expression :

$Y = 1 + 0.22x$ ($r^2 = 0.913$, $p < 0.05$)

where, Y is potassium content (mg g^{-1}) in fruits and x is concentration of chlormequat (ppm).

Seed soaking + foliar spray treatment

Potassium content in fruits for the control and treated plants was separately averaged on the results of two years experiment and given in Fig. 4.25 C. Potassium content was lower in fruits of control plants than that in fruits of treated plants. Results suggested that potassium content in fruit significantly ($p < 0.05$) increased with increasing concentration of chlormequat. A positive relationship was obtained between potassium content in fruits and increasing concentration of chlormequat according to the following expression :

$Y = 1.005 + 0.226x$ ($r^2 = 0.881$, $p < 0.05$)

where, Y is potassium content (mg g^{-1}) in fruits and x is concentration of chlormequat (ppm).

Effect of Application Methods

There was no significant difference among the Methods of application for increasing potassium content in fruit. Results further suggested that combination of seed soaking + foliar spray treatment increasing potassium content in fruit more than other two treatments.

Interaction

All the interactions involving concentrations of chlormequat and methods of application were found non-significant.

Effect of Chlormequat on Residual Nitrogen Content in Soil

Seed soaking treatment

Residual nitrogen content in soil with control and treated okra plants were separately averaged on the data of experiment and shown in Fig. 4.26 A. Nitrogen content in soil was maximum under control conditions, While it was minimum in the soil when okra plants were treated with 1500 ppm chlormequat. The data suggested that nitrogen content significantly ($p < 0.05$) decreased in the soil with increasing concentration of chlormequat. A negative relationship was obtained between nitrogen content in soil and increasing concentration of chlormequat according to the following expression :

$$Y = 92.5 - 4.2\,x \quad (r^2 = 0.9,\ p < 0.05)$$

where, Y is nitrogen content in soil (kg ha^{-1}) and x is concentration of chlormequat (ppm).

Foliar spray treatment

Residual nitrogen content in soil having control and treated plants was separately averaged on the data of experiment and shown in Fig. 4.26 B. Nitrogen content in soil was lower under treated conditions than that under control conditions. Result suggested that the nitrogen in soil significantly ($p < 0.05$) decreased with the increasing concentration of chlormequat. There was a negative relationship between nitrogen content in soil and increasing concentration of chlormequat according to the following expression :

$$Y = 95.5 - 5.3x \; (r^2 = 0.92, p < 0.05)$$

where, Y is nitrogen content in soil (kg ha^{-1}) and x is concentration of chlormequat (ppm).

Seed soaking + foliar spray treatment

Residual nitrogen content in soil under control and treated conditions was separately averaged on the data of experiment and given in Fig. 4.26 C. Nitrogen status in soil was higher under control conditions than that in soil under the treatment conditions. Result suggested that the concentration of nitrogen in soil significantly ($p < 0.05$) decreased with increasing concentration of chlormequat. There was a negative relationship between nitrogen status in soil and increasing concentration of chlormequat according to the following expression :

$$Y = 95.5 - 6x \; (r^2 = 0.815, p < 0.05)$$

where, Y is nitrogen content in soil (kg ha^{-1}) and x is concentration of chlormequat (ppm).

Effect of Application Methods

There was no significant difference among the Methods of application for decreasing residual nitrogen content in soil. Results further suggested that combination of seed soaking + foliar spray treatment decreasing nitrogen content in soil more than other two treatments.

Interaction

All the interactions involving concentrations of chlormequat and methods of application were found non-significant.

Effect of Chlormequat on Residual Phosphorus Content in Soil

Seed soaking treatment

Residual phosphorus content in soil under control and treated conditions was separately averaged on the data of experiment and given in Fig. 4.27 A. The concentration of phosphorus in soil was higher under control conditions than that in soil under treated conditions. Result suggested that the concentration of phosphorus significantly ($p < 0.05$) decreased with increasing concentration of chlormequat. There was a negative relationship between phosphorus content in soil and increasing concentration of chlormequat according to the following expression :

$Y = 44.5 - 2.6x$ ($r^2 = 0.89$, $p < 0.05$)

where, Y is phosphorus content in soil (kg ha^{-1}) and x is concentration of chlormequat (ppm).

Foliar spray treatment

Residual phosphorus content in soil under control and treated conditions was separately averaged on the data of experiment and given in Fig. 4.27 B. The concentration of phosphorus in soil was higher in soil under control conditions than that in soil under treated conditions. Results, further suggested that the concentration of phosphorus in soil significantly ($p < 0.05$) decreased with increasing concentration of chlormequat. There was a negative relationship between phosphorus content in soil and increasing concentration of chlormequat according to the following expression :

$Y = 43.5 - 2.6x$ ($r^2 = 0.89$, $p < 0.05$)

where, Y is phosphorus content in soil (kg ha^{-1}) and x is concentration of chlormequat (ppm).

Seed soaking + foliar spray treatment

The concentration of residual phosphorus content in soil under control and treated conditions was separately averaged on the data of experiment and given in Fig. 4.27 C. The concentration of phosphorus in soil was greater in soil under control conditions than that in soil under treated conditions. Results, further suggested that the concentration of phosphorus in soil significantly ($p < 0.05$) decreased with increasing concentration of chlormequat. There was a negative relationship between phosphorus content in soil and increasing concentration of chlormequat according to the following expression :

$Y = 46 - 3.9x$ ($r^2 = 0.859$, $p < 0.05$)

where, Y is phosphorus content in soil (kg ha^{-1}) and x is concentration of chlormequat (ppm).

Effect of Application Methods

There was no significant difference among the Methods of application for decreasing residual phosphorus content in soil. Results further suggested that combination of seed soaking + foliar spray treatment decreasing phosphorus content in soil more than other two treatments.

Interaction

All the interactions involving concentrations of chlormequat and methods of application were found non-significant.

Effect of Chlormequat on Residual Potassium Content in Soil

Seed soaking treatment

The concentration of potassium in soil under control and treated conditions was separately averaged on the data of experiment and shown Fig. 4.28 A. The concentration of potassium in soil was greater in soil under control conditions than that soil under treated conditions. Results, further suggested that the concentration of potassium in soil significantly ($p < 0.05$) decreased with increasing concentration of chlormequat. A negative relationship was obtained between potassium content in soil and increasing concentration of chlormequat according to the following expression :

$Y = 272 - 7.2 x$ ($r^2 = 0.88$, $p < 0.05$)

where, Y is potassium content in soil (kg ha^{-1}) and x is concentration of chlormequat (ppm).

Foliar spray treatment

Potassium content in soil under the control and treated conditions was separately averaged on the data of experiment and given in Fig. 4.28 B. The concentration of residual potassium was greater in the soil under control conditions than that in the soil under treated conditions. Results, further suggested that potassium content significantly ($p < 0.05$) decreased with increasing concentration of chlormequat. There was a negative relationship between potassium content in soil and increasing concentration of chlormequat according to the following expression :

$Y = 276 - 8.5 x$ ($r^2 = 0.92$, $p < 0.05$)

where, Y is potassium content in soil (kg ha^{-1}) and x is concentration of chlormequat (ppm).

Seed soaking + foliar spray treatment

Potassium content in soil under control and treated conditions was separately averaged on the data of experiment and shown in Fig. 4.28 C. The concentration of residual potassium was greater in the soil under control conditions than that in the soil under treated conditions. Moreover, potassium content in soil significantly ($p < 0.05$) decreased with increasing concentration of chlormequat. There was a negative relationship between potassium content in soil and increasing concentration of chlormequat according to the following expression :

$$Y = 276.5 - 9.5\,x \quad (r^2 = 0.912,\ p < 0.05)$$

where, Y is potassium content in soil (kg ha^{-1}) and x is concentration of chlormequat (ppm).

Effect of Application Methods

There was no significant difference among the Methods of application for decreasing residual potassium content in soil. Results further suggested that combination of seed soaking + foliar spray treatment decreasing potassium content in soil more than other two treatments.

Interaction

All the interactions involving concentrations of chlormequat and methods of application were found non-significant.

DISCUSSION

Plant growth retardants are supposed to play a significant role in agriculture and horticulture in order to increase production. Thousands of synthetic organic chemicals are known which can retard the plant height. However, effects of most of the chemicals on plants have not been evaluated. The potential usefulness of chemical in biology is not realized unless they are screened against the number of different biological systems. Besides, retarding stem elongation, plant growth regulators have many other biological effects. No endogenous growth retarding substances have yet been recognized in plants. Although quaternary ammonium compounds, such as choline, are commonly, present. These compounds are active in metabolic processes, particularly in lipid metabolism, and formation of cell membranes (Noggle and Fritz, 1992). In the present study, increasing concentration of chlormequat enhanced the seed germination. A similar result of increased seed germination for *Lycopersicum esculentsus* with increasing concentration of chlormequat (Irulappan and Muthukrishanan , 1973 ; Rana et al., 2002). The basic processes in seed germination are: water imbibitions, cell expansion, transport of soluble metabolites to the embryo and synthesis of cellular constituents in the embryo, accompanied by cell division. Growth and development of embryonic axis into a vigorous seedling depend on new cell formation, a process requiring energy (ATP) and substrates for anabolic metabolism. In addition, after the onset of water imbibitions the activity of some major hydrolytic enzymes can be detected. The enzymes catalyze the breakdown of inert storage macromolecules into small molecules or ions that can be transported to active metabolic centers within the seeds (Noggle and Fritz, 1992). Further, cytokinins, gibberellins and a number of inhibitors (mainly abscisic acid, ABA) play an important role in seed germination (Khan and Tao 1978). However, there is no much understanding of how chlormequat influences seed germination.

Increasing concentration of chlormequat caused linear decrease in internodal length and thereby reduced plant height. It is reported that the most common response of growth retardants is inhibition of stem elongation. Many of the retardant are suppressors of gibberellins biosynthetic pathway and are therefore useful compounds to investigate the roles of gibberellins in metabolism and plant growth and development (Malik, 1999). Davis et al. (1986) and Malik and Thind (1994) reported that growth retardant such as paclobutrazol reduces the height of several fruit trees by inhibiting cell elongation. Maharana and Pani (1982) found that cycocel at 5000 - 10000 ppm reduced the height of hybrid rose. Tetcyclasis inhibits cell division in suspension cultures of various plant species (Malik, 1999). However, application of gibberellins reverses the inhibitory effect of paclobutrazol. It is understood that GA affects growth through cell division or cell expansion or both. Cells which have lost capacity to synthesize GA or with added GA inhibitors do not divide. Evidently decreased internodal length and stem height can be explained by inhibitory effect of cycocel on cell division and cell elongation. Halevy et at. (1965) reported that the retardants interact with gibberellins or IAA- oxidase (or its co-factors and inhibitors) or lower the levels of diffusible auxin and thereby suppress vegetative growth. The reduction in height of plants can be related with reduced lodging of plants. Pain and Nayek (1981) sprayed sesame (S*esame indicum*) plants with 10 - 100 ppm chlormequat at 10 days intervals after sowing until flower initiation. Increased chlormequat concentration produced linear decrease in plant height and increased chlorophyll content. Ashok et al. (1984) sprayed finger millet with chlormequat 20 days after transplanting and found increase in straw yield, though plant height decreased. Shah et at. (1991) investigated the effect of CCC on the growth and yield of mung bean (*Vigna radiata*). At 1000 ppm it reduced stem length. In addition to reduction in shoot height, chlormequat also reduces root length. This result can be attributed to the inhibitory effects of chlormequat on cell division and cell elongation. In the present study, reduction in internodal length and plant height was dependent on concentration of chlormequat. As a result, the optimum concentration of chlormequat to reduce plant height was 1500 ppm.

Chlormequat increased number of branches, leaf number, leaf area and dry weight of stem, leaf and root components of plants Llango et at. (2003). Lowering of concentration of diffusible auxins might have reduced apical dominances and produced favourable conditions for growth of dormant branch initials Rathod and Patel (1996). Muradi et at. (2003) reported that chlormequat treatments on okra were effective in suppressing apical dominance, thus promoting the growth of axillary buds into new stems. Retarding of plant height and formation of lateral branches considerably increase flowers and fruit bearing sites. Singh and Patel (1991) reported that application of chlormequat to okra retarded plant height, induced formation of branches, produced more number of fruits per plant and more seeds per fruit and thereby resulted in higher yield. Khan and Wash (1982) observed influence of chlormequat on the growth and development of wheat. Chlormequat increased root length but root dry weight was increased only with 1000 ppm. Treatment with 1000 ppm chlormequat increased number of tillers, spikelets, grain and length of ears. In general, leaves of plants treated with retardants are deep green in colour due to enhanced synthesis of chlorophyll. Effect of retardants on photosynthesis is still unclear. It may decrease or increase photosynthesis, some contradictory results are available. Nevertheless, most retardants delay senescence and hence photosynthetic activity of a given leaf continues for a longer period. Further, leaves are also retained on the treated plants for a longer duration. In oilseed rapes paclobutrazol and chlormequat alter the canopy structure and influence light penetration and absorption (Malik, 1999). These effects of growth retardants may favour the vegetative growth of plants. In the present study, chlormequat increased the dry matter of leaves, stems and roots of okra plants though it significantly reduced plant height. Raut and Sobale (2003) reported similar effect of chlormequat on chickpea. Khan et al. (2003) found that cycocel at 400 ppm + 60 kg N / ha enhanced leaf photosynthetic rate, water use efficiency, leaf area and dry mass of leaves and stems. Moreover, effect of growth regulator was concentration dependent. Bhattacharya et al. (1984) in a trial on *Dahlia variabilis* reported that chlormequat at 2500 -5000 ppm significantly increased the number and weight of tuberous roots.

The increasing concentration of chlormequat hastened flowering of okra plants. The optimum concentration of chlormequat was 1000 ppm and / or 1500 ppm. Besides advanced flowering these concentrations of chlormequat prolonged the duration of reproductive phase. Advanced flowering and prolonged reproductive phase increased time period for formation of flowers and fruits. Consequently, fruit yield was greater for treated plants than that for control plants. These results are in conformity with the finding of Zayed et al. (1985) and Patel (1988). The highest floret opening - longevity or survival was obtained with cycocel at 1000 ppm (Maurya and Nagda, 2002). Maharana and Pani (1982) reported that cycocel at 5000 or 10000 ppm advanced flowering of hybrid rose. Rath et al. (1982) showed manipulation of flowering in mango by forcing cycocel (chlormequat) at 3000 ppm gave 90, 89 and 81 % flowering in the " of ", " on " and " off " years, respectively compared with 8.67 and 2 % in the controls. Bhattacharya and Rao (1982) observed early flowering in papaya with growth retardants. Parmar and Singh (1983) reported that in order to reduce plant size and increase flower number, seedings of marigold (*Tagetes erecta*) cv. Fantastic were treated with CCC (chlormequat), M.H. or TIBA at 10 days after transplanting and twice more at 10 days intervals. Moderate growth reduction and the highest number of flower per plant (11.4 -11.7) were obtained with CCC at 500 ppm or TIBA at 750 ppm. Bhattacharjee (1983) analysed growth and flowering of *Jasminium grandiflorum* in response to PGRs treatments. He found that all CCC treatment, B-9 at 1000 ppm and NAA at 10 ppm induced early flower initiation.

There was significant increase in fruit length, fruit thickness, fruit weight and number of fruits per plant. Mehrotra et al. (1970) reported that the chlormequat at 500 ppm, increased the yield and fruit number per plant and decreased fruit length. Shukla and Tewari (1973) sprayed twice the pot grown okra plants, either with chlorophonium at 100 or 1000 ppm or with chlormequat chloride at 1000 or 5000 ppm. The first spray was applied when the seedlings had only one fully expanded leaf and two cotyledons and the second a week before anthesis. Fruit length 12 days after anthesis increased with application of both growth substances and the greater effect was obtained with chlorophonium at 1000 ppm which resulted in fruits 1.4 times longer and 1.7 times heavier compared to those of control. Fruit maturity was also delayed by about a week. However, fruit flavour was not affected. Tosh et al. (1978) worked on okra plants cv. Pusa Sawani at Burdwan University, India. The okra plants at seedlings, flowering and fruiting stages were sprayed with M.H. at 200 or 500 ppm CCC (chlormequat) or a benzimidazole fungicide (not specified), each at 500 ppm, on 10 consecutive days. Fruit number per plant, average fruit size (length and diameter) and total yields per square meter were enhanced by all treatments. Moreover, time of maturity was delayed, especially CCC delayed fruit maturity by 4 to 5 days. Zayed et al. (1985) reported a considerable increase in the number of pods per plant and more yield per hectare with the application of CCC at 1000 ppm to cv. Clemson Spineless. The seed yield was highest with application of 1000 ppm cycocel at flower initiation stage (Kanade et al., 2002). Chlormequat increased yield - contributing parameters were reported (Garai and Datta 2003; Reddy and Khan 2001). Khan et al. (2003) reported that at maturity pod number and seed yield increased. The effect of plant growth regulators was concentration dependent. Above results are in the agreement with the results of the present study.

In the present study, application of chlormequat resulted in shortening of plant height, increased number of branches and leaves, increased dry weight of plants and increased fruit yield per plant. In view of the above result an increase in fruit yield per hectare is reasonable and expected. Further, seed yield of okra is expected to increase with increase in fruit yield. In addition to fruit yield, 100 seed weight also increased with the increasing concentration of chlormequat. The increased fruit yield and seed weight will together increase the seed yield. Patel (1988) recorded significantly high yield of immature okra fruits (265.84 q) and seed yield (17.80 q) per hectare due to the foliar application of CCC at 1000 ppm + urea at 1.0 percent.

It is understandable from the present study that increasing concentration of chlormequat can result in increased yield of immature fruits. Moreover, in order to understand which method is most suitable for higher yield, data were analysed by F-test. There was a significant difference in methods of application for reducing the internodal length and for increasing fruit length, fruit girth, average fruit weight, number of fruits per plant, fruit weight per plant and fruit yield per hectare. Similar results were reported by

Rani et al., 2001; Bharathkumar et al., 2001 and Ganiger et al., 2003. The combination of seed soaking and foliar spray reduced internodal length of stems, increased length, thickness and weight of fruits, and promoted number of fruits per plant to a greater extent compared to other two treatments. Consequently, combination of seed soaking and foliar spray can be categorized as the best method among the three methods of application. According to Sajjan et al. (2003) seed soaking + foliar spray combination resulted in the highest seed yield. Patel and Singh (1991) reported that foliar application of CCC proved superior to seed treatment with respect to most of vegetative, floral and fruit characters and ultimately yield of immature fruits and seed per hectare. An efficient absorption of solution has already been known though foliage.

In the present study, chlormequat increased concentration of nitrogen, phosphorus and potassium in okra fruits. Castro et al. (1975) treated pot grown plants of *Zinnia elegans* with chlormequat at 5000 ppm and found that stem and leaf N, P, K, Ca, Mg and S contents increased compared to that of control plants. Mishra and Reddy (1984) reported that cycocel application significantly enhanced N., P. and K. Guroo and Patel (1999) reported that in mustard chlormequat application increased seed yield and uptake of N, P and k.

The increased concentration of N, P and K in fruits suggests that application of cycocel may enhance nutritive value of okra fruits. On the contrary, concentration of residual N, P and K in soil of plots with cycocel treated plants decreased as compared to that in soil of control plots. These data are in accordance with the results for higher uptake of N, P and K by treated plants compared to that with control plants.

SUMMARY

The present investigation was carried out to understand the effect of chlormequat on vegetative growth and yield of okra (*Abelmoschus esculentus* (L.) Moench) cv. Gujarat Bhinda 2. Seeds were sown in a field at Horticulture Farm of B.R.S. college at Dumiyani in Upleta taluka of Rajkot district during the kharif season of the year 2002 and 2003. Experiment was laid out in a factorial Randomized Block Design. Okra plants were treated with 0, 500, 1000 and 1500 ppm concentration of chlormequat. In addition to four concentrations, three methods of application, viz, (i) seed soaking, (ii) foliar spray and (iii) combination of seed soaking and foliar spray were followed. Seeds were soaked in chlormequat solutions of different concentrations for 24 hours before sowing and foliar spray was done at 20 and 40 days after sowing. The present study further aims to single out the method and concentration of chlormequat to have maximum yield of newly released okra variety Gujarat Binda 2. The major findings are summarized as below :

1. Increasing concentration of chlormequat enhanced the seed germination. There was a significant ($p < 0.05$) positive relationship between percentage of seed germination and increasing concentration of chlormequat.
2. Reduction in internodal length and plant height was recorded with increasing concentration of chlormequat.
3. Chlormequat promoted number of branches, number of leaves and leaf area per plant.
4. Root elongation decreased with increasing concentration of chlormequat.
5. Dry weight of leaves, stems and roots increased with increasing concentration of chlormequat.
6. Flowering of okra was hastened with increase in concentration of chlormequat.
7. Reproductive period of plants was prolonged with increasing concentration of chlormequat.

8. Fruit length, fruit girth, fruit weight and number of fruits per plant increased with increasing concentration of chlormequat.

9. Fruit yield ha^{-1} increased with increase in concentration of chlormequat.

10. Number and weight of seed per fruit increased with increase in concentration of chlormequat.

11. Fruit N, P and K content increased with increase in concentration of chlormequat.

12. Combination of seed soaking and foliar spray was a better method than other two methods in order to increase fruit yield.

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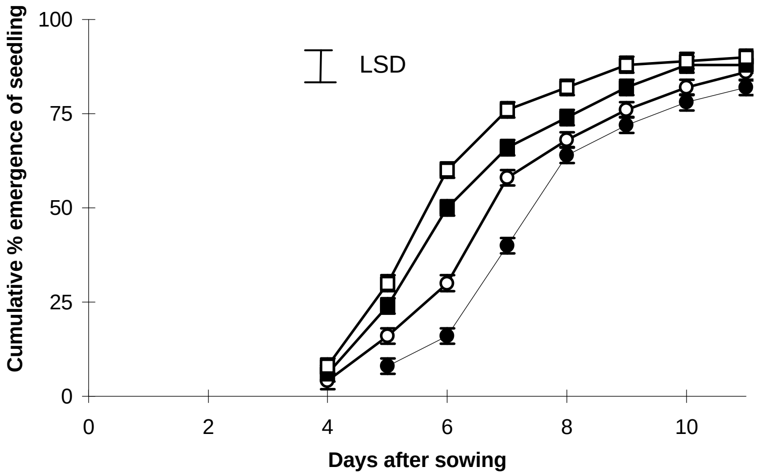

Fig. 4.1 Cumulative emergence of seedlings of *Abelmoschus esculentus* over time (days) in response to increasing concentration of chlormequat. Error bars represent SE.