EFFECT OF CALMAX, A FOLIAR MICRONUTRIENT FERTILIZER ON GROWTH AND YIELD OF HYBRID COTTON UNDER NORTHERN TRANSITIONAL ZONE OF KARNATAKA

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I. INTRODUCTION

Cotton (*Gossypium* spp.) is one of the most important fibre crops of the world which plays a key role in the economic activity. It is the oldest among the commercial crops and is regarded as white gold.

Cotton enjoys a pre-eminent status among all the commercial crops in the country, being the principal raw material for flourishing textile industry. Cotton industry provides livelihood to about sixty million people. It is an important agricultural commodity providing remunerative income to millions of farmers both in developed and developing countries. In India, in spite of several competition from synthetic fibres in recent years, it is occupying a premiere position with 70 per cent share in the textile industry.

Presently in India cotton is being grown over an area of 88.20 lakh hectares with an annual production of 242.50 lakh bales and the productivity of 467 kg lint per hectare. In Karnataka, it is cultivated on an area of 3.81 lakh hectares and producing 7.00 lakh bales with the productivity of 312 kg lint per hectare (Anon., 2006).

In India, cotton is primarily grown in dry tropical and subtropical climates at temperatures between 16°C and 25°C with a annual rainfall of 550 to 1500 mm. It is cultivated in India from sub-Himalayan region of Punjab in the north to Tamil Nadu in south and from dry regions of Kutch to high rainfall areas of Manipur in east. Major states cultivating cotton are Maharashtra, Gujarat, Andhra Pradesh, Karnataka, Madhya Pradesh, Punjab, Rajasthan, Haryana, Tamil Nadu and Uttar Pradesh.

There are four cultivated species of cotton. The most widely (97%) cultivated species of cotton in the world are *Gossypium hirsutum* and *Gossypium barbadense* called as new world or American cotton species having high yield potential. The other two species are *Gossypium arborium* and *Gossypium herbaceum* called as old world or Asiatic cottons having poor yield and fibre quality.

The primary reason for the low productivity of cotton in India is mainly because of 70 per cent of cotton cultivation is under rainfed condition and inadequate supply of nutrients and their poor efficiency. In addition, about 28 per cent of area under cotton in India is covered by *desi* cotton (*Gossypium herbaceum* and *G. arboreum*) which are low yielders due to poor genetic makeup, long duration and physiological constraints like shedding of plant parts, leaf reddening, bad boll opening and exposure to biotic and abiotic stresses. In irrigated and assured rainfall areas, development of excessive vegetative growth leads to low reproductive load and fruit set thereby reducing the harvest index.

However, to meet the requirement of 2020 AD (*i.e.* 320 lakh bales), the current production has to be increased by nearly 50 per cent. This increase has to come from increased productivity (Anon., 1998). The higher yield in future would have to be harvested from vertical rather than horizontal expansion of net cropped area. No doubt, high analysis chemical fertilizers increased the productivity but due to high fertilizer cost, the profit margin was low. Soil fertility is the primary limiting factor which influences production under intensive crop cultivation. After introduction of exhaustive high yielding varieties and hybrids in many crops including cotton, increased use of high analysis chemical fertilizers devoid of micronutrients and inadequate application of organic manures due to scarcity resulted in wide spread micronutrient deficiency and nutrient imbalance which adversely affected yield of cotton and many other crops. Therefore, it is essential to supply macro and micro nutrients in a balanced ratio in required quantity for obtaining higher cotton kapas yield.

Foliar feeding with plant nutrients gives quick benefits and economizes nutrient element as compared to soil application (Verma, 1973). Foliar feeding is often effective when roots are unable to absorb sufficient nutrients from the soil due to high degree of fixation, losses from leaching, low soil temperature and lack of soil moisture (Sing *et al.*, 1970).

In cotton, flowering is a continuous process. However, all flower produced are not retained and harvested. About 40 to 50 per cent of flowers and bolls will shed due to bollworm attack or nutritional or moisture stress. Hence, there is a need to supplement cotton crop with proper micro and macronutrients in balanced way for higher flower production and retention for obtaining higher yield. Calmax a liquid micronutrient fertilizer is ideally suited to supply the micronutirents in a balanced way for better cotton growth and yield. It contains N, Cao, Mgo, Mn, Fe, B, Cu, Zn and Mo. In view of the above, an experiment was conducted at Main Agricultural Research Station, Dharwad during *kharif*, 2005 using calmax a liquid micronutrient foliar fertilizer with the following objectives.

1. To findout the effect of calmax on growth and yield of cotton
2. To findout the optimum dose and stage of application of calmax in cotton
3. To findout the effect of calmax on the retention of bolls in cotton

II. REVIEW OF LITERATURE

The role of foliar application of essential elements (micro and macronutrients) on various physiological processes in plants is well known, which enable rapid change in the phenotype of the plant to achieve desirable results. The essential elements (micro and macronutrients) are required by the plants for normal growth and development and have an important role in the translocation of photosynthates to the reproductive sinks, besides improving quality. Now-a-days foliar application of micronutrients have assumed a greater importance in view of lower cost and higher efficiency compared to the traditional method of soil application. Since soils are becoming more and more deficient in micronutrients due to excessive use of inorganic fertilizers and fixation in soil resulting in decreased yields.

The foliar application of micronutrients at peak physiological stage in the ontogeny is the most practical approach. Hence, an attempt has been made in the present investigation to identify suitable stage and dose of application of foliar micronutrient fertilizer-calmax. The literature pertaining to these aspects are reviewed and presented in this chapter.

2.1 EFFECT OF MICRO AND MACRONUTRIENTS ON GROWTH AND GROWTH ATTRIBUTES

Ahlawat (1974) observed significant variation in plant height and branches per plant in cotton due to different methods of micronutrient application.

Oosterhuis (1976) reported that foliar application of boron along with insecticide in cotton increased the plant height from 1.1 to 1.4 m.

In a study conducted by Vanangamudi *et al*. (1987) observed significant increase in plant height, with foliar application of one per cent diammonium phosphate.

Azab and El-Halawamy (1989) showed that application of micronutrient (*viz.*, Fe) increased the leaf chlorophyll and carotenoid content. Internodal length was increased with application of Zn or Mn + Zn.

Roychoudhury *et al*. (1990) observed that application of calcium chloride @ 0.15 g per pot increased the plant height, number of leaves per plant and number of branches per plant of chilli.

Sharma (1995) found that soil application of calcium @ 10 kg per hectare has increased the plant height and number of branches per plant in tomato over control.

The results of field experiment conducted by El-Fouly *et al*. (1997) shown that when cotton cv. Giza-75 was sprayed with 0-100 ppm Fe as different Fe-chelated compounds, the growth and plant mineral content increased upto 50 ppm Fe, but decreased at 100 ppm Fe.

According to Basavarajappa *et al*. (1997) foliar application of $FeSO_4$, $CuSO_4$, $ZnSO_4$, $MnSO_4$ and borax @ 5 kg/ha each sprayed in two equal split at 60 and 90 DAS. Among the foliar applications $FeSO_4$ @ 5 kg/ha recorded significant increase in plant height, monopodial and sympodial branches per plant.

Thakar Singh and Sidhu (1997) found that application of Biozyme (GA_3 + IAA + Zeatin + micronutrient) @ 600 ml/ha increased the plant height and number of sympodial branches per plant.

Foliar application of Zn (40 ppm) at 75 and 95 days after sowing (DAS) and Ca (0, 20, 40 or 60 ppm) at 80 and 95 DAS has increased the plant height and dry matter production (Sawan *et al*., 1999).

Hanumanthareddy (1999) revealed that, foliar application of NAA incombination with $MgSO_4$ increased the number of monopodial and sympodial branches.

The results of field experiment conducted by Chellaiah *et al*. (2001) indicated that foliar spray of humic acid alone or incombation with 2 per cent DAP or 1 per cent KCl in cotton had significant improvement on the plant height, dry matter accumulation and sympodial branches per plant.

Carvalho *et al*. (2001) observed that foliar application of nitrogen as urea and potassium as potassium chloride with a concentration of 1 per cent and potassium chloride at 4 per cent respectively, increased the plant height and number of reproductive branches in cotton crop.

2.2 EFFECT OF PLANT GROWTH REGULATORS ON GROWTH AND GROWTH ATTRIBUTES

Dastur and Prakash (1954) observed that foliar application of NAA @ 40 ppm increased the plant height.

Annappan and Aaron (1969) indicated that NAA increased the cotton plant height, when sprayed at 60 and 75 DAS.

Abdullah and Shalabay (1980) noticed higher number of fruiting branches with 1000 ppm IBA and NAA spray. Similar results were also found that foliar application of NAA @ 10 ppm + urea, increased the number of branches per plant in cotton (Reddy and Rao, 1981).

The results of field experiment conducted by Eid and Al-Abdel (1985) revealed that foliar application of 5, 10 or 20 ppm NAA at the beginning of flowering increased the leaf area per plant and leaf area index in cotton cv. Ashmouni, Giza-45 and Giza-75.

According to Kapagate *et al*. (1989) spraying of GA (500 ppm) was most effective in increasing plant height followed by NAA (1000 ppm) in cotton cv. Branil-1007.

Plant height, number of sympodial branches per plant of cotton were higher with NAA @ 10 ppm and 20 ppm NAA (Patel, 1993).

Pothiraj *et al*. (1995) showed that spraying three round of NAA (40 ppm) with or without 3 per cent DAP were more effective in increasing the number of sympodial branches per plant.

2.3 EFFECT OF MICRO AND MACRONUTRIENTS ON YIELD AND YIELD ATTRIBUTES

Bodade and Madankar (1965) observed an increase of cotton yield by 14 per cent through foliar application of nitrogen.

Ferraz *et al*. (1969) reported that cotton crop given a basal dressing of PK and 5, 10, 15 or 20 kg N ha^{-1} applied as foliar spray of (a) urea (b) NH_4NO_3 (c) $NaNO_3$ at the rate of 450 l ha^{-1}, increased the seed cotton yield.

The results of a field experiment conducted by Burkalov (1969) at Plovdir, Bulgaria shown that spraying of cotton leaves with 0.5 per cent solution of boron increased seed cotton yield by 14.4 per cent compared with control plots.

Hunasagi *et al*. (1969) observed that, boron sprayed at 0.25 kg per acre recorded higher yield of 585 g per pot. Highest yield of 591 g per pot was obtained by spraying all micronutrients in conjunction with NAA @ 10 ppm.

Dubey and Chokhey Singh (1969) studied the efficiency of soil and foliar applied micronutrients on cotton and observed that, combination of Mn+Zn+Cu+B+Mo increased the seed cotton yield both in soil and foliar spray (820 and 868 kg ha^{-1}, respectively).

Chowdhary and Hisani (1970) reported increased seed cotton yield with spraying boron @ 20 ppm.

Marphy and Lancaster (1971) found significant increase in yield of seed cotton with boron (0.1 kg ha^{-1}) sprayed at weekly interval for five weeks.

Ramdas *et al*. (1971) indicated that 15 kg N ha^{-1}, alone or in combination with 7.5 kg P_2O_5 ha^{-1} in three equal foliar applications lead to increased seed cotton yield by 3.4-45.7 per cent compared with water spray alone.

Ahlawat (1974) reported that foliar spray of magnesium sulphate increased the seed cotton yield over other micronutrient and control. Foliar application of manganese, zinc, copper and molybdenum gave 31.3, 4.0, 14.6, 18.6 per cent higher seed cotton yield over their respective soil application.

Ramanathapillai *et al*. (1975) observed that foliar application of 0.5 per cent diammonium phosphate, significantly increased the number of bolls per plant and seed cotton yield (858 kg ha^{-1}) over control (639 kg ha^{-1}).

Honischo (1975) reported that foliar application of boron to cotton cv. Albar 637 increased the seed cotton yield in five out of eight trials. The highest yield was obtained with application of 2 to 4 kg boron per hectare.

In the field trials at Shabkan, Egypt, cotton variety Giza-69 was given foliar spray of NPK and important micronutrients (10.1% N; 5.6% P_2O_5; 5.29% K_2O; 0.16% Mg; 0.007% Fe; 0.0025% Cu; 0.059% Zn and 0.021% B). They have increased seed cotton yield by 15.34 to 26.87 per cent over that of soil fertilization, but the increase was not significant (Elgala *et al*., 1976).

Oosterhuis (1976) reported that foliar application of boron along with insecticides increased the boll weight and seed cotton yiled from 4.1 to 4.4 g and 1.2 to 1.4 tonnes per ha, respectively.

Nageswara Rao (1976) conducted a field experiment and observed that soil application of 25 kg ha^{-1} and foliar spray of 0.5 per cent of magnesium sulphate increased the seed cotton yield by 16 and 25 per cent more than control. Boron @ 17.5 kg ha^{-1} through soil and foliar application at 0.2 per cent increased the yield of seed cotton by 26 and 32 per cent respectively over control.

There was significant increase in seed cotton yield with the foliar application of 2 per cent magnesium and 0.2 per cent zinc and also with combination of zinc and magnesium (Eweida *et al*., 1979).

Silva *et al*. (1982) observed that application of boron @ 1.23 kg ha^{-1} significantly increased boll weight, seed cotton yield. Also it induced earliness.

Hosny *et al*. (1984) observed that foliar application of boron and copper with different concentrations increased the seed cotton yield and number of bolls per plant but boll weight was unaffected by boron or copper application.

The field experiment conducted by Sawan *et al*. (1986) shown that three foliar application of micronutrients in cotton has increased seed yield per plant and seed index. Among the micronutrients tested, copper sulphate (12.5 ppm), ferrous sulphate (25.0 ppm) and manganese sulphate (25.0 ppm) gave significantly higher seed cotton yield of 16.23, 15.38, 15.48 g per plant respectively compared to other micronutrients and these micronutrients were on par.

Abd-El-Hadi *et al*. (1986) reported that a foliar spray of waxal suspension and liquid form various combination of macro and micro nutrients, the wuxal formula containing NPK, Mn, Fe gave the highest yield.

Vanangamudi *et al*. (1987) indicated that significant increase in number of bolls per plant and seed cotton yield ha^{-1} with foliar application of one per cent diammonium phosphate.

The results of a field experiment conducted by Sawan *et al*. (1989) revealed that seed cotton yield per plant increased with increasing N rate and application of Ca, Cu, Zn, Fe or Mn.

Hussain *et al*. (1989) reported that combined application of iron with zinc and boron through soil or foliar spray recorded significantly higher number of fruits per plant (208), longer fruit size and green chilli yield (13.5 t ha^{-1}).

Application of calcium chloride @ 0.15 g per pot has increased the total number of flowers per plant, number of fruits per plant and chilli yield per plant (Roychoudhury *et al*., 1990). Also he reported that, application of $FeCl_2$ @ 0.05 g per pot increased total number of flowers (200), number of fruits and chilli yield per plant (44 g).

Mehetre *et al*. (1990) found that foliar application of 2 per cent diammonium phosphate resulted in higher number of bolls per plant, boll weight and higher seed cotton yield by 21.8 per cent compared to control.

McConnel *et al*. (1992) found that foliar application of boron (220 g/ha) at different growth stages increased the seed cotton yield and lint yield significantly.

Namdeo *et al*. (1992) revealed that foliar application of micnelf 1 per cent at 30, 65 and 90 DAS gave significantly higher seed cotton yield over control, which was followed by magnesium sulphate 2 per cent sprayed at 30 and 60 DAS.

Sharma *et al*. (1993) indicated that foliar application of 2 per cent diammonium phosphate spray gave higher seed cotton yield compared to control.

A field trial was conducted by Saad *et al*. (1994) at Moshtohor, Egypt with cotton cv. Giza 75 and sprayed 1-3 times with 1-3 g of urea/l, the highest seed cotton yield was given by 3 sprays of urea applied at highest rate.

Haq-Nawaz *et al*. (1994) found that, seed cotton yield was increased in the order of Cu>Zn>Fe>Mn>B trace elements applied together.

Wankhade *et al*. (1994) revealed that, foliar spray of 0.1 per cent borax at peak square and peak flowering stages recorded significantly higher seed cotton yield per plant over control. Similar results were also recorded with respect to bolls per plant and seed cotton yield per hectare.

Prasad and Prasad (1994) observed that, application of 80:40:20 kg NPK per hectare in combination with or without zinc sulphate, gypsum, borax, manganese sulphate or magnesium sulphate resulted in increased seed cotton yield. The highest seed cotton yield was observed with NPK + Zn or Mg.

Sharma (1996) observed that, in chilli number of fruits per plant, fruit yield per plant and per hectare, seed yield plot^{-1} and per hectare were significantly influenced by calcium application and highest values were obtained with 10 kg $CaCO_3$ per hectare. Similarly, a positive response in tomato due to calcium nutrition was also reported by Evans and Troxler (1953).

In the field experiment at Leme, Sao Paulo, Brazil, boron was applied to cotton cv. IAC-17 by side dressing @ 0.75 kg and 0.15 kg through foliar application of boron at the early growth stages increased yield and fibre length. Carvalho *et al*. (1996) and Raja Rajeswari (1996) reported that, foliar application of 0.5 per cent boron increased the number of bolls per plant, mean boll weight and kapas yield significantly in cotton.

Chitdeshwari *et al*. (1997) observed that, foliar application of magnesium sulphate increased the seed cotton yield and also decreased the leaf reddening

Thakar Singh and Sidhu (1997) found that application of biozyme (GA_3+IAA+Zeatin+micronutrients) at 600 ml/ha increased the number of bolls per plant and seed cotton yield as compared with the water sprayed control.

The results of a field experiment conducted by Basavarajappa *et al*. (1997) under rainfed conditions in black soil at Dharwad revealed that foliar application of $FeSO_4$ @ 5 kg/ha recorded significantly superior cotton yield of 1911 kg/ha over 1456 kg/ha of absolute control.

Basavaraja *et al*. (1998) found that the application of copper tailings (iron content 21.09 mg kg^{-1} of COT) @ 0.5 t per hectare resulted in a higher fruit yield (14 q ha^{-1}) of chilli when combined with urea, as compared to control.

Gollagi (1999) observed that application of micronutrients (($FeSO_4$ (1087 kg ha^{-1}), $ZnSO_4$ (1140 kg ha^{-1}) and $MgSO_4$ (1076 kg ha^{-1}) recorded significantly higher fruit yield of chilli over control (933 kg ha^{-1}).

Hanumanthareddy (1999) revealed that, the foliar application of NAA in combination with $MgSO_4$ increased the number of monopodial and sympodial branches, number of good bolls per plant, average boll weight, seed weight per plant, number of seeds per boll. Significantly the highest kapas yield was recorded with $MgSO_4$ (1%) in combination with NAA (10 ppm) compared to control.

Ullagaddi (2000) indicated that, the foliar spray of $ZnSO_4$ (0.1%) plus boron (0.1%) in combination with GA_3 (50 ppm) in cotton significantly increased the number of squares, flowers and matured bolls per plant and the highest seed yield.

Pratima Sinha *et al*. (2001) observed that, spraying of boron @ 0.33 mg l^{-1} significantly increased the yield, 100 seed weight and fibre length in cotton.

A trial was conducted in cotton using cv. SVPR-2 during the winter season in Srivilliputhur, Tamil Nadu by Chellaiah *et al*. (2001), it revealed that foliar application of 2 per cent diammonium phosphate and 1 per cent humic acid at peak squaring and peak flowering stages recorded significantly highest seed cotton yield of 1293 kg/ha compared to water spray.

2.4 EFFECT OF PLANT GROWTH REGULATORS ON YIELD AND YIELD ATTRIBUTES

Dastur and Prakash (1954) reported that application of NAA @ 40 ppm significantly increased the boll set percentage, boll weight, number of bolls and seed cotton yield per plant.

Negi and Avatar Singh (1956) indicated increased yield by 116 kg kapas per hectare with the application of 10 ppm NAA during early flowering stage in P-126 F variety of cotton. And also the effect of 20 ppm NAA increased boll number (11.2%) and seed cotton yield (12.8%) compared to control (Avatar Singh and Dargan, 1960).

Ramdas *et al*. (1971) studied the effect of foliar application of nitrogen and phosphorus with or without harmone (NAA with nitrogen, NAA with N and P, and NAA alone respectively) cv. Mysore-14. The seed cotton yield increased by 25.6, 37.3 and 21.5 per cent over control, respectively

Bhat (1972) found that increased seed cotton yields by 300-470 g/ha compared with 244-383 kg/ha in control by application of 10 ppm of planofix @ 1000 l ha^{-1} applied during flower initiation and full bloom stage.

Kulandaivelu *et al*. (1974) reported that foliar application of 40 ppm CCC at 70 DAS, 2 foliar sprays of 10 ppm NAA solution at 60 and 80 DAS, or combination of CCC + NAA treatments gave seed cotton yields of 2.92, 2.7 and 3.0 t ha^{-1}, respectively compared with 2.64 t ha^{-1} of control.

Sankaran and Balasubramanian (1975) reported that application of 30 ppm planofix (NAA) at flowering stage and 20 ppm planofix at 15 days later increased the number of bolls per plant and increased the seed cotton yield of 21.8 q/ha compared to 12.5 q ha^{-1} in control. Similarly application of 10 ppm planofix (NAA) at flowering stage increased the number of bolls per plant from 8.6-9.0 in untreated control to 24.7 -27.0 and seed cotton yields from 1.11 to 1.27-1.4 t ha^{-1} (Chowdappan and Morachan, 1975).

Rao *et al*. (1978) observed that increased boll weight, increased number of bolls per plant and seed cotton yield per ha with the foliar spray of NAA 5 ppm at 82 DAS compared to control (no spray).

Chowdappan *et al*. (1979) found that application of 3 foliar spray of 10, 20, 30 ppm NAA as planofix to cotton, cv. MCV-8 at 10 to 15 days interval beginning with the flower initiation, increased the number of bolls per plant from 9.4 to 12.2-21.3 and seed cotton yield from 1.97 to 2.1-2.3 t ha^{-1} in 1976 and from 13.4 to 22.2 and from 1.41 to 2.05-2.79 t ha^{-1} in 1979, respectively.

Vanangamudi and Ramaswamy (1979) indicated that foliar application of 20 ppm of naphthalene acetic acid at 70.80 and 90 DAS increased the kapas yield by 30.3 per cent and seed yield by 31.2 per cent over control.

Jadhav and Kalbhor (1981) reported that NAA @ 20 ppm increase the boll number and seed cotton yield. Similarly application of NAA @ 20 ppm increased the number of bolls per plant and seed yield per plant in cotton genotype cv. Giza 75. Sawan *et al*. (1989), Patel (1993) also observed significantly higher seed cotton yield (10.3%) over control, with application of NAA @ 10 ppm.

Venkatakrishnan *et al*. (1994) reported that foliar application of NAA (40 ppm) + DAP (3%) with topping increased the number of bolls per plant and seed cotton yield.

Pothiraj *et al*. (1995) studied the effect of growth regulators in cotton cv. MCU-9 for 2 years and reported that foliar spray of NAA @ 40 ppm with or without 3 per cent DAP at 45^{th}, 60^{th}, 75^{th} DAS leads to significant increased in yield when compared to water spray.

Maiya (1999) reported that foliar spray of NAA (@ 20 ppm) significantly increased the seed cotton yield followed by DAP (2%) and cytozyme (0.1%).

Katkar (2002) revealed that foliar application of NAA @ 10 ppm, DAP 2 per cent, IAA @ 20 ppm and cobalt chloride 2.0 millimolar, respectively recorded significantly higher seed cotton yield by 38.7, 37.1, 31.3 and 21.2 per cent over control.

2.5 EFFECT OF MICRO AND MACRONUTRIENT ON DOSE AND STAGE OF APPLICATION

Bhoj *et al*. (1969) reported that in pot trials with cotton cv. 320 F, solution containing 0.2 per cent N or 0.2 per cent of N, P or N+P applied as foliar sprays at the squaring stage and again at the flowering stage, significantly increased the seed cotton yields. Spray of N+P was effective than spraying with either of them alone.

Ramadas *et al*. (1971) found that 15 kg N/ha, alone or in combination with 7.5 kg P_2O_5/ha in three equal foliar applications at 45, 75 and 105 days after sowing increased seed cotton yield by 13.4-45.7 per cent compared with water spray alone.

Khodzhaev and Stesnyagina (1983) reported that spraying of cotton plants at flowering stage with a mixture of 0.02 per cent boric acid and 0.1 per cent zinc sulphate markedly increased the number of bolls per plant and seed cotton yield per ha.

Sarour (1988) conducted an experiment on cotton cv. Giza-76 which was given foliar application of 4 per cent urea or 4 per cent of calcium super phosphate and trace elements mixture spray twice during vegetative period or twice during flowering period or both. Foliar application increased the seed cotton yield with 4 per cent calcium sulphur phosphate + trace elements giving the highest yields of 6.22-6.46 kentars per feddan compared with 5.88-5.89 kentars per feddan in unfertilized control. Foliar application also increased the number of opened bolls per plant and seed index but had no effect on lint percentage.

Vanangamudi *et al*. (1987) recorded significantly increase in number of bolls per plant and seed cotton yield per ha in cotton with foliar application of one per cent diammonium phosphate at 70, 80 and 90 days after sowing.

In the field trials at Giza, Egypt, cotton Giza-75 (*Gosssypium barbadense* L.) conducted by Sawan *et al*. (1989) revealed that effect of nitrogen rate (108 or 216 kg N/ha), the chelated form of calcium (Ca at 50 mg/l) and five micronutrients (Cu, Zn or Co at 12.5 mg/l, Fe or Mn at 25 mg/l) all applied in three times as foliar spray at 70, 85 and 100 DAS. It led to significant increase in the seed index and seed cotton yield per plant.

Ebelher (1988) reported that application of harvest plus (a formulation of NPK and micronutrients) at a total rate of 20, 30, 40 or 60 lb/acre applied bi weekly or 20, 30, 40 or 60 lb/acre applied monthly from 6^{th} week post-sowing onwards increased seed cotton yield and lint yield.

Dong Jinfeng (1995) found that spraying boron as borax or boric acid with 0.2 per cent at the seedling stage, early flowering and boll formation stage increased the yield by 16.1 per cent over control.

The results of field experiment conducted by Venugopalan *et al*. (1998) at Nagpur, Maharashtra revealed that cotton cv. Anjali was given foliar application of 6.4 kg N/ha as urea at 75 DAS and 2.0 kg P as DAP at 95 DAS have increased the seed cotton yield (1951 kg/ha) over control (1695 kg/ha).

Field experiments were conducted during 2 successive season at the Agricultural Research Center, Giza, on a clay loam soil by Sawan *et al*. (1997) found that foliar application of Zn (0 or 40 ppm) at 75 and 90 DAS and Ca (0, 20, 40 and 60 ppm) at 80 and 95 DAS and

P fertilization to soil (44 or 75 kg P_2O_5/ha) increased the opened bolls per plant, boll weight, seed index, lint index, seed cotton yield per plant of *Gossypium barbadense* cv. Giza 75

Sasthri *et al*. (2000) studied the effect of foliar nutrition on non-aged and aged seed of cotton cv. MCU-5 with 2 per cent $MgSO_4$, 2 per cent DAP and 0.5 per cent Borax at 75 and 90 DAS. Seed cotton yield and yield of both aged and non-aged were significantly higher with 2 per cent DAP over control and other treatments. Also, the effect of DAP as 2 per cent foliar spray at squaring stage of crop improved the vegetative growth and yield significantly in cotton cv. LRA5166. Ravichandran (2000).

Carvalho *et al*. (2001) stated that foliar application of nitrogen (urea) and potassium (potassium chloride) at 2, 4, 6 or 8 weeks after beginning of flowering. Urea at a concentration of 1.0 per cent and potassium chloride at 4 per cent were applied at a rate of 250 l ha^{-1} spray mixture which led to significant increase in number of bolls per plant and increase the seed cotton yield.

2.6 EFFECT OF PLANT GROWTH REGULATORS ON DOSE AND STAGE OF APPLICATION

Dharmarajalu (1967) indicated that, foliar application of NAA at two stages, one at square formation and second at flower initiation, leads to significant reduction in boll shedding and increase in boll number per plant in cotton.

Mote (1975) reported, increased yields upto 41 per cent in three chilli cultivars with 50 ppm NAA sprayed twice at full bloom and 20 days later.

The results of field trials with cotton cv. AC-134 revealed that spraying of NAA in varying concentrations (10 ppm to 40 ppm) at the initiation of flowering recorded increased seed cotton yield from 1.44 to 35.25 per cent (Jalis and Chowdhary, 1977).

Eid and Al-abdel (1985) found increased seed cotton yield by the application of 5, 10 or 20 ppm NAA in cotton cv. Ashmani, Giza-45 and Giza-75, when sprayed at beginning of flowering.

The results of field experiment conducted by Sawan *et al*. (1989) shown that in cotton cv. Giza-75, application of NAA @ 0-25 ppm in 1-3 sprays at 75, 90 and 105 or 90, 105 and 120 DAS increased the seed cotton yield per plant and number of seeds compared with untreated control. Application of 20 ppm NAA gave the highest seed yield and seed index.

2.7 EFFECT OF PLANT GROWTH REGULATORS AND MICRONUTRIENTS ON BOLL RETENTION

Dastur and Prakash (1954) observed that foliar application of 2, 3, 5-triiodobenzoic acid and NAA increased the boll settings per cent.

Bhatt and Date (1955) were the first to report that foliar application of NAA in low concentration to field grown cotton crop to reduce boll shedding and thus increased yield of seed cotton. Similarly application of 10 ppm NAA enhanced flower and boll setting percentage (Dastur and Bhatt, 1956).

Bharadwaj and Santhanam (1964) studied the application of NAA 20 ppm at seedling and bud formation stages which resulted in increased yield by 18.0 per cent due to reduced shedding. Irrespective of fertilizer application, two sprays of NAA at seedling and bud formation stage were found to be superior compared to single spray at either seedling or bud formation stage in cotton.

Dharmarajalu (1971) indicated, significant reduction in boll shedding and increase in boll number per plant in cotton with application of NAA (20 ppm) at square formation and flower initiation stage.

Subbaiah and Maria Kulandai (1972) revealed that boll retention in cotton cv. MCU-5 was increased when plants were sprayed with NAA (10 ppm).

Foliar application of NAA @ 15 ppm recorded less shedding of squares compared to control treatment (Padaki *et al*., 1974).

Lal and Shastri (1975) observed reduced boll shedding with the application of NAA @ 5 ppm at the flowering stage.

According to Chowdappan and Morchan (1975) spraying of planofix to cotton shown reduction in boll shedding. Application of 10 ppm planofix at flowering and boll setting stage showed increase in boll setting (67%) compared to control. Similarly increase in boll retention and seed cotton yield was observed with application of 10 ppm NAA (Jalis and Choudhary, 1977).

Application of NAA not only reduced the abscission but also erased completely the primitive effect of ABA on abscission (Verma, 1976). Similarly when NAA was applied to cut ends of pedicels, NAA delayed or inhibited abscission (Chatterjee, 1977).

Jadhav and Kalbhor (1981) reported that NAA increased the number of bolls and seed cotton yield.

The results of field experiment conducted by Bhat and Nathan (1986) shown significant reduction in shedding of bolls and buds with the foliar application of 20 ppm NAA and followed by foliar application of DAP (1%).

Patel (1993) noticed higher number of bolls per plant by spraying NAA @ 10 ppm and it was on par with NAA @ 20 ppm.

According to Venkatakrishnan (1994) foliar spray of NAA (40 ppm), CCC (40 ppm) and DAP (3%) either alone or in combination with tapping significantly increased the retention of squares and bolls.

Pothiraj *et al*. (1995) studied the effect of growth regulators in cotton cv. MCU-9 and reported that, spraying of 40 ppm of NAA resulted in significant increase in boll setting percentage when compared to water spray.

NAA used in cotton to induce flowering and prevent boll dropping and to increase seed yield and quality. Spraying of NAA at the rate of 40 ppm at flower initiation and 15 days after flowering recorded increase in boll setting percentage, number of bolls per plant, boll weight and seed cotton yield per plant (Anonymous, 1995).

Rajarajeshwari (1996) also noticed increase in boll set and seed cotton yield with foliar application of 20 ppm NAA compared to control.

Sawan *et al*. (1998) concluded that, among different doses of NAA (@ 5, 10, 15, 20 or 25 mg l^{-1}) applied at square initiation and boll development stages of cotton cv. Giza-71, application of NAA @ 25 ppm increased the number of bolls per plant.

Katkar (2000) studied, foliar application of NAA @ 10 ppm, DAP @ 2 per cent, IAA @ 20 ppm and cobalt chloride @ 2.0 millimolar. Higher boll setting was recorded in NAA 10 ppm (56.3%) followed by IAA 20 ppm (54.7%) and DAP 2 per cent (54.2%).

Brar *et al*. (1982) reported that application of NAA @ 30 ppm recorded the highest number of harvested bolls and per cent boll setting.

Sarour *et al*. (1988) revealed that foliar application of 4 per cent urea singly or in combination with mixture of micronutrients on cotton, significantly increased the fruit set per plant while decreased the shedding per cent when compared with control.

III. MATERIAL AND METHODS

A field experiment was conducted at Main Agricultural Research Station, University of Agricultural Sciences, Dharwad (Karnataka) during *kharif*, 2005 to study the effect of calmax, a foliar micronutrient fertilizer on growth and yield of hybrid cotton under northern transitional zone of Karnataka. The material used and techniques employed during the course of experimentation were described in this chapter.

3.1 GENERAL DESCRIPTION

3.1.1 Experimental site

The experiment was conducted at Main Agricultural Research Station, Dharwad in plot number 131 of 'E' block. Dharwad is situated on a latitude of 15°26'N, longitude 75°07'E with an altitude of 678 m above the mean sea level.

3.1.2 Soil and its characteristics

The soil of the experimental site belongs to *vertisol*. A composite soil sample was collected from 0 to 30 cm depth in experimental plot before sowing and analysed for physical and chemical properties. The results of soil analysis along with methods followed were furnished in Table 1.

3.1.3 Climatic conditions

The Main Agricultural Research Station is situated in Northern Transititional Zone (Zone-8) of the Karnataka state. This zone receives rainfall from both southwest and northeast monsoons, which is well distributed from June and October with lower coefficient of variation. The mean monthly meteorological data on rainfall, temperature and relative humidity during the period of experimental year (2005-06) and normal values for the last 55 years (1950-2004) are presented in Table 2 and depicted in Fig. 1. During 2005-06 a total rainfall of 1011.5 mm was received which was 251.97 mm more than the normal of 55 years. During the period of experimentation 907.1 mm of rainfall was received, which was 197.57 m more than the normal rainfall. The rainfall was higher in June, July, August and September than the normal. During 2005-06, mean monthly maximum temperature ranged from 27.10°C to 37.00°C while the mean monthly minimum temperature ranged from 12.90°C to 21.50°C. The mean relative humidity was highest during the month of September (85%) and ranged between 51 to 85 per cent during the cropping period.

3.1.4 Previous crop on the experimental site

The previous crop grown on the field during *kharif* 2004 was cotton and the field was kept fallow during summer.

3.2 EXPERIMENTAL DETAILS

The details of the experiment with regard to the composition of foliar micronutrient fertilizer calmax, treatments, design and plot size are given below.

3.2.1 Information about calmax product

Calmax is manufactured by Omex Agrifluid Ltd., with production facility at England and United States and registered office at Norfolk, England.

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

	Particulars	Value obtained		Method employed
I	Physical properties			
1.	Textural composition			
a	Coarse sand (%)	9.30		
b	Fine sand (%)	16.30		
c	Silt (%)	11.50		Hydrometer method (Piper, 1966)
d	Clay (%)	62.90		
e.	Soil texture	Clay loam		
2.	Bulk density (Mg/m^3)	1.30		Core sampler method (Dastane, 1967)
II	Chemical properties			
		Value	Rating	
1.	Available nitrogen (kg ha^{-1})	209	Low	Alkaline permanganate method (Subbaiah and Asija, 1956)
2.	Available phosphorus (P_2O_5) (kg ha^{-1})	30	Medium	Olsen's method (Jackson, 1967)
3.	Available potassium (K_2O) (kg ha^{-1})	338	High	Flame photometer method (Jackson, 1967)
4.	Organic carbon (%)	0.52	Medium	Walkley and Black Wet oxidation method (Jackson, 1967)
5.	Soil pH (1:2.5 soil:water)	7.6	Neutral	Potentiometric method (Piper, 1966)

Table 2. Monthly meteorological data for the experimental year (2005-06) and the mean of past 55 years (1950-2004) of Main Agricultural Research Station, University of Agricultural Sciences, Dharwad

Month	Rainfall (mm)		Temperature (°C)				Relative humidity (%)	
			Mean maximum		Mean minimum			
	2005-06	1950-2004	2005-06	1950-2004	2005-06	1950-2004	2005-06	1950-2004
April	75 (5)	48.88	36.3	37.38	21.3	19.83	53	76
May	29.4 (3)	80.45	37.0	33.66	21.5	21.40	55	66
June	151 (10)	109.86	30.9	28.84	21.4	21.50	76	81
July	290.2 (19)	148.33	27.4	29.17	21.5	21.01	83	87
August	138.8 (15)	96.09	27.1	27.00	20.4	20.30	81	86
September	194.5 (14)	102.21	27.5	28.58	20.3	19.91	85	82
October	89.4 (9)	130.15	29.6	30.09	19.1	18.41	70	76
November	38.0 (1)	32.11	29.4	30.19	14.9	15.88	51	68
December	0	5.51	28.9	29.39	13.1	12.51	53	63
January	0	0.08	29.9	29.61	12.9	14.67	52	63
February	0	1.14	33.4	32.52	14.8	16.37	62	51
March	5.2 (1)	0.14	34.1	36.48	18.1	19.59	45	56
Total	1011.5 (77)	759.53						

Note: Figures shown in parenthesis indicates number of rainy days

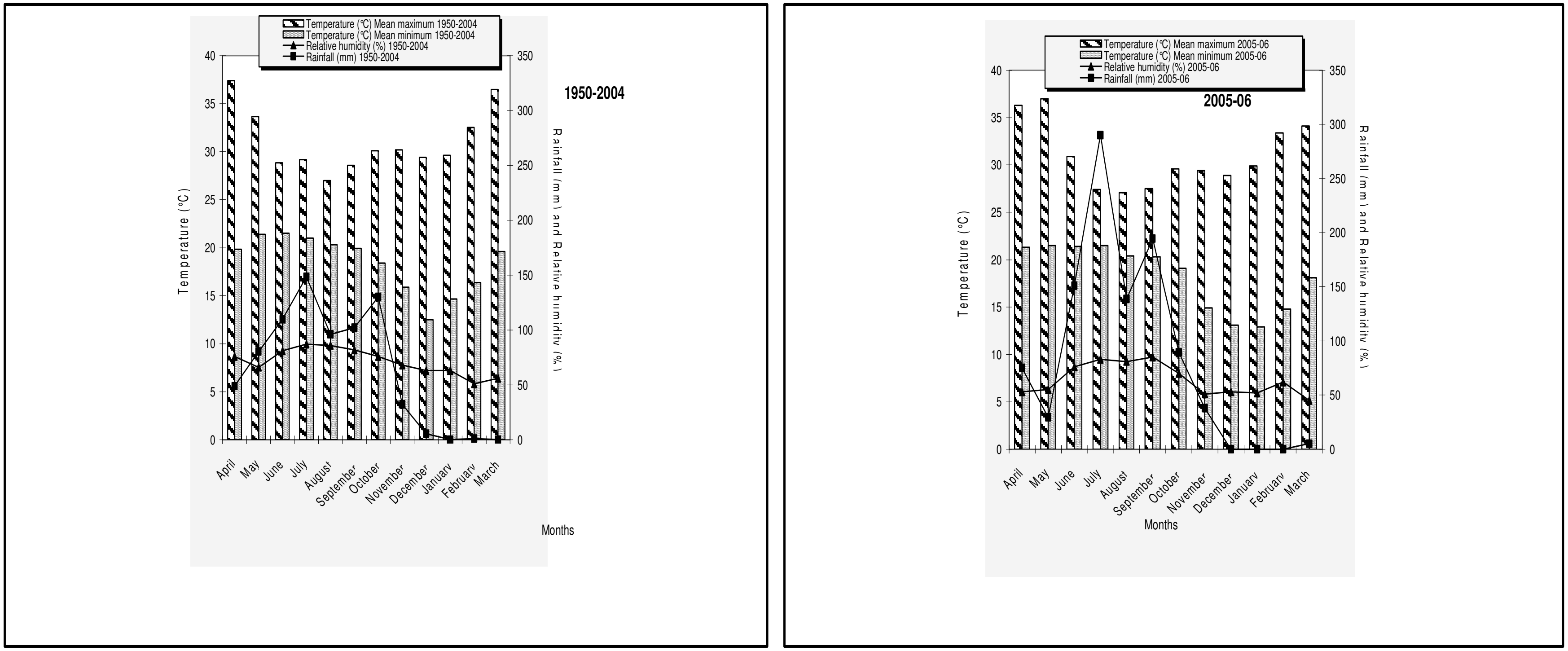

Fig. 1. Monthly meteorological data for the experimental year (2005-06) and the mean of past 55 years (1950-2004) of Main Agricultural Research Station, University of Agricultural Sciences, Dharwad

Description

Calmax is fully water soluble fluid emulsion product containing 22.5 per cent calcium and balance ranged from micro elements. Calmax is specifically formulated for use as foliar fertilizer. It can be applied to many fruits, vegetable and field crops to improve fruit firmness storability, colour and to improve flower and boll retention and yield.

Analysis of calmax		Weight/volume (%)	Weight/weight (%)
Total nitrogen	N	15.00	10.00
Nitrate		12.10	8.05
Ammonia	N	0.90	0.60
Urea	N	2.00	1.35
Calcium	Cao	22.50	15.0
Magnesium	Mgo	3.00	2.00
Manganese	Mn	0.15	0.100
Iron	Fe	0.075	0.050
Boron	B	0.075	0.050
Copper	Cu	0.060	0.040
Zinc	Zn	0.030	0.020
Molybdenum	Mo	0.0015	0.001
pH (10% solution)		5.5-6.5	
Specific gravity		1.50@18C	

3.2.2 Treatment details

T_1-Calmax spray @ 3 l ha^{-1} once at square formation

T_2-Calmax spray @ 3 l ha^{-1} twice equally at square formation and flower initiation

T_3-Calmax spray @ 3 l ha^{-1} thrice equally at square formation, flower initiation and peak flowering

T_4-Calmax spray @ 3 l ha^{-1} once at peak flowering

T_5-Calmax spray @ 6 l ha^{-1} once at square formation

T_6-Calmax spray @ 6 l ha^{-1} twice equally at square formation and flower initiation

T_7-Calmax spray @ 6 l ha^{-1} thrice equally at square formation, flower initiation and peak flowering

T_8-Calmax spray @ 6 l ha^{-1} once at peak flowering

T_9-Calmax spray @ 9 l ha^{-1} once at square formation

T_{10}-Calmax spray @ 9 l ha^{-1} twice equally at square formation and flower initiation

T_{11}-Calmax spray @ 9 l ha^{-1} thrice equally at square formation, flower initiation and peak flowering

T_{12}-Calmax spray @ 9 l ha^{-1} once at peak flowering

T_{13}-Urea + Planofix (as per the recommendation)*

T_{14}-Control (water spray)

* Urea @ 2 per cent at 90 and 110 DAS after sowing and planofix @ 4.5 ml/18 litre of water at 70 and 90 DAS.

3.2.3 Plot size

Gross plot : 7.2 m x 7.2 m

Net plot : 5.4 m x 6.0 m

3.2.4 Design and layout

The experiment was laid out in Randomized Complete Block Design with 14 treatments as detailed below and with three replications. The plan of layout is given in Fig. 2 (Plate 1 and 2).

3.2.5 Spacing

The recommended spacing of 90 cm x 60 cm for hybrid cotton was adopted.

3.2.6 Cultivar of hybrid cotton : DHH-11

The cultivar DHH-11 is an interspecific hybrid cotton having medium staple length, hairy, fairly tolerant to boll worm and sucking pest and with a duration of 160 to 170 days.

3.3 CULTURAL OPERATIONS

3.3.1 Land preparation

The land was ploughed once with the help of a tractor after the harvest of previous crop. This was followed by harrowing thrice and smoothening with wooden plank to prepare a fine seed bed. Plots were laidout as per the plan well in advance of sowing of cotton.

3.3.2 Fertilizer application

Recommended dose of fertilizer (80:40:40 kg N, P_2O_5, K_2O ha^{-1}) was applied to hybrid cotton. All phosphorus, potassium and 50 per cent nitrogen was applied after germination in ring method and remaining 50 per cent nitrogen was applied at flowering.

3.3.3 Seeds and sowing

Healthy seeds of cotton hybrid DHH-11 was sown on 14th July 2005 by hand dibbling. Seeds were spaced 90 cm from row to row and 60 cm from plant to plant within the rows. To ensure better population, three to four seeds were sown at each hill and at about 16-18 days after sowing (DAS) 1st thinning was done leaving 2 seedlings per hill. Final thinning was done at about 25 DAS to maintain only one seedling per hill.

3.3.4 After care

3.3.4.1 Intercultivation and hand weeding

Thrice hand weeding at 30, 60 and 90 DAS were carried out during the crop growth period. Intercultivation was taken up once before first weeding and second one before second weeding.

3.3.4.2 Plant protection measures

The schedule of plant protection measures taken up during the crop growth period.

3.3.5 Cotton pickings

Harvesting of seed cotton in net plot and border was done separately in 3 pickings *viz.*, 4/1/2006, 3/2/2006 and 7/3/2006.

L E G E N D

T_1-Calmax spray @ 3 l ha^{-1} once at square formation

T_2-Calmax spray @ 3 l ha^{-1} twice equally at square formation and flower initiation

T_3-Calmax spray @ 3 l ha^{-1} thrice equally at square formation, flower initiation and peak flowering

T_4-Calmax spray @ 3 l ha^{-1} once at peak flowering

T_5-Calmax spray @ 6 l ha^{-1} once at square formation

T_6-Calmax spray @ 6 l ha^{-1} twice equally at square formation and flower initiation

T_7-Calmax spray @ 6 l ha^{-1} thrice equally at square formation, flower initiation and peak flowering

T_8-Calmax spray @ 6 l ha^{-1} once at peak flowering

T_9-Calmax spray @ 9 l ha^{-1} once at square flowering

T_{10}-Calmax spray @ 9 l ha^{-1} twice equally at square formation and flower initiation

T_{11}-Calmax spray @ 9 l ha^{-1} thrice equally at square formation, flower initiation and peak flowering

T_{12}-Calmax spray @ 9 l ha^{-1} once at peak flowering

T_{13}-Urea + Planofix (as per the recommendation)

T_{14}-Control (water spray)

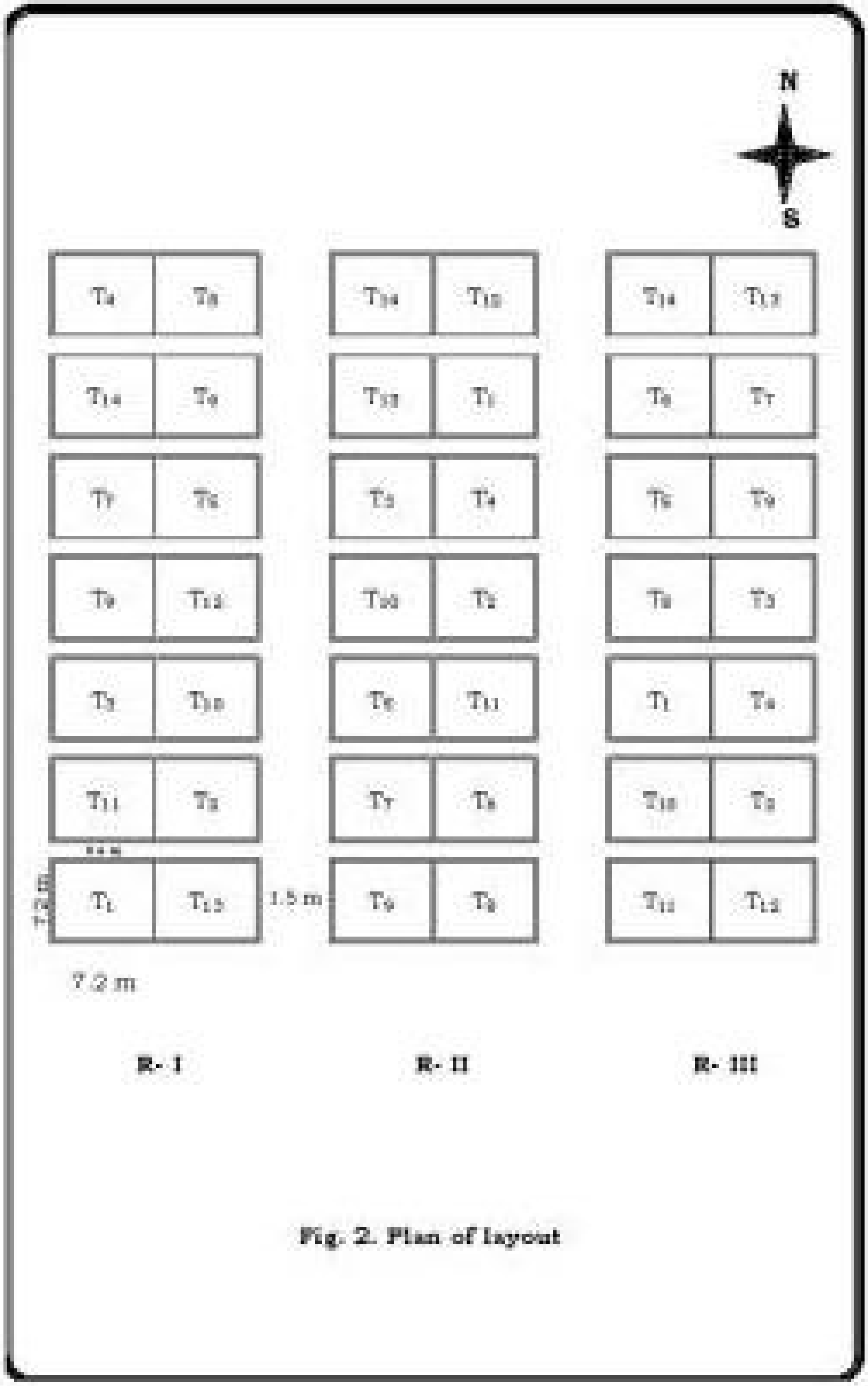

Fig.2. Plan of layout

Plate 1. General view of experimental plot at flower initiation stage

Plate 1. General view of experimental plot at flower initiation stage

Plate 2. General view of experimental plot at boll opening stage

Plate 2. General view of experimental plot at boll opening stage

3.4 COLLECTION OF EXPERIMENTAL OBSERVATIONS

3.4.1 Sampling procedure

In each treatment, from net plot, 5 plants of cotton were randomly selected and tagged. The observations on growth components at different growth stages and yield components at harvest were recorded.

3.4.2 Growth components

3.4.2.1 Plant height

The height of five plants at different stages in all the treatment were measured from the base of the plant to the tip of the main stem of randomly tagged plants and expressed in centimeters (cm) as the average per plant.

3.4.2.2 Number of monopodial branches per plant

The total number of monopodial branches produced per plant counted at different stages of five randomly tagged plants in all the treatment. The mean of five plants was recorded as number of monopodial branches per plant.

3.4.2.3 Number of sympodial branches per plant

The total number of fruiting branches per plant was counted at different stages of five randomly tagged plants in all the treatments. The mean of five plants was recorded as number of sympodial branches per plant.

3.4.2.4 Dry matter production and distribution

The five randomly selected plants from destructive sampling area were used to record the dry matter production at different crop growth stages. The sampled plants were separated into leaves, stem and reproductive parts. These samples were oven dried at 65° to 70℃ to a constant weight. Dry weight was recorded separately at each stage for calculating dry matter accumulation in different parts and total dry matter production which expressed in grams per plant.

3.4.2.5 Absolute growth rate (AGR)

The absolute growth rate was calculated by using the formula of Radford (1967) and expressed in g day^{-1}.

$$AGR = \frac{W_2 - W_1}{t_2 - t_1} \quad (g\ day^{-1})$$

Where,

W_1 and W_2 = Total dry weights of plants at time t_1 and t_2 respectively

3.4.2.6 Crop growth rate (CGR)

Crop growth rate is defined as the rate of dry matter accumulation per unit ground area (Watson, 1952) and expressed as g m^{-2} day^{-1}. It was calculated by using the following formula.

$$CGR = \frac{1}{P} \text{ X } \frac{W_2 - W_1}{T_2 - t_1} \quad (g\ m^{-2}\ day^{-1})$$

Where,

W_1 and W_2 = The dry weight per m^2 land area at time t_1 and t_2 respectively

P = Land area

3.4.2.7 Relative growth rate (RGR)

Relative growth rate is the increase in dry weight per unit dry weight per unit time and is expressed as $g\ g^{-1}\ day^{-1}$ and calculated by the formula of Radford (1967) as follows.

$$RGR = \frac{\log_e W_2 - \log_e W_1}{t_2 - t_1} \quad (g\ g^{-1}\ day^{-1})$$

Where,

W_1 and W_2 = Total dry weights of plant at time t_1 and t_2 respectively

3.4.2.8 Net assimilation rate (NAR)

Net assimilation rate is the rate of increase in dry weight per unit leaf area per unit time (Watson, 1952) and is expressed as $g\ dm^{-2}\ day^{-1}$. It was calculated by the formula of Radford (1967) as follows.

$$NAR = \frac{(W_2 - W_1)\ (\log_e L_2 - \log_e L_1)}{(t_2 - t_1)\ (L_2 - L_1)} \quad (g\ dm^{-2}\ day^{-1})$$

Where,

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

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

3.4.2.9 Leaf area (LA)

Leaf area was measured by disc method as suggested by Vivekanandan *et al.* (1972). Fifty leaf discs of known size were taken using the cork borer from five plants. Both discs and remaining leaf blades were oven dried at 70°C. The leaf area was calculated by using the following formula at different growth stages of crop growth.

$$LA = \frac{Wa \times A}{Wd}$$

Where,

LA = Leaf area (dm^2/plant)

Wa = Weight of all leaves (inclusive of 50 disc weight) in grams

Wd = Weight of 50 discs (g)

A = Area of 50 disc in dm^2

3.4.2.10 Leaf area index (LAI)

The leaf area index was calculated at different growth stages manually following method suggested by Sestak *et al.* (1971).

$$LAI = \frac{\text{Leaf area per plant } (dm^2)}{\text{Land area covered by individual plant } (dm^2)}$$

3.5 YIELD AND YIELD ATTRIBUTES

3.5.1 Number of squares per plant

Total number of squares was recorded from five tagged plants at different growth stages in all the treatments. Mean of these five plants was taken as number of squares produced per plant.

3.5.2 Number of flowers per plant

Total number of flowers were recorded from five tagged plants at different growth stages of crop growth in all the treatments. Mean of these five plants was taken as number of flowers per plant.

3.5.3 Number of green bolls per plant

Total number of green bolls were recorded from five tagged plants at different growth stages in all the treatments. The mean of five plants was taken as number of green bolls per plant.

3.5.4 Number of harvested bolls per plant

The bolls to be picked from the five tagged plants of each treatment were counted during all the three pickings. To obtain number of bolls picked per plant, the total number of bolls picked was divided by the number of plants form which the bolls were picked and the result is expressed as the number of harvested bolls per plant.

3.5.5 Mean boll weight

Seed cotton obtained from 10 randomly selected bolls from net plot covering top to bottom in each picking were weighed. The mean boll weight was worked and expressed in grams.

3.5.6 Seed cotton yield per plant

Seed cotton from the five tagged plants was picked separately at each picking. Seed cotton yield per plant was obtained by adding cotton yield of all pickings and was expressed in grams.

3.5.7 Seed cotton yield per hectare

Seed cotton from the net plot was picked separately from each treatment. Seed cotton every time and yield per hectare was worked out based on the net plot yield (including 5 random plants and ten bolls) of all the three pickings and expressed in kg per ha.

3.5.8 Seed index

Seed index is the weight of 100 seeds of cotton. After ginning 100 seeds were randomly taken and their weight was recorded in grams.

3.5.9 Harvest index

Harvest index was calculated by using the formula of Donald (1962) and expressed as per cent.

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

3.5.10 Ginning percentage

Seed cotton obtained of all pickings from each treatment net plot was mixed thoroughly. A representative sample of 300 grams from each treatment net plot for taken was ginning. Ginning percentage was calculated by using the following formula.

$$\text{Ginning percentage} = \frac{\text{Weight of lint (g)}}{\text{Weight of seed cotton (g)}} \times 100$$

3.6 STATISTICAL ANALYSIS

Fisher's method of analysis of variance was applied for the analysis of the data and interpretation of the results as suggested by Panse and Sukhatme (1967). The level of significance used in 'F' and 't' tests was P=0.05. Critical differences (CD) value were calculated at 5 per cent probability level, wherever 'F' test was significant.

Correlation analysis was carried out to study the nature and degrees of relationship between morphological, physiological, growth parameters as well as yield and yield components following the method of Panse and Sukhatme (1967).

IV. EXPERIMENTAL RESULTS

A field experiment was conducted during *kharif* 2005 to study the effect of calmax, a foliar micronutrient fertilizer on growth and yield of hybrid cotton under northern transitional zone of Karnataka at Main Agricultural Research Station, University of Agricultural Sciences, Dharwad. The results obtained in the present investigation were presented in this chapter.

4.1 GROWTH PARAMETERS

4.1.1 Plant height (cm)

The data on plant height recorded at different stages of crop growth (square formation, flower initiation, peak flowering, boll formation and harvest) as influenced by various treatments of calmax spray were presented in Table 3.

Plant height differed significantly in all the growth stages of crop except at square formation and flower initiation stage.

At peak flowering stage, application of calmax @ 9 l ha^{-1} thrice equally at square formation, flower initiation and peak flowering stages resulted in significantly higher plant height (75.20 cm) over other treatments. But it was on par with T_{10}, T_7, T_6, T_3 and T_2 treatments.

At boll formation stage, plant height was significantly higher (119.73 cm) with clamax @ 9 l ha^{-1} sprayed, thrice equally formation, flower initiation and peak flowering stages which was on par with T_{13}, T_7, T_{10}, T_3, T_6 and T_{12}. However control (water spray) recorded significantly lower plant height (96.57 cm).

At harvest, calmax sprayed @ 9 l ha^{-1} thrice equally at square formation, flower initiation and peak flowering stages recorded significantly higher plant height (123.87 cm) over rest of the treatments. But it was on par with T_{13}, T_7, T_{10} and T_3. The lowest plant height (99.43 cm) was recorded with control (water spray).

4.1.2 Number of monopodial branches per plant

The data pertaining to the number of monopodial branches per plant at different stages of crop growth (at flower initiation, peak flowering, boll formation and at harvest) as influenced by various treatments were presented in Table 4.

The effect of foliar application of calmax on the number of monopodial branches per plant was not significant at all the growth stages.

4.1.3 Number of sympodial branches per plant

The data on the number of sympodial branches per plant at different stage of crop growth (flower initiations, peak flowering, boll formation and at harvest) as influenced by various treatments were furnished in Table 5 and Fig. 3.

At peak flowering stage, application of calmax @ 9 l ha^{-1} equally thrice at square formation, flower initiation and peak flowering stages recorded significantly more number of sympodial branches (20.70) per plant over other treatments. But it was on par with T_{10}, T_7 and T_6, whereas the lowest (12.66) number of sympodial branches per plant was recorded with calmax @ 3 l ha^{-1} sprayed once at peak flowering stage but it was on par with control (water spray).

At boll formation stage, significantly higher number of sympodial branches per plant (29.46) were recorded with calmax sprayed @ 9 l ha^{-1} equally thrice at square formation, flower initiation and peak flowering stages compared to all other treatments which was on par with T_7, T_{13} and T_{10}. However, lower number of sympodial branches per plant (19.80) were observed with control (water spray).

At harvest, the number of sympodial branches per plant was significant with the application of calmax @ 9 l ha^{-1} at square formation, flower initiation and peak flowering stages (32.20) over rest of the treatments. It was on par with T_7, T_{13} and T_{10}, whereas control (water spray) recorded the lowest number of sympodial branches per plant (22.53).

Table 3. Plant height (cm) at different growth stages of hybrid cotton (DHH-11) as influenced by foliar application of calmax

Treatments	At square formation	At flower initiation	At peak flowering	At boll formation	At harvest
T_1-Calmax spray @ 3 l ha^{-1} once at square formation	19.13	45.33	65.02	107.86	109.00
T_2-Calmax spray @ 3 l ha^{-1} twice equally at square formation and flower initiation	18.14	45.86	69.44	109.75	111.38
T_3-Calmax spray @ 3 l ha^{-1} thrice equally at square formation, flower initiation and peak flowering	21.21	45.53	69.50	111.27	115.66
T_4-Calmax spray @ 3 l ha^{-1} once at peak flowering	21.31	44.53	59.04	106.13	107.61
T_5-Calmax spray @ 6 l ha^{-1} once at square formation	19.32	47.40	66.34	108.62	109.81
T_6-Calmax spray @ 6 l ha^{-1} twice equally at square formation and flower initiation	20.34	47.13	72.43	110.66	113.43
T_7-Calmax spray @ 6 l ha^{-1} thrice equally at square formation, flower initiation and peak flowering	21.51	47.86	73.20	116.93	120.13
T_8-Calmax spray @ 6 l ha^{-1} once at peak flowering	22.43	44.42	59.92	108.01	109.00
T_9-Calmax spray @ 9 l ha^{-1} once at square flowering	21.32	49.86	69.83	108.24	109.12
T_{10}-Calmax spray @ 9 l ha^{-1} twice equally at square formation and flower initiation	19.18	49.26	75.06	115.17	117.48
T_{11}-Calmax spray @ 9 l ha^{-1} thrice equally at square formation, flower initiation and peak flowering	19.23	49.50	75.20	119.73	123.87
T_{12}-Calmax spray @ 9 l ha^{-1} once at peak flowering	20.81	44.00	59.23	110.43	112.65
T_{13}-Urea + Planofix (as per the recommendation)	20.14	44.89	60.36	116.65	119.91
T_{14}-Control (water spray)	19.11	44.17	59.43	96.57	99.43
S.Em±	1.56	8.79	1.79	2.89	2.88
CD at 5%	NS	NS	5.21	8.39	8.38

Table 4. Number of monopodial branches per plant in hybrid cotton (DHH-11) as influenced by foliar application of calmax

Treatments	At flower initiation	At peak flowering	At boll formation	At harvest
T_1-Calmax spray @ 3 l ha^{-1} once at square formation	1.20	2.80	2.80	3.20
T_2-Calmax spray @ 3 l ha^{-1} twice equally at square formation and flower initiation	1.20	2.80	2.93	3.26
T_3-Calmax spray @ 3 l ha^{-1} thrice equally at square formation, flower initiation and peak flowering	1.26	2.93	3.06	3.33
T_4-Calmax spray @ 3 l ha^{-1} once at peak flowering	1.20	2.80	2.80	3.26
T_5-Calmax spray @ 6 l ha^{-1} once at square formation	1.26	2.80	2.86	3.26
T_6-Calmax spray @ 6 l ha^{-1} twice equally at square formation and flower initiation	1.33	2.86	3.00	3.13
T_7-Calmax spray @ 6 l ha^{-1} thrice equally at square formation, flower initiation and peak flowering	1.36	3.00	3.26	3.40
T_8-Calmax spray @ 6 l ha^{-1} once at peak flowering	1.20	2.60	2.86	3.20
T_9-Calmax spray @ 9 l ha^{-1} once at square flowering	1.33	2.80	2.86	3.13
T_{10}-Calmax spray @ 9 l ha^{-1} twice equally at square formation and flower initiation	1.32	2.86	3.00	3.33
T_{11}-Calmax spray @ 9 l ha^{-1} thrice equally at square formation, flower initiation and peak flowering	1.40	3.06	3.13	3.46
T_{12}-Calmax spray @ 9 l ha^{-1} once at peak flowering	1.20	2.86	3.00	3.26
T_{13}-Urea + Planofix (as per the recommendation)	1.21	2.93	3.00	3.36
T_{14}-Control (water spray)	1.20	2.73	1.80	3.12
S.Em±	1.17	0.25	0.30	0.32
CD at 5%	NS	NS	NS	NS

Table 5. Number of sympodial branches per plant at different growth stages of hybrid cotton (DHH-11) as influenced by foliar application of calmax

Treatments	At flower initiation	At peak flowering	At boll formation	At harvest
T_1-Calmax spray @ 3 l ha^{-1} once at square formation	8.26	15.46	23.20	27.46
T_2-Calmax spray @ 3 l ha^{-1} twice equally at square formation and flower initiation	8.20	18.20	25.86	27.93
T_3-Calmax spray @ 3 l ha^{-1} thrice equally at square formation, flower initiation and peak flowering	8.43	18.00	26.46	29.13
T_4-Calmax spray @ 3 l ha^{-1} once at peak flowering	7.80	12.66	23.00	27.26
T_5-Calmax spray @ 6 l ha^{-1} once at square formation	8.60	16.06	25.46	27.66
T_6-Calmax spray @ 6 l ha^{-1} twice equally at square formation and flower initiation	8.66	19.46	26.46	28.33
T_7-Calmax spray @ 6 l ha^{-1} thrice equally at square formation, flower initiation and peak flowering	8.86	19.73	27.93	31.26
T_8-Calmax spray @ 6 l ha^{-1} once at peak flowering	7.80	15.13	23.33	27.56
T_9-Calmax spray @ 9 l ha^{-1} once at square flowering	9.13	17.60	23.66	27.60
T_{10}-Calmax spray @ 9 l ha^{-1} twice equally at square formation and flower initiation	9.26	19.96	26.80	30.90
T_{11}-Calmax spray @ 9 l ha^{-1} thrice equally at square formation, flower initiation and peak flowering	9.06	20.70	29.46	32.20
T_{12}-Calmax spray @ 9 l ha^{-1} once at peak flowering	7.80	15.43	26.06	28.20
T_{13}-Urea + Planofix (as per the recommendation)	7.66	18.46	27.86	31.20
T_{14}-Control (water spray)	7.53	13.33	19.80	22.53
S.Em±	0.47	0.66	0.90	0.83
CD at 5%	NS	1.93	2.62	2.43

L E G E N D

T_1-Calmax spray @ 3 l ha^{-1} once at square formation

T_2-Calmax spray @ 3 l ha^{-1} twice equally at square formation and flower initiation

T_3-Calmax spray @ 3 l ha^{-1} thrice equally at square formation, flower initiation and peak flowering

T_4-Calmax spray @ 3 l ha^{-1} once at peak flowering

T_5-Calmax spray @ 6 l ha^{-1} once at square formation

T_6-Calmax spray @ 6 l ha^{-1} twice equally at square formation and flower initiation

T_7-Calmax spray @ 6 l ha^{-1} thrice equally at square formation, flower initiation and peak flowering

T_8-Calmax spray @ 6 l ha^{-1} once at peak flowering

T_9-Calmax spray @ 9 l ha^{-1} once at square flowering

T_{10}-Calmax spray @ 9 l ha^{-1} twice equally at square formation and flower initiation

T_{11}-Calmax spray @ 9 l ha^{-1} thrice equally at square formation, flower initiation and peak flowering

T_{12}-Calmax spray @ 9 l ha^{-1} once at peak flowering

T_{13}-Urea + Planofix (as per the recommendation)

T_{14}-Control (water spray)

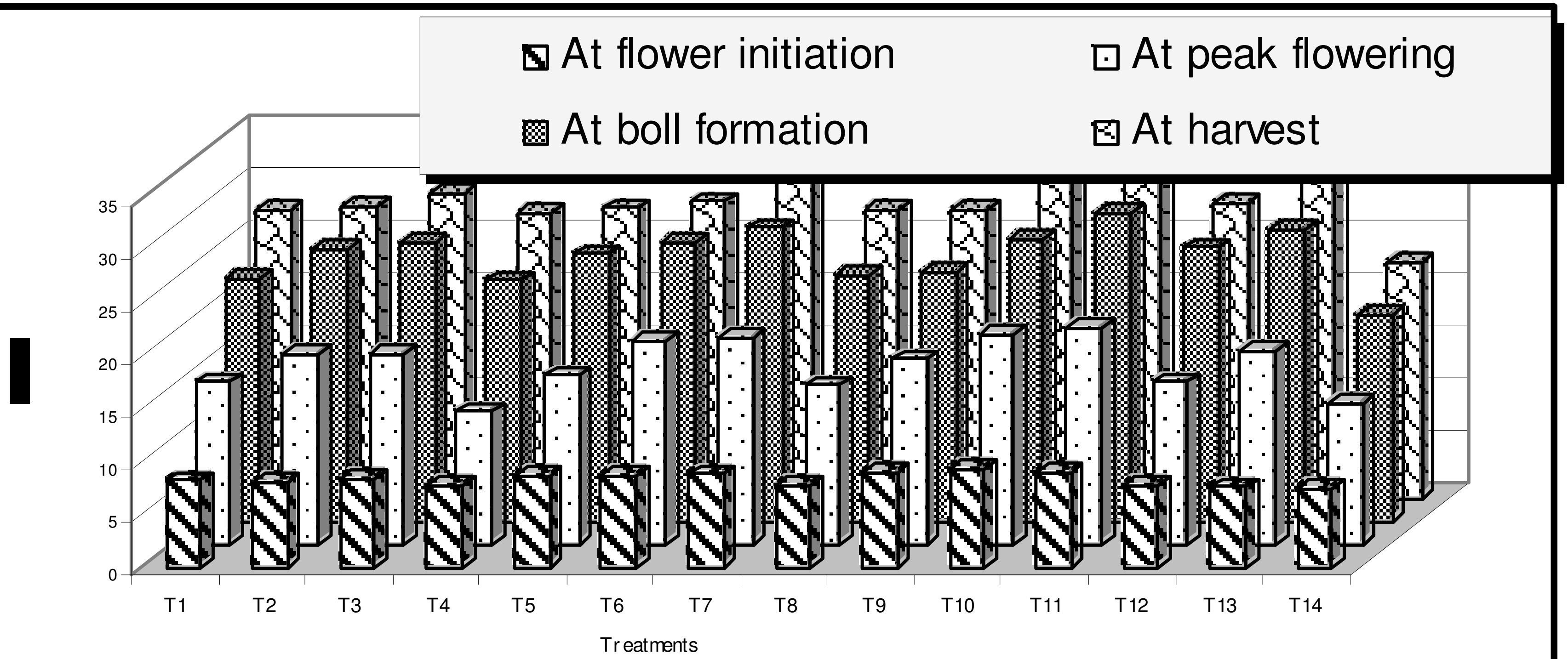

Fig. 3. Number of sympodial branches per plant at different growth stages of hybrid cotton (DHH-11) as influenced by foliar application of calmax

Fig. 3. Number of sympodial branches per plant at different growth stages of hybrid cotton (DHH-11) as influenced by foliar application of calmax

4.1.4 Leaf area (dm^2 $plant^{-1}$)

The data regarding leaf area at different stages of crop growth (at square formation, flower initiation, peak flowering, boll formation and at harvest) as influenced by various treatments were presented in Table 6.

Leaf area per plant increased as the growth stages advances and it was maximum at boll formation stage and there after it declined.

The differences in leaf area per plant was not significant at square formation stage, whereas the treatments differed significantly at flower initiation stage, peak flowering stage, boll formation stage and at harvest.

Leaf area per plant at flower initiation stage was significantly higher (42.64 dm^2) with the application of calmax @ 9 l ha^{-1} equally thrice at square formation, flower initiation and peak flowering stages compared to rest of the treatments which was on par with the T_2, T_3, T_6, T_7, T_{10} and T_{13}. The lowest leaf area per plant (32.16 dm^2) was recorded with clamax @ 6 l ha^{-1} once at peak flowering stage and it was on par with control (water spray).

At peak flowering stage, foliar application of calmax @ 9 l ha^{-1} sprayed equally thrice at square formation, flower initiation and peak flowering stages were registered significantly higher leaf area (76.69 dm^2) compared to rest of the treatments. But which was on par with T_7, T_{10} and T_{13} and lowest leaf area per plant (53.72 dm^2) was recorded with control (water spray).

At boll formation stage, leaf area per plant differed significantly due to foliar application of calmax in different doses and stages. Highest leaf area (135.17 dm^2) was registered with application of calmax @ 9 l ha^{-1} equally thrice at square formation, flower initiation and peak flowering stages and it was on par with T_7, T_{10} and T_{13}. The control (water spray) recorded the lowest (95.25 dm^2) leaf area per plant.

At harvest, application of calmax @ 9 l ha^{-1} equally thrice at square formation, flower initiation and peak flowering stages were recorded significantly higher leaf area per plant (36.81 dm^2) followed by T_7 and T_{13} and remaining treatments were found to be on par with each other. However, the lowest leaf area per plant (27.12 dm^2) was recorded with control (water spray).

4.1.5 Leaf area index (LAI)

The data pertaining to leaf area index was recorded at different stages of crop growth (at square formation, flower initiation, peak flowering, boll formation and at harvest) as influenced by various treatments were presented in Table 7.

At square formation stage, there was no significant differences among the different treatments. However, marginally higher leaf area index (0.33) was recorded in calmax spray @ 9 l ha^{-1} once at square formation stage. At flower initiation stage, among various treatments, calmax @ 9 l ha^{-1} sprayed equally thrice at squares formation, flower initiation and peak flowering stages recorded significantly higher leaf area index (0.79) followed by T_{11}, T_6, T_7, T_3 and T_2. Significantly lower leaf area index (0.59) was recorded with calmax spray @ 3 l ha^{-1} once at peak flowering stage.

At peak flowering stage, the foliar application of calmax @ 9 l ha^{-1} sprayed equally thrice at square formation, flower initiation and peak flowering stages registered significantly highest leaf area index (1.42) which was on par with T_7, T_{11} and T_{13}. However, lower leaf area index (0.99) was recorded with control (water spray).

At boll formation stage, leaf area index differed significantly due to foliar application of calmax in different doses and time. Calmax sprayed @ 9 l ha^{-1} equally thrice at square formation, flower initiation and peak flowering stages indicated significantly higher leaf area index (2.50) followed by T_7, T_{13} and T_{10}. Whereas control (water spray) recorded lowest leaf area index (1.76) and remaining treatments are on par with each other.

At harvest, significantly higher leaf area index (0.90) was registered with calmax sprayed @ 9 l ha^{-1} equally thrice at square formation, flower initiation and peak flowering stages compared to other treatments but was on par with T_7. While significantly lower leaf area index (0.54) was recorded with control (water spray).

Table 6. Leaf area per plant (dm^2) at different growth stages of hybrid cotton (DHH-11) as influenced by foliar application of calmax

Treatments	At square formation	At flower initiation	At peak flowering	At boll formation	At harvest
T_1-Calmax spray @ 3 l ha^{-1} once at square formation	15.84	38.64	56.86	110.75	29.42
T_2-Calmax spray @ 3 l ha^{-1} twice equally at square formation and flower initiation	15.71	40.13	62.87	120.81	33.23
T_3-Calmax spray @ 3 l ha^{-1} thrice equally at square formation, flower initiation and peak flowering	14.89	40.68	67.08	126.56	34.57
T_4-Calmax spray @ 3 l ha^{-1} once at peak flowering	13.79	32.16	54.95	105.23	29.17
T_5-Calmax spray @ 6 l ha^{-1} once at square formation	16.22	39.52	60.08	117.08	33.01
T_6-Calmax spray @ 6 l ha^{-1} twice equally at square formation and flower initiation	15.78	41.21	66.48	124.87	34.26
T_7-Calmax spray @ 6 l ha^{-1} thrice equally at square formation, flower initiation and peak flowering	16.73	41.72	73.99	132.69	35.98
T_8-Calmax spray @ 6 l ha^{-1} once at peak flowering	14.45	32.16	57.90	113.14	30.24
T_9-Calmax spray @ 9 l ha^{-1} once at square flowering	16.82	39.57	59.72	115.67	32.91
T_{10}-Calmax spray @ 9 l ha^{-1} twice equally at square formation and flower initiation	16.28	42.39	68.57	129.72	34.96
T_{11}-Calmax spray @ 9 l ha^{-1} thrice equally at square formation, flower initiation and peak flowering	15.50	42.64	76.69	135.17	36.81
T_{12}-Calmax spray @ 9 l ha^{-1} once at peak flowering	15.79	33.14	64.75	123.93	33.67
T_{13}-Urea + Planofix (as per the recommendation)	14.81	40.53	71.80	131.21	35.72
T_{14}-Control (water spray)	15.25	32.49	53.72	95.25	27.12
S.Em±	0.96	1.06	2.92	2.45	0.76
CD at 5%	NS	3.09	8.50	7.12	2.22

Table 7. Leaf area index (LAI) at different growth stages of hybrid cotton (DHH-11) as influenced by foliar application of calmax

Treatments	At square formation	At flower initiation	At peak flowering	At boll formation	At harvest
T_1-Calmax spray @ 3 l ha^{-1} once at square formation	0.29	0.71	1.05	2.05	0.60
T_2-Calmax spray @ 3 l ha^{-1} twice equally at square formation and flower initiation	0.29	0.74	1.16	2.23	0.61
T_3-Calmax spray @ 3 l ha^{-1} thrice equally at square formation, flower initiation and peak flowering	0.27	0.75	1.24	2.34	0.64
T_4-Calmax spray @ 3 l ha^{-1} once at peak flowering	0.25	0.59	1.01	1.94	0.62
T_5-Calmax spray @ 6 l ha^{-1} once at square formation	0.30	0.73	1.11	2.16	0.61
T_6-Calmax spray @ 6 l ha^{-1} twice equally at square formation and flower initiation	0.31	0.76	1.23	2.31	0.63
T_7-Calmax spray @ 6 l ha^{-1} thrice equally at square formation, flower initiation and peak flowering	0.30	0.76	1.37	2.47	0.87
T_8-Calmax spray @ 6 l ha^{-1} once at peak flowering	0.26	0.59	1.07	2.09	0.56
T_9-Calmax spray @ 9 l ha^{-1} once at square flowering	0.33	0.73	1.10	2.14	0.60
T_{10}-Calmax spray @ 9 l ha^{-1} twice equally at square formation and flower initiation	0.30	0.78	1.26	2.40	0.78
T_{11}-Calmax spray @ 9 l ha^{-1} thrice equally at square formation, flower initiation and peak flowering	0.28	0.79	1.42	2.50	0.90
T_{12}-Calmax spray @ 9 l ha^{-1} once at peak flowering	0.29	0.61	1.19	2.29	0.62
T_{13}-Urea + Planofix (as per the recommendation)	0.27	0.74	1.32	2.42	0.84
T_{14}-Control (water spray)	0.28	0.60	0.99	1.76	0.54
S.Em±	0.02	0.02	0.05	0.04	0.01
CD at 5%	NS	0.05	0.16	0.12	0.04

4.1.6 Absolute growth rate (g day^{-1})

The data on absolute growth rate (AGR) of cotton recorded at different growth stages as influenced by various treatments were present in Table 8.

The absolute growth rate followed an increasing trend in the initial stages of crop growth and decreasing trend at later stages.

At 45-75 DAS, significantly higher AGR was noticed in the treatment calmax spray @ 9 l ha^{-1} equally twice at square formation, flower initiation stages (0.927 g day^{-1}) followed by T_{11}, T_6, T_7 and T_9. Significantly lower AGR was found in urea + planofix spray as per recommendation (0.651 g day^{-1}).

At 75-105 DAS, AGR differed significantly with calmax spray at different doses and time of application. Application of calmax spray @ 9 l ha^{-1} equally thrice at square formation, flower initiation and peak flowering stages resulted in significantly higher AGR (1.583 g day^{-1}) and it was on par with almost all treatments except T_4 (calmax spray @ 3 l ha^{-1} once at peak flowering stage) (1.310 g day^{-1}).

At 105-135 DAS, calmax spray @ 9 l ha^{-1} equally thrice at square formation, flower initiation and peak flowering stages recorded significantly higher AGR (1.273 g day^{-1}) over control (water spray) (0.970 g day^{-1}). But it was on par with T_{13}, T_{12}, T_8, T_7, T_5, T_4 and T_3.

At 135, at harvest there was no significant differences among the treatments. However, marginally higher AGR was observed with calmax spray @ 9 l ha^{-1} equally thrice at square formation, flower initiation and peak flowering stages (0.825 g day^{-1}).

4.1.7 Crop growth rate (g m^{-2} day^{-1})

The date on crop growth at various growth stages as influenced by various treatments were presented in Table 9.

CGR increased from 45-75 DAS and was maximum at 75-105 DAS and decrease thereafter. There was significant differences between the treatments only at 45-75, 75-105 and 105-135 DAS.

Between 45-75 DAS, significantly higher CGR was noticed in calmax spray @ 9 l ha^{-1} equally twice at square formation and flower initiation stages (1.717 g m^{-2} day^{-1}). But it was on par with T_{11}, T_9, T_5, T_6 and T_7. Whereas lower CGR was recorded with control (water spray) (1.131 g m^{-2} day^{-1}).

Between 75-105 DAS, urea + planofix spray (as per recommendation) (3.122 g m^{-2} day^{-1}) recorded significantly higher CGR. But it was on par with T_{11}, T_{10}, T_6, T_7, T_2 and T_3. however, lowest CGR was observed with calmax spray @ 9 l ha^{-1} once at peak flowering stage (2.429 g m^{-2} day^{-1}).

Between 105-135 DAS, calmax spray @ 9 l ha^{-1} equally thrice at square formation, flower initiation and peak flowering stages (2.358 g m^{-2} day^{-1}) found significantly higher CGR. However, it was on par with T_{13}, T_7, T_8, T_{12}, T_3 and T_4, whereas control (water spray) recorded least CGR (1.619 g m^{-2} day^{-1}).

4.1.8 Relative growth rate (g g^{-1} day^{-1})

The data pertaining to the relative growth rate of cotton at different growth stages as influenced by various treatments were presented in Table 10. The RGR decreased with the age of the crop.

The effect of foliar application of calmax on the relative growth rate was not significant at all the growth stages.

Table 8. Absolute growth rate (AGR, g day^{-1}) at different growth stages of hybrid cotton (DHH-11) as influenced by foliar application of calmax

Treatments	45-75	75-105	105-135	135-at harvest
T_1-Calmax spray @ 3 l ha^{-1} once at square formation	0.802	1.433	0.926	0.800
T_2-Calmax spray @ 3 l ha^{-1} twice equally at square formation and flower initiation	0.810	1.485	0.999	0.793
T_3-Calmax spray @ 3 l ha^{-1} thrice equally at square formation, flower initiation and peak flowering	0.796	1.474	1.082	0.782
T_4-Calmax spray @ 3 l ha^{-1} once at peak flowering	0.692	1.310	1.100	0.770
T_5-Calmax spray @ 6 l ha^{-1} once at square formation	0.795	1.339	1.026	0.795
T_6-Calmax spray @ 6 l ha^{-1} twice equally at square formation and flower initiation	0.909	1.559	0.874	0.783
T_7-Calmax spray @ 6 l ha^{-1} thrice equally at square formation, flower initiation and peak flowering	0.891	1.564	1.179	0.815
T_8-Calmax spray @ 6 l ha^{-1} once at peak flowering	0.696	1.327	1.175	0.770
T_9-Calmax spray @ 9 l ha^{-1} once at square flowering	0.864	1.404	0.997	0.766
T_{10}-Calmax spray @ 9 l ha^{-1} twice equally at square formation and flower initiation	0.927	1.581	0.911	0.771
T_{11}-Calmax spray @ 9 l ha^{-1} thrice equally at square formation, flower initiation and peak flowering	0.911	1.583	1.273	0.825
T_{12}-Calmax spray @ 9 l ha^{-1} once at peak flowering	0.711	1.312	1.161	0.771
T_{13}-Urea + Planofix (as per the recommendation)	0.651	1.686	1.215	0.802
T_{14}-Control (water spray)	0.727	1.349	0.970	0.718
S.Em±	0.032	0.081	0.075	0.151
CD at 5%	0.094	0.235	0.217	NS

Table 9. Crop growth rate (CGR, g m^{-2} day^{-1}) at different growth stages of hybrid cotton (DHH-11) as influenced by foliar application of calmax

Treatments	45-75	75-105	105-135	135-at harvest
T_1-Calmax spray @ 3 l ha^{-1} once at square formation	1.486	2.654	1.715	1.482
T_2-Calmax spray @ 3 l ha^{-1} twice equally at square formation and flower initiation	1.501	2.749	1.851	1.470
T_3-Calmax spray @ 3 l ha^{-1} thrice equally at square formation, flower initiation and peak flowering	1.472	2.730	2.005	1.448
T_4-Calmax spray @ 3 l ha^{-1} once at peak flowering	1.283	2.488	1.985	1.426
T_5-Calmax spray @ 6 l ha^{-1} once at square formation	1.688	2.479	1.901	.472
T_6-Calmax spray @ 6 l ha^{-1} twice equally at square formation and flower initiation	1.683	2.887	1.788	1.451
T_7-Calmax spray @ 6 l ha^{-1} thrice equally at square formation, flower initiation and peak flowering	1.651	2.896	2.185	1.510
T_8-Calmax spray @ 6 l ha^{-1} once at peak flowering	1.289	2.457	2.176	1.427
T_9-Calmax spray @ 9 l ha^{-1} once at square flowering	1.600	2.600	1.847	1.419
T_{10}-Calmax spray @ 9 l ha^{-1} twice equally at square formation and flower initiation	1.717	2.927	1.688	1.427
T_{11}-Calmax spray @ 9 l ha^{-1} thrice equally at square formation, flower initiation and peak flowering	1.688	2.931	2.358	1.528
T_{12}-Calmax spray @ 9 l ha^{-1} once at peak flowering	1.317	2.429	2.150	1.428
T_{13}-Urea + Planofix (as per the recommendation)	1.221	3.122	2.250	1.486
T_{14}-Control (water spray)	1.131	2.498	1.619	1.331
S.Em±	0.060	0.150	0.150	0.280
CD at 5%	0.174	0.435	0.436	NS

Table 10. Relative growth rate (RGR, g g^{-1} day^{-1}) at different growth stages of hybrid cotton (DHH-11) as influenced by foliar application of calmax

Treatments	45-75	75-105	105-135	135-at harvest
T_1-Calmax spray @ 3 l ha^{-1} once at square formation	0.041	0.027	0.010	0.007
T_2-Calmax spray @ 3 l ha^{-1} twice equally at square formation and flower initiation	0.043	0.027	0.011	0.006
T_3-Calmax spray @ 3 l ha^{-1} thrice equally at square formation, flower initiation and peak flowering	0.040	0.027	0.012	0.007
T_4-Calmax spray @ 3 l ha^{-1} once at peak flowering	0.036	0.027	0.012	0.007
T_5-Calmax spray @ 6 l ha^{-1} once at square formation	0.044	0.024	0.011	0.006
T_6-Calmax spray @ 6 l ha^{-1} twice equally at square formation and flower initiation	0.044	0.027	0.009	0.007
T_7-Calmax spray @ 6 l ha^{-1} thrice equally at square formation, flower initiation and peak flowering	0.042	0.027	0.012	0.006
T_8-Calmax spray @ 6 l ha^{-1} once at peak flowering	0.036	0.027	0.013	0.006
T_9-Calmax spray @ 9 l ha^{-1} once at square flowering	0.043	0.026	0.011	0.006
T_{10}-Calmax spray @ 9 l ha^{-1} twice equally at square formation and flower initiation	0.045	0.027	0.009	0.006
T_{11}-Calmax spray @ 9 l ha^{-1} thrice equally at square formation, flower initiation and peak flowering	0.043	0.027	0.011	0.006
T_{12}-Calmax spray @ 9 l ha^{-1} once at peak flowering	0.037	0.027	0.014	0.007
T_{13}-Urea + Planofix (as per the recommendation)	0.034	0.032	0.012	0.006
T_{14}-Control (water spray)	0.030	0.028	0.011	0.007
S.Em±	0.003	0.001	0.001	0.001
CD at 5%	NS	NS	NS	NS

4.1.9 Net assimilation rate (g m^{-2} day^{-1})

The data on net assimilation rate (NAR) of cotton at different growth stages as influenced by various treatments were presented in Table 11. The NAR increased from 45-75 DAS to 75-105 DAS and decreased thereafter. It differed significantly at 45-75, 75-105 and 105-135 only. Between 45-75 DAS, calmax spray @ 6 l ha^{-1} equally thrice at square formation, flower initiation and peak flowering stages recorded significantly higher NAR (0.0692 g dm^{-2} day^{-1}) over rest of the treatments. But it was on par with all most all treatments except T_8 and T_3.

Between 75-105 DAS significantly higher NAR value was recorded by calmax spray @ 6 l ha^{-1} once at peak flowering stage (0.1970 g dm^{-2} day^{-1}) over rest of the treatments. However, calmax spray @ 3 l ha^{-1} equally thrice at square formation, flower initiation and peak flowering stages recorded lowest NAR value (0.1453 g dm^{-2} day^{-1}).

Between 105-135 DAS, urea + planofix spray (as per recommendation) resulted significantly higher NAR value (0.0937 g m^{-2} day^{-1}) over rest of the treatments. However, lower NAR value was found in calmax spray @ 6 l ha^{-1} equally twice at square formation and flower initiation stage (0.0774 g dm^{-2} day^{-1}).

4.1.10 Dry matter accumulation in leaves per plant (g/plant)

The data on dry matter accumulation in leaves per plant as influenced by various treatments at different growth stages of crop (at square formation, flower initiation, peak flowering, boll formation and at harvest) were furnished in the Table 12.

At square formation stage, there was no significant differences among different treatments. However, marginally higher dry matter accumulation in leaves per plant (6.97 g $plant^{-1}$) was recorded in calmax spray @ 9 l ha^{-1} once at peak flowering stage.

At flower initiation stage, the dry matter accumulation in leaves per plant differed significantly due to application of calmax. Among the various treatments calmax spray @ 9 l ha^{-1} once at square formation stage (15.93 g $plant^{-1}$) significantly increase in dry matter accumulation in leaves as compared to all other treatments. But it was on par with T_7, T_{10}, T_{11}, T_5 and T_6. However calmax spay @ 3 l ha^{-1} once at peak flowering stage recorded lower dry matter accumulation in leaves (12.88 g $plant^{-1}$). But it was on par with control (water spray).

At peak flowering stage, among the various treatments calmax @ 9 l ha^{-1} sprayed equally thrice at square formation, flower initiation and peak flowering stags were registered significantly highest dry matter accumulation in leaf (22.14 g $plant^{-1}$) over rest of the treatments which was on par with T_{10}, T_7, T_6 and T_{13}. However, calmax @ 3 l ha^{-1} once at peak flowering stage recorded lowest dry matter accumulation in leaves (18.81 g $plant^{-1}$).

At boll formation stage, significantly higher dry matter accumulation in leaves per plant (29.12 g $plant^{-1}$) were recorded with application of calmax @ 9 l ha^{-1} equally thrice at square formation, flower initiation and peak flowering stages over all other treatments, but which was on par with T_7, T_{13}, T_{10} and T_{13} whereas lowest dry matter accumulation in leaves per plant (24.02 g $plant^{-1}$) was noticed with control (water spray) and rest of the treatments are on par with each other.

At harvest, clamax sprayed @ 9 l ha^{-1} equally thrice at square formation, flower initiation and peak flowering stages were registered significantly higher dry matter accumulation in leaves (23.92 g $plant^{-1}$) over rest of the treatments, which was on par with T_7 and T_{13}. However control (water spray) noticed lower dry matter accumulation in leaves (18.62 g $plant^{-1}$) and rest of the treatments are on par with each other.

4.1.11 Dry matter accumulation in stem (g $plant^{-1}$)

The data pertaining to dry matter accumulation in stem at different growth stages of crop (at square formation, flower initiation, peak flowering, boll formation and at harvest) as influenced by various treatments were furnished in the Table 13.

At square formation stage, the effect of foliar application of calmax on the dry matter accumulation in stem per plant was non-significant. However, marginally higher dry matter accumulation in stem (4.19 g $plant^{-1}$) was noticed in calmax spray @ 6 l ha^{-1} equally thrice at square formation, flower initiation and peak flowering stages.

At flower initiation stage, foliar application of calmax @ 9 l ha^{-1} equally thrice at square formation, flower initiation and peak flowering stages found significantly highest dry matter accumulation in stem (20.11 g $plant^{-1}$) over rest of the treatments. But which was on par with T_{10}, T_7, T_5 and T_6 whereas planofix + urea recorded lower dry matter accumulation in stem (16.50 g $plant^{-1}$) but it was on par with control (water spray).

At peak flowering stage, foliar application of clamax @ 9 l ha^{-1} equally twice at square formation and flowering initiation stages were registered significantly higher dry matter accumulation in stem (51.02 g $plant^{-1}$) compared to T_{14}, T_4 and T_2. But which was on par with rest of the treatments.

At boll formation stages, among the various treatments significantly higher dry matter accumulation in stem (62.17 g $plant^{-1}$) was observed with calmax spay @ 9 l ha^{-1} thrice equally at square formation, flower initiation and peak flowering stages compared to T_1, T_4 and T_{14}. But it was on par with rest of the treatments.

At harvest, dry matter accumulation in stem differed significantly with application of calmax in different doses and stages. Calmax spray @ 9 l ha^{-1} equally thrice at square formation, flower initiation and peak flowering stages were registered significantly higher dry matter accumulation in stem (74.25 g $plant^{-1}$) over rest of the treatments. But which was on par with T_7, T_{13}, T_{10} and T_3. However control (water spray) (63.08 g $plant^{-1}$) recorded lower dry matter accumulation in stem.

4.1.12 Dry matter accumulation in reproductive parts (g $plant^{-1}$)

The data on dry matter accumulation in reproductive parts per plant at different stages of crop growth (at flower initiation, peak flowering, boll formation and at harvest) as influenced by various treatments were presented in the Table 14.

At flower initiation stage, the effect of foliar application of calmax on the dry matter accumulation in reproductive parts per plant was non-significant. However, marginally higher dry matter accumulation in reproductive parts (2.04 g $plant^{-1}$) were noticed in calmax @ 9 l ha^{-1} sprayed once at square formation stage.

At peak flowering stage, significantly higher dry matter accumulation in reproductive parts (12.39 g $plant^{-1}$) were registered with calmax spray @ 9 l ha^{-1} equally thrice at square formation, flower initiation and peak flowering stages as compared to the other treatments but which was on par with T_{10}, T_6, T_{13}, T_7, T_9 and T_5, whereas calmax @ 3 l ha^{-1} sprayed once at peak flowering stage recorded lowest dry matter accumulation in reproductive parts (9.02 g $plant^{-1}$), but which was on par with control (water spray).

At boll formation stage, among the various treatments calmax spray @ 9 l ha^{-1} equally thrice at square formation, flower initiation and peak flowering stages indicated significantly higher dry matter accumulation in reproductive parts (28.11 g $plant^{-1}$) compared to rest of the treatments. But which was on par with T_7, T_{13}, T_{10}, T_3, T_{12}. whereas lower dry matter accumulation in reproductive parts (23.01 g $plant^{-1}$) were observed with control (water spray).

At harvest, dry matter accumulation in reproductive parts were significantly higher with application of calmax @ 9 l ha^{-1} equally thrice at square formation, flower initiation and peak flowering stages (47.25 g $plant^{-1}$) over rest of the treatments. But which was on par with T_7, T_{13}, T_{10}, T_3, T_{12} and T_6. The lower dry matter accumulation in reproductive parts (40.94 g $plant^{-1}$) were recorded with control (water spray) and rest of the treatments are on par with each other.

Table 11. Net assimilation rate (NAR, g dm^{-2} day^{-1}) at different growth stages of hybrid cotton (DHH-11) as influenced by foliar application of calmax

Treatments	45-75	75-105	105-135	135-at harvest
T_1-Calmax spray @ 3 l ha^{-1} once at square formation	0.0630	0.1635	0.0894	-0.0523
T_2-Calmax spray @ 3 l ha^{-1} twice equally at square formation and flower initiation	0.0649	0.1491	0.0868	-0.0523
T_3-Calmax spray @ 3 l ha^{-1} thrice equally at square formation, flower initiation and peak flowering	0.0610	0.1453	0.0883	-0.0505
T_4-Calmax spray @ 3 l ha^{-1} once at peak flowering	0.0609	0.1574	0.0813	-0.0513
T_5-Calmax spray @ 6 l ha^{-1} once at square formation	0.0619	0.1500	0.0881	-0.0527
T_6-Calmax spray @ 6 l ha^{-1} twice equally at square formation and flower initiation	0.0683	0.1619	0.0774	-0.0522
T_7-Calmax spray @ 6 l ha^{-1} thrice equally at square formation, flower initiation and peak flowering	0.0692	0.1578	0.0910	-0.0524
T_8-Calmax spray @ 6 l ha^{-1} once at peak flowering	0.0582	0.1970	0.0824	-0.0505
T_9-Calmax spray @ 9 l ha^{-1} once at square flowering	0.0654	0.1704	0.0873	-0.0512
T_{10}-Calmax spray @ 9 l ha^{-1} twice equally at square formation and flower initiation	0.0676	0.1646	0.0788	-0.0498
T_{11}-Calmax spray @ 9 l ha^{-1} thrice equally at square formation, flower initiation and peak flowering	0.0651	0.1597	0.0884	-0.0499
T_{12}-Calmax spray @ 9 l ha^{-1} once at peak flowering	0.0629	0.1829	0.0826	-0.0530
T_{13}-Urea + Planofix (as per the recommendation)	0.0510	0.1647	0.0937	-0.0498
T_{14}-Control (water spray)	0.0615	0.1160	0.0978	-0.0558
S.Em±	0.003	0.007	0.003	0.003
CD at 5%	0.009	0.021	0.008	NS

Table 12. Dry matter accumulation in leaves (g plant^{-1}) of hybrid cotton (DHH-11) as influenced by foliar application of calmax

Treatments	At square formation	At flower initiation	At peak flowering	At boll formation	At harvest
T_1-Calmax spray @ 3 l ha^{-1} once at square formation	6.02	14.32	19.39	25.32	20.09
T_2-Calmax spray @ 3 l ha^{-1} twice equally at square formation and flower initiation	5.87	14.29	19.93	26.12	20.89
T_3-Calmax spray @ 3 l ha^{-1} thrice equally at square formation, flower initiation and peak flowering	6.53	14.39	20.01	27.03	21.53
T_4-Calmax spray @ 3 l ha^{-1} once at peak flowering	6.90	12.88	18.81	25.04	18.99
T_5-Calmax spray @ 6 l ha^{-1} once at square formation	5.92	15.46	19.91	25.98	20.87
T_6-Calmax spray @ 6 l ha^{-1} twice equally at square formation and flower initiation	6.23	15.30	21.87	26.64	21.31
T_7-Calmax spray @ 6 l ha^{-1} thrice equally at square formation, flower initiation and peak flowering	6.43	15.86	21.98	28.98	23.83
T_8-Calmax spray @ 6 l ha^{-1} once at peak flowering	6.61	13.04	18.81	25.44	20.28
T_9-Calmax spray @ 9 l ha^{-1} once at square flowering	5.84	15.93	19.98	25.96	20.68
T_{10}-Calmax spray @ 9 l ha^{-1} twice equally at square formation and flower initiation	6.02	15.86	22.02	27.53	21.79
T_{11}-Calmax spray @ 9 l ha^{-1} thrice equally at square formation, flower initiation and peak flowering	6.47	15.79	22.14	29.12	23.92
T_{12}-Calmax spray @ 9 l ha^{-1} once at peak flowering	6.97	13.13	18.93	26.22	21.08
T_{13}-Urea + Planofix (as per the recommendation)	6.47	12.98	21.53	28.69	23.57
T_{14}-Control (water spray)	5.98	12.96	19.06	24.02	18.62
S.Em±	0.76	0.42	0.51	0.75	0.59
CD at 5%	NS	1.25	1.50	2.19	1.73

Table 13. Dry matter accumulation in stem (g $plant^{-1}$) at different growth stages of hybrid cotton (DHH-11) as influenced by foliar application of calmax

Treatments	At square formation	At flower initiation	At peak flowering	At boll formation	At harvest
T_1-Calmax spray @ 3 l ha^{-1} once at square formation	3.83	17.86	46.07	55.08	66.39
T_2-Calmax spray @ 3 l ha^{-1} twice equally at square formation and flower initiation	3.79	17.90	48.23	57.18	68.29
T_3-Calmax spray @ 3 l ha^{-1} thrice equally at square formation, flower initiation and peak flowering	4.02	17.99	48.28	58.33	69.40
T_4-Calmax spray @ 3 l ha^{-1} once at peak flowering	4.00	17.03	43.01	55.07	66.29
T_5-Calmax spray @ 6 l ha^{-1} once at square formation	3.93	19.88	46.30	57.16	68.09
T_6-Calmax spray @ 6 l ha^{-1} twice equally at square formation and flower initiation	3.59	19.84	50.12	57.82	68.75
T_7-Calmax spray @ 6 l ha^{-1} thrice equally at square formation, flower initiation and peak flowering	4.19	19.95	50.23	62.02	72.99
T_8-Calmax spray @ 6 l ha^{-1} once at peak flowering	4.07	16.80	43.88	56.62	66.97
T_9-Calmax spray @ 9 l ha^{-1} once at square flowering	4.14	17.95	46.41	57.01	67.35
T_{10}-Calmax spray @ 9 l ha^{-1} twice equally at square formation and flower initiation	3.96	19.99	51.02	58.57	69.50
T_{11}-Calmax spray @ 9 l ha^{-1} thrice equally at square formation, flower initiation and peak flowering	4.13	20.11	50.83	62.17	74.25
T_{12}-Calmax spray @ 9 l ha^{-1} once at peak flowering	3.81	16.90	42.98	57.26	68.61
T_{13}-Urea + Planofix (as per the recommendation)	3.99	16.50	48.16	61.73	72.06
T_{14}-Control (water spray)	4.02	17.00	43.09	54.06	63.08
S.Em±	0.53	0.55	1.49	1.59	1.66
CD at 5%	NS	1.60	4.33	4.62	4.82

Table 14. Dry matter accumulation in reproductive parts (g plant^{-1}) at different growth stages of hybrid cotton (DHH-11) as influenced by foliar application of calmax

Treatments	At flower initiation	At peak flowering	At boll formation	At harvest
T_1-Calmax spray @ 3 l ha^{-1} once at square formation	1.74	10.11	24.31	42.24
T_2-Calmax spray @ 3 l ha^{-1} twice equally at square formation and flower initiation	1.79	10.36	25.21	43.14
T_3-Calmax spray @ 3 l ha^{-1} thrice equally at square formation, flower initiation and peak flowering	1.72	10.27	26.42	43.67
T_4-Calmax spray @ 3 l ha^{-1} once at peak flowering	1.69	9.07	24.03	41.96
T_5-Calmax spray @ 6 l ha^{-1} once at square formation	1.86	11.38	25.01	43.04
T_6-Calmax spray @ 6 l ha^{-1} twice equally at square formation and flower initiation	1.95	12.01	25.77	43.35
T_7-Calmax spray @ 6 l ha^{-1} thrice equally at square formation, flower initiation and peak flowering	1.89	11.93	27.97	46.86
T_8-Calmax spray @ 6 l ha^{-1} once at peak flowering	1.72	9.91	24.57	42.50
T_9-Calmax spray @ 9 l ha^{-1} once at square flowering	2.04	11.62	24.96	42.48
T_{10}-Calmax spray @ 9 l ha^{-1} twice equally at square formation and flower initiation	1.98	12.23	26.51	44.45
T_{11}-Calmax spray @ 9 l ha^{-1} thrice equally at square formation, flower initiation and peak flowering	2.01	12.39	28.11	47.25
T_{12}-Calmax spray @ 9 l ha^{-1} once at peak flowering	1.59	9.09	25.69	43.53
T_{13}-Urea + Planofix (as per the recommendation)	1.64	11.96	27.68	45.61
T_{14}-Control (water spray)	1.68	9.98	23.01	40.94
S.Em±	0.33	0.44	0.74	1.20
CD at 5%	NS	1.30	2.17	3.49

4.1.13 Total dry matter production (g/plant)

The results on total dry matter production as influenced by various treatments at different crop growth stages are presented in Table 15 and Fig. 4.

At square formation stage, there was no significant difference among the different treatments with respect to total dry matter production per plant. However, calmax spray @ 3 l ha^{-1} once at peak flowering stage recorded maximum total dry matter accumulation per plant (13.33 g plant^{-1}).

At flower initiation stage, the total dry matter production differed significant due application of calmax in different doses and stages. Calmax sprayed @ 9 l ha^{-1} equally thrice at square formation, flower initiation and peak flowering stages were registered significantly higher (37.94 g plant^{-1}) total dry matter production over rest of the treatments. But it was on par with T_{10}, T_7, T_5, T_6 and T_9, whereas lower total dry matter production (31.66 g plant^{-1}) registered in control (water spray) and rest of the treatments are on par with each other.

At peak flowering stage, among the various treatments calmax spray @ 9 l ha^{-1} equally thrice at square formation, flower initiation and peak flowering stages observed. Significantly higher total dry matter production per plant (85.36 g plant^{-1}) which was on par with T_{10}, T_7, T_6 and T_{13}. Whereas clamax @ 3 l ha^{-1} sprayed once at peak flowering stage recorded lower total dry matter production (71.13 g plant^{-1}) per plant but it was on par with control (water spray).

At boll formation stage, calmax spray @ 9 l ha^{-1} equally thrice at square formation, flower initiation and peak flowering stages recorded significantly higher dry matter production per plant (120.75 g plant^{-1}) as compared to all other treatments. But which was on par with T_7, T_{13} and T_{10}. Whereas, control (water spray) recorded significantly lower (101.09 g plan^{-1}) total dry matter production per plant.

At harvest, significantly higher total dry matter production per plant (145.21 g plant^{-1}) recorded with calmax spray @ 9 l ha^{-1} equally thrice at square formation, flower initiation and peak flowering stages. But which was on par with T_7, T_{13}, T_{10} and T_3. However lowest total dry matter production per plant (122.65 g plant^{-1}) was found with control water spray.

4.2 YIELD AND YIELD COMPONENTS

4.2.1 Number of squares per plant

The data on number of squares per plant recorded at different crop growth stages (square formation, flower initiation, peakr flowering, boll formation and at harvest) as influenced by various treatments are presented in Table 16.

At square formation stage, there was no significant difference among the treatments, however higher number of squares (1.60) were noticed in calmax sprayed @ 9 l ha^{-1} equally thrice at square formation, flower initiation and peak flowering stages.

At flower initiation stage, number of squares per plant was differed significantly with the application of calmax in different doses and times. Application of calmax @ 9 l ha^{-1} equally twice at square formation and flower initiation stages (17.86) recorded significantly more number of squares per plant over other treatments. But it was on par with T_{11}, T_9 and T_7. Whereas the lowest number of squares per plant was recorded with application of calmax @ 6 l ha^{-1} once at peak flowering stage (12.33).

At peak flowering stage, significantly higher number of squares per plant (33.66) were recorded with application of calmax @ 9 l ha^{-1} thrice equally at square formation, flower initiation and peak flowering stage over all other treatments. But it was on par with T_7, T_{13}, T_{10} and T_6. However the lowest number of squares per plant (23.60) was recorded with control (water spray).

At boll formation stage, among the various treatments calmax spray @ 9 l ha^{-1} thrice equally at square formation, flower initiation and peak flowering stages noticed higher number of squares per plant (22.60) as compared to all other treatments, but it was on par with T_7, T_{13} and T_{10}. Whereas control (water spray) recorded lowest number (13.53) of squares per plant.

Table 15. Total dry matter production (g plant^{-1}) at different growth stages of hybrid cotton (DHH-11) as influenced by foliar application of calmax

Treatments	At square formation	At flower initiation	At peak flowering	At boll formation	At harvest
T_1-Calmax spray @ 3 l ha^{-1} once at square formation	9.85	33.92	76.92	104.71	128.72
T_2-Calmax spray @ 3 l ha^{-1} twice equally at square formation and flower initiation	9.66	33.98	78.52	108.51	132.32
T_3-Calmax spray @ 3 l ha^{-1} thrice equally at square formation, flower initiation and peak flowering	10.55	34.43	78.66	111.14	134.60
T_4-Calmax spray @ 3 l ha^{-1} once at peak flowering	10.90	31.68	71.13	104.14	127.24
T_5-Calmax spray @ 6 l ha^{-1} once at square formation	9.85	37.20	77.36	108.15	132.00
T_6-Calmax spray @ 6 l ha^{-1} twice equally at square formation and flower initiation	9.82	37.09	84.00	110.23	133.73
T_7-Calmax spray @ 6 l ha^{-1} thrice equally at square formation, flower initiation and peak flowering	10.62	37.36	84.14	118.97	143.72
T_8-Calmax spray @ 6 l ha^{-1} once at peak flowering	10.68	31.56	71.37	106.63	129.75
T_9-Calmax spray @ 9 l ha^{-1} once at square flowering	9.97	35.89	78.01	107.93	130.92
T_{10}-Calmax spray @ 9 l ha^{-1} twice equally at square formation and flower initiation	9.98	37.79	85.27	112.61	135.74
T_{11}-Calmax spray @ 9 l ha^{-1} thrice equally at square formation, flower initiation and peak flowering	10.60	37.94	85.36	120.75	145.21
T_{12}-Calmax spray @ 9 l ha^{-1} once at peak flowering	10.78	31.62	70.98	109.17	133.25
T_{13}-Urea + Planofix (as per the recommendation)	10.76	31.07	81.65	118.10	141.23
T_{14}-Control (water spray)	10.00	31.66	71.98	101.09	122.65
S.Em±	1.06	1.04	2.25	3.20	3.80
CD at 5%	NS	3.03	6.54	9.04	11.06

L E G E N D

T_1-Calmax spray @ 3 l ha^{-1} once at square formation

T_2-Calmax spray @ 3 l ha^{-1} twice equally at square formation and flower initiation

T_3-Calmax spray @ 3 l ha^{-1} thrice equally at square formation, flower initiation and peak flowering

T_4-Calmax spray @ 3 l ha^{-1} once at peak flowering

T_5-Calmax spray @ 6 l ha^{-1} once at square formation

T_6-Calmax spray @ 6 l ha^{-1} twice equally at square formation and flower initiation

T_7-Calmax spray @ 6 l ha^{-1} thrice equally at square formation, flower initiation and peak flowering

T_8-Calmax spray @ 6 l ha^{-1} once at peak flowering

T_9-Calmax spray @ 9 l ha^{-1} once at square flowering

T_{10}-Calmax spray @ 9 l ha^{-1} twice equally at square formation and flower initiation

T_{11}-Calmax spray @ 9 l ha^{-1} thrice equally at square formation, flower initiation and peak flowering

T_{12}-Calmax spray @ 9 l ha^{-1} once at peak flowering

T_{13}-Urea + Planofix (as per the recommendation)

T_{14}-Control (water spray)

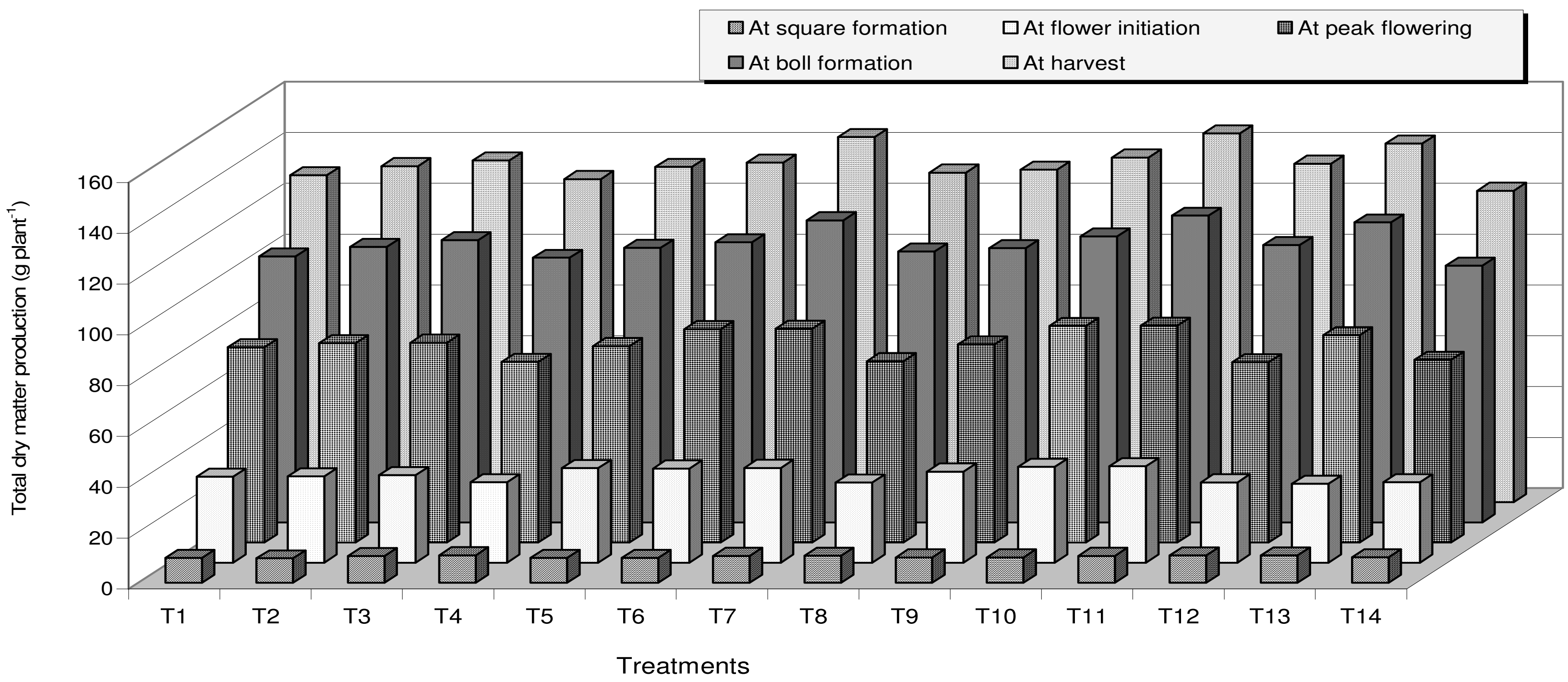

Fig. 4. Total dry matter production (g plant^{-1}) at different growth stages of hybrid cotton (DHH-11) as influenced by foliar application of calmax

Fig. 4. Total dry matter production (g plant-1) at different growth stages of hybrid cotton (DHH-11) as influenced by foliar application of calmax

Table 16. Number of squares per plant at different growth stages of hybrid cotton (DHH-11) as influenced by foliar application of calmax

Treatments	At square formation	At flower initiation	At peak flowering	At boll formation	At harvest
T_1-Calmax spray @ 3 l ha^{-1} once at square formation	1.00	15.40	27.06	16.27	3.46
T_2-Calmax spray @ 3 l ha^{-1} twice equally at square formation and flower initiation	1.40	15.66	32.13	18.73	4.20
T_3-Calmax spray @ 3 l ha^{-1} thrice equally at square formation, flower initiation and peak flowering	1.40	15.80	32.73	19.86	4.66
T_4-Calmax spray @ 3 l ha^{-1} once at peak flowering	1.20	12.86	23.53	15.86	3.13
T_5-Calmax spray @ 6 l ha^{-1} once at square formation	1.40	15.93	28.53	18.13	4.06
T_6-Calmax spray @ 6 l ha^{-1} twice equally at square formation and flower initiation	1.60	16.20	34.02	19.53	4.60
T_7-Calmax spray @ 6 l ha^{-1} thrice equally at square formation, flower initiation and peak flowering	1.20	16.40	36.33	21.46	4.80
T_8-Calmax spray @ 6 l ha^{-1} once at peak flowering	0.86	12.33	24.13	16.73	3.73
T_9-Calmax spray @ 9 l ha^{-1} once at square flowering	1.40	17.53	29.33	17.60	3.76
T_{10}-Calmax spray @ 9 l ha^{-1} twice equally at square formation and flower initiation	1.20	17.86	34.80	20.73	4.66
T_{11}-Calmax spray @ 9 l ha^{-1} thrice equally at square formation, flower initiation and peak flowering	1.60	17.66	36.66	22.60	5.40
T_{12}-Calmax spray @ 9 l ha^{-1} once at peak flowering	1.00	12.66	24.40	19.13	4.53
T_{13}-Urea + Planofix (as per the recommendation)	1.40	12.60	35.20	21.20	4.73
T_{14}-Control (water spray)	1.00	12.73	23.60	13.53	2.80
S.Em±	0.18	0.51	1.01	0.90	0.74
CD at 5%	NS	1.50	2.95	2.63	NS

At harvest, the effect of foliar application of calmax on number of squares per plant was non-significant. However the maximum number of squares per plant (5.40) were observed with calmax spray @ 9 l ha^{-1} equally thrice at square formation, flower initiation and peak flowering stages.

4.2.2 Number of flowers per plant

The data on the number of flowers per plant at different growth stages of crop (at flower initiation, peak flowering, boll formation and at harvest) as influence by various treatments are furnished in Table 17.

Significant differences among the treatments were found with respect to number of flowers per plant at all the growth stages of crop except at flower initiation stage and at harvest.

At peak flowering stage, number of flowers per plant was statistically significant with the application of calmax. Application of calmax spray @ 9 l ha^{-1} thrice equally at square formation, flower initiation and peak flowering stages (11.86) were found significant over all other treatments but it was on par with T_7. Whereas, lower number of flowers per plant (7.13) was noticed with calmax spray @ 3 l ha^{-1} once at peak flowering stage but it was on par with control (water spray).

At boll formation stage, among all the treatments calmax spray @ 9 l ha^{-1} equally thrice at square formation, flower initiation and peak flowering stages were found significantly higher number of flowers per plant (7.93) over all other treatments but it was on par with T_7, T_{13} and T_{10}. However, control (water spray) was recorded lowest number of flowers per plant (4.03).

4.2.3 Number of green bolls per plant

The data on the number of green bolls per plant at growth stages of crop (at peak flowering, boll formation and at harvest) as influenced by various treatments are presented in Table 18.

At peak flowering stage there was no significant differences among different treatments were found. However, marginally higher number of green bolls per plant (2.06) was noticed in clamax spray @ 9 l ha^{-1} equally thrice at square formation, flower initiation and peak flowering stages.

At boll formation stage, significantly higher number of bolls per plant (31.93) was recorded with calmax @ 9 l ha^{-1} applied equally thrice at square formation, flower initiation and peak flowering stages as compared to all other treatments, but it was on par with T_7 and T_{13}. Whereas lower number of green bolls per plant (24.58) was recorded with control (water spray) and rest of the treatments are on par with each other.

At harvest, no significant results were found with respect to the application of calmax. However, marginally higher number of green bolls per plant (1.93) were found in calmax spray @ 9 l ha^{-1} equally thrice at square formation, flower initiation and peak flowering stages.

4.2.4 Total number of bolls produced per plant

The data pertaining to the total number of bolls produced per plant as influenced by various treatments are presented in Table 18.

Different treatment differed significantly with respect to total number of bolls per plant. Among the different treatments calmax spray @ 9 l ha^{-1} applied equally thrice at square formation, flower initiation and peak flowering stages were recorded significantly higher number of total bolls produced per plant (33.86) over rest of the treatments. But it was on par with T_7, T_{13}, T_{10} and T_3 whereas lower number of total bolls produced per plant (26.33) was noticed in control (water spray).

Table 17. Number of flowers per plant at different growth stages of hybrid cotton (DHH-11) as influenced by foliar application of calmax

Treatments	At flower initiation	At peak flowering	At boll formation	At harvest
T_1-Calmax spray @ 3 l ha^{-1} once at square formation	3.40	8.33	5.13	2.00
T_2-Calmax spray @ 3 l ha^{-1} twice equally at square formation and flower initiation	4.73	9.20	6.40	2.16
T_3-Calmax spray @ 3 l ha^{-1} thrice equally at square formation, flower initiation and peak flowering	3.93	9.33	7.20	2.26
T_4-Calmax spray @ 3 l ha^{-1} once at peak flowering	3.56	7.13	4.93	2.15
T_5-Calmax spray @ 6 l ha^{-1} once at square formation	4.13	9.20	6.13	2.08
T_6-Calmax spray @ 6 l ha^{-1} twice equally at square formation and flower initiation	4.86	10.73	7.13	2.33
T_7-Calmax spray @ 6 l ha^{-1} thrice equally at square formation, flower initiation and peak flowering	4.93	11.40	7.86	2.59
T_8-Calmax spray @ 6 l ha^{-1} once at peak flowering	3.63	7.33	5.60	2.33
T_9-Calmax spray @ 9 l ha^{-1} once at square flowering	4.86	10.13	5.93	1.98
T_{10}-Calmax spray @ 9 l ha^{-1} twice equally at square formation and flower initiation	5.46	10.86	7.40	2.14
T_{11}-Calmax spray @ 9 l ha^{-1} thrice equally at square formation, flower initiation and peak flowering	5.50	11.86	7.93	2.94
T_{12}-Calmax spray @ 9 l ha^{-1} once at peak flowering	3.60	7.40	6.86	2.04
T_{13}-Urea + Planofix (as per the recommendation)	4.86	10.93	7.66	2.67
T_{14}-Control (water spray)	3.50	7.20	4.03	1.94
S.Em±	0.54	0.30	0.24	0.22
CD at 5%	NS	0.88	0.71	NS

Table 18. Number of green bolls at different growth stages of hybrid cotton (DHH-11) as influenced by foliar application of calmax

Treatments	At peak flowering	At boll formation	At harvest
T_1-Calmax spray @ 3 l ha^{-1} once at square formation	1.33	27.46	1.62
T_2-Calmax spray @ 3 l ha^{-1} twice equally at square formation and flower initiation	1.73	29.63	1.63
T_3-Calmax spray @ 3 l ha^{-1} thrice equally at square formation, flower initiation and peak flowering	1.60	30.00	1.75
T_4-Calmax spray @ 3 l ha^{-1} once at peak flowering	1.46	27.38	1.88
T_5-Calmax spray @ 6 l ha^{-1} once at square formation	1.80	29.00	1.58
T_6-Calmax spray @ 6 l ha^{-1} twice equally at square formation and flower initiation	1.80	29.93	1.73
T_7-Calmax spray @ 6 l ha^{-1} thrice equally at square formation, flower initiation and peak flowering	1.86	30.90	1.90
T_8-Calmax spray @ 6 l ha^{-1} once at peak flowering	1.46	28.00	1.65
T_9-Calmax spray @ 9 l ha^{-1} once at square flowering	1.66	28.42	1.61
T_{10}-Calmax spray @ 9 l ha^{-1} twice equally at square formation and flower initiation	1.66	30.00	1.75
T_{11}-Calmax spray @ 9 l ha^{-1} thrice equally at square formation, flower initiation and peak flowering	2.60	31.93	1.93
T_{12}-Calmax spray @ 9 l ha^{-1} once at peak flowering	1.40	29.66	1.70
T_{13}-Urea + Planofix (as per the recommendation)	1.80	30.20	1.88
T_{14}-Control (water spray)	1.53	24.58	1.51
S.Em±	0.32	0.65	1.13
CD at 5%	NS	1.91	NS

4.2.5 Number of harvested bolls per plant

The data on number of harvested bolls per plant as influenced by various treatments are given in Table 19.

Number of harvested bolls per plant was differed significantly with the application of calmax at different dose and stage of application. Calmax @ 9 l ha^{-1} applied equally thrice at square formation, flower initiation of peak flowering stages were recorded significantly higher number of harvested bolls per plant (31.66) compared to all other treatments, but it was on par with T_7, T_{13} and T_{10}. Whereas number of harvested bolls per plant was lower in control 20.33 (water spray).

4.2.6 Mean boll weight (g)

The data pertaining to the mean boll weight (g) as influenced by various treatments are given in Table 19 and Fig.5.

Among the different treatments calmax @ 9 l ha^{-1} applied equally thrice at square formation, flower initiation and peak flowering stages were recorded significantly higher mean boll weight (5.56 g) over rest of the treatments, but it was on par with T_7, T_{13}, T_{10} and T_3. Whereas lower mean boll weight (3.80 g) was recorded in control (water spray) and other treatments are on par with each other.

4.2.7 Seed cotton yield per plant (g)

The data on seed cotton yield (g $plant^{-1}$) as influenced by various treatments are furnished in Table 19 and Fig.5.

Seed cotton yield per plant was significantly higher (75.90 g) in case of calmax @ 9 l ha^{-1} applied thrice equally at square formation, flower initiation and peak flowering stages compared to rest of the treatments, but it was on par with T_7, T_{13} and T_{10}. However, lower seed cotton yield per plant (67.78 g) was recorded with control (water spray).

4.2.8 Seed cotton yield (kg ha^{-1})

The results revealed that calmax spray @ 9 l ha^{-1} applied thrice equally at square formation, flower initiation and peak flowering stages of cotton hybrid DHH-11 recorded the highest kapas yield (1406 kg ha^{-1}) which was 9.8 per cent higher than the control treatment (water spray) (1280 kg ha^{-1}). Calmax spray @ 6 l ha^{-1} applied thrice equally at square formation, flower initiation and peak flowering of cotton (1395 kg ha^{-1}), calmax spray @ 9 l ha^{-1} applied twice equally at square formation and flower initiation (1332 kg ha^{-1}) and foliar spray of urea and planofix (as per recommendation) revealed on par kapas yield with calmax sprayed @ 9 l ha^{-1} thrice equally at square formation, flower initiation and peak flowering (1406 kg ha^{-1}) (Table 19 and Fig.5).

4.2.9 Seed index

The data on seed index as influenced by various treatments are presented in Table 20.

Among the treatments, statistically non-significant difference were found in seed index. However, marginally higher seed index (10.10 g) was noticed in calmax spray @ 9 l ha^{-1} equally thrice at square formation, flower initiation and peak flowering stages.

4.2.10 Harvest index

The data on harvest index as influenced by various treatments are furnished in Table 20.

Significant differences among the treatments were recorded with respect to harvest index. Calmax @ 9 l ha^{-1} applied equally thrice at square formation, flower initiation and peak flowering stages were found significantly higher (34.78) seed index over the rest of the treatments. But which was on par with T_7, T_{13} and T_{10}. Whereas control (water spray) noticed lower (25.34) harvest index.

Table 19. Number of bolls per plant, mean boll weight (g), seed cotton yield (g $plant^{-1}$) and seed cotton yield (kg ha^{-1}) as influenced by foliar application of calmax in hybrid cotton (DHH-11)

Treatments	Bolls $plant^{-1}$		Mean boll weight (g)	Seed cotton yield $plant^{-1}$ (g)	Seed cotton yield (kg ha^{-1})
	Total bolls produced	Harvested bolls $plant^{-1}$			
T_1-Calmax spray @ 3 l ha^{-1} once at square formation	29.43	24.46	3.89	69.93	1295
T_2-Calmax spray @ 3 l ha^{-1} twice equally at square formation and flower initiation	30.93	26.93	4.17	70.96	1308
T_3-Calmax spray @ 3 l ha^{-1} thrice equally at square formation, flower initiation and peak flowering	31.82	28.66	4.97	71.17	1318
T_4-Calmax spray @ 3 l ha^{-1} once at peak flowering	29.26	24.00	3.85	69.71	1291
T_5-Calmax spray @ 6 l ha^{-1} once at square formation	30.66	26.46	4.11	70.47	1305
T_6-Calmax spray @ 6 l ha^{-1} twice equally at square formation and flower initiation	31.66	28.27	4.18	71.11	1317
T_7-Calmax spray @ 6 l ha^{-1} thrice equally at square formation, flower initiation and peak flowering	32.80	30.20	5.49	75.33	1395
T_8-Calmax spray @ 6 l ha^{-1} once at peak flowering	29.73	24.93	3.98	70.09	1298
T_9-Calmax spray @ 9 l ha^{-1} once at square flowering	29.93	25.43	4.41	70.25	1301
T_{10}-Calmax spray @ 9 l ha^{-1} twice equally at square formation and flower initiation	31.93	29.05	5.09	71.94	1332
T_{11}-Calmax spray @ 9 l ha^{-1} thrice equally at square formation, flower initiation and peak flowering	33.86	31.66	5.56	75.90	1406
T_{12}-Calmax spray @ 9 l ha^{-1} once at peak flowering	31.36	27.66	4.52	71.06	1316
T_{13}-Urea + Planofix (as per the recommendation)	32.46	29.56	5.23	74.15	1373
T_{14}-Control (water spray)	26.33	20.33	3.80	67.78	1280
S.Em±	0.63	0.90	0.19	1.52	26
CD at 5%	1.85	2.61	0.57	4.43	76

L E G E N D

T_1-Calmax spray @ 3 l ha^{-1} once at square formation

T_2-Calmax spray @ 3 l ha^{-1} twice equally at square formation and flower initiation

T_3-Calmax spray @ 3 l ha^{-1} thrice equally at square formation, flower initiation and peak flowering

T_4-Calmax spray @ 3 l ha^{-1} once at peak flowering

T_5-Calmax spray @ 6 l ha^{-1} once at square formation

T_6-Calmax spray @ 6 l ha^{-1} twice equally at square formation and flower initiation

T_7-Calmax spray @ 6 l ha^{-1} thrice equally at square formation, flower initiation and peak flowering

T_8-Calmax spray @ 6 l ha^{-1} once at peak flowering

T_9-Calmax spray @ 9 l ha^{-1} once at square flowering

T_{10}-Calmax spray @ 9 l ha^{-1} twice equally at square formation and flower initiation

T_{11}-Calmax spray @ 9 l ha^{-1} thrice equally at square formation, flower initiation and peak flowering

T_{12}-Calmax spray @ 9 l ha^{-1} once at peak flowering

T_{13}-Urea + Planofix (as per the recommendation)

T_{14}-Control (water spray)

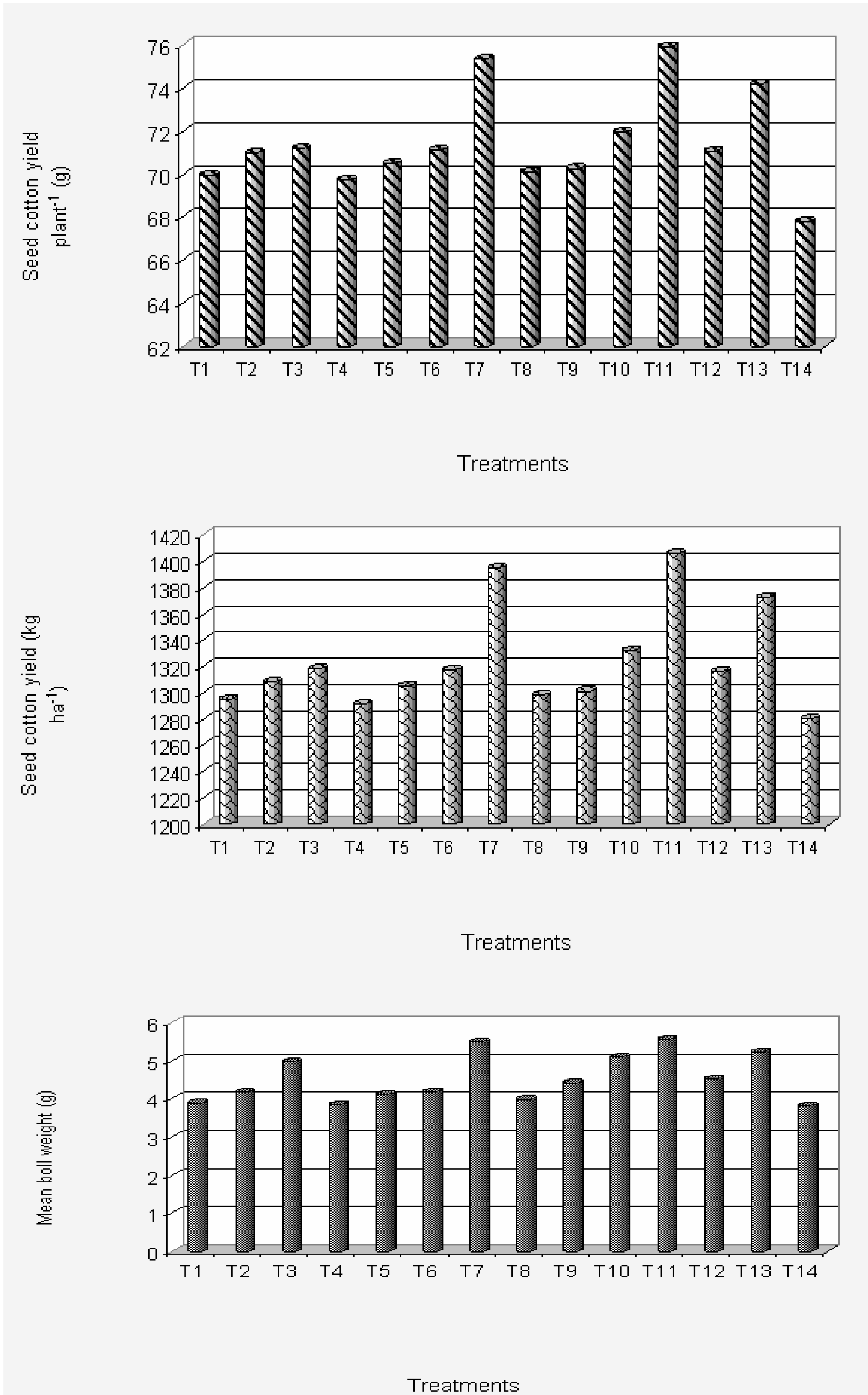

Fig. 5. Mean boll weight (g), seed cotton yield (g plant-1) and seed cotton yield (kg ha-1) as influenced by foliar application of calmax in hybrid cotton (DHH-11)

Table 20. Seed index, harvest index and ginning percentage as influenced by foliar application of calmax in hybrid cotton (DHH-11)

Treatments	Seed index	Harvest index	Ginning (%)
T_1-Calmax spray @ 3 l ha^{-1} once at square formation	9.64	29.25	37.61
T_2-Calmax spray @ 3 l ha^{-1} twice equally at square formation and flower initiation	9.69	30.90	37.87
T_3-Calmax spray @ 3 l ha^{-1} thrice equally at square formation, flower initiation and peak flowering	9.75	31.73	38.26
T_4-Calmax spray @ 3 l ha^{-1} once at peak flowering	9.62	28.90	37.59
T_5-Calmax spray @ 6 l ha^{-1} once at square formation	9.68	30.79	37.76
T_6-Calmax spray @ 6 l ha^{-1} twice equally at square formation and flower initiation	9.73	31.67	38.04
T_7-Calmax spray @ 6 l ha^{-1} thrice equally at square formation, flower initiation and peak flowering	10.02	34.50	38.74
T_8-Calmax spray @ 6 l ha^{-1} once at peak flowering	9.65	29.40	37.64
T_9-Calmax spray @ 9 l ha^{-1} once at square flowering	9.67	30.63	37.69
T_{10}-Calmax spray @ 9 l ha^{-1} twice equally at square formation and flower initiation	9.94	33.18	38.36
T_{11}-Calmax spray @ 9 l ha^{-1} thrice equally at square formation, flower initiation and peak flowering	10.10	34.78	38.80
T_{12}-Calmax spray @ 9 l ha^{-1} once at peak flowering	9.71	31.52	37.96
T_{13}-Urea + Planofix (as per the recommendation)	9.98	33.59	38.54
T_{14}-Control (water spray)	9.30	25.34	37.20
S.Em±	0.32	1.04	0.79
CD at 5%	NS	3.04	NS

Table 21. Correlation coefficient (r) between seed cotton yield (kg ha^{-1}) and growth and yield components of hybrid cotton (DHH-11)

Components	‘r’ values
I. Yield components	
1. Yield per plant	0.99**
2. Harvested bolls per plant	0.86**
3. Mean boll weight	0.92**
II. Growth components	
1. Sympodial branches	0.85**
2. Leaf area	0.82**
3. Leaf area index	0.83**
4. Dry matter accumulation in reproductive parts	0.99**
5. Total dry matter accumulation	0.97**
6. Absolute growth rate (AGR)	0.74**
7. Crop growth rate (CGR)	0.74**
8. Relative growth rate (RGR)	-0.48 (NS)
9. Net assimilation rate (NAR)	0.46 (NS)

** Significant at 1 per cent level
NS – Non-significant

4.2.11 Ginning (%)

The results of ginning percentage as influenced by various treatments are furnished in Table 20.

Ginning percentage as influenced by various treatments showed non-significant differences. However, numerically higher ginning percentage (38.8%) recorded due to application of calmax @ 9 l ha^{-1} equally thrice at square formation, flower initiation and peak flowering stages.

4.3 CORRELATION STUDIES

Correlation between yield and yield components shown that the seed cotton yield had a significant and positive correlation with yield components *viz.*, yield per plant (r=0.99), harvest bolls per plant (r=0.86) and mean boll weight (r=0.92). Also the growth components *viz.*, sympodial branches (r=0.85), leaf area (r=0.82), leaf area index (r=0.83), dry matter accumulation in reproductive parts (r=0.99), total dry matter production (r=0.97), absolute growth rate (r=0.74) and crop growth rate (r=0.74) had significant and positive correlation with seed cotton yield. However, relative growth rate (r=-0.48) was found to be negatively correlated with seed cotton yield. Net assimilation rate did not have significant correlation (r=0.46) with the seed cotton yield (Table 21).

V. DISCUSSION

The results obtained from the experiment conducted at Main Agricultural Research Station, during the year 2005-06 to study the effect of calmax, a foliar micronutrient fertilizer on growth and yield of hybrid cotton under northern transitional zone of Karnataka were discussed through cause and effect relationship in this chapter.

5.1 WEATHER CONDITIONS

Crop growth and yield potential is mainly dependent on the genetic make up and environmental factors. Fluctuation in weather conditions greatly influence the growth, development and yield of crop.

The rainfall received during the year of experimentation was 1011.5 mm (2005-06) which was 33.17 per cent more than the normal of past 55 years. During cropping season from June to March rainfall of 907.1 mm was received, which was 19.42 per cent higher than the normal rainfall during the same period. Rainfall was well distributed during the entire growing season with intermittent high intensity rains. There was dry weather during December, January and February. In cotton most critical period for moisture stress is between the first flower opening and peak boll development. Stress during these phases cause shedding of buds and bolls thereby reducing boll number. But at these stages there was no moisture stress because of good rainfall. The other weather parameters like maximum and minimum temperature and relative humidity did not vary much compared to the normal. They did not had any adverse effect on crop growth and yield.

Since the normal weather conditions prevailed throughout the cropping period, there was better crop growth and yield.

Growing high yield varieties and hybrids continuously during the last four decades and non-replenishment of many plant nutrients lead to wide spread deficiency of micronutrients which had adverse effect on yield in cotton and many other crops. It can be overcome through foliar spray of micronutrients, for which calmax is used as suitable liquid micronutrient fertilizer.

Calmax is a liquid micronutrient fertilizer ideally suited to supply the micronutrients in a balanced way for better cotton growth and yield. It contains nitrogen (10%), calcium (15%), magnesium (2%), manganese (0.100%), iron (0.050%), boron (0.050%), copper (0.040%), zinc (0.020%) and molybdenum (0.001%). Calcium is an important constituent of cell wall and cell membranes. Magnesium is constituent of chlorophyll and enzyme activator.

Essential micronutrients (Zn, Fe, Mn, Cu, B and Mo) play an important role in physiology of cotton crop. Being a part of the enzyme system or as catalyst in enzymetic reactions, they are required for plant metabolic activities such as respiration, meristemetic development, chlorophyll formation, photosynthesis, energy system, protein synthesis, oil content, gossypol, tannin and phenolic compounds. Mo had little effect on fruiting index but plays an important role in nitrogen metabolism. Zn is involved in the biosynthesis of growth harmone auxin, indole 3 acetic acid (IAA) and has a marked influence on the partitioning of vegetative and reproductive growth. Fe is an important constituent of iron porphyrin proteins like cytochrome peroxidase, catalases and it is essential for the synthesis of chlorophyll.

Boron facilitates the translocation of sugars and affects the boll number and checks squares, flowers and boll shedding of floral parts. Mn is an activator of many respiratory enzymes and essential in photosynthesis and it acts as an activator of some enzymes *viz.*, oxidases, peroxidases, dehydrogenases, kinases, decarboxylases *etc.* and it is essential for formation of chlorophyll, deficiency results in formation of reddish gray leaves, while crinkled leaves are observed due to excess of Mn.

Copper is a component of Cu protein complex and plays an important role in respiration. Mg is a very important constituent of chlorophyll and acts as activator of many enzymes in phosphate transfer reactions particularly in carbohydrate metabolism and nucleic acid synthesis and deficiency leads to reddening of leaves and reduce photosynthetic activity.

The yield variations due to different treatments of foliar microutrient are discussed in this chapter.

5.2 EFFECT OF FOLIAR APPLICATION OF CALMAX ON YIELD AND YIELD ATTRIBUTING CHARACTERS OF COTTON

The major factors responsible for the seed cotton yield are the variations in yield components *viz.*, number of squares per plant, number of flowers per plant, number of green bolls per plant, total number of bolls produced per plant, number of harvested bolls per plant, mean boll weight and yield per plant . It is well known that adverse climatic conditions results in an imbalance in the growth and development of plant leading to the shedding of reproductive parts, thereby reducing the yield considerably in cotton. The macro and micronutrients are capable of well distribute the dry matter in the plant thereby bring about an improvement in the yield (Wankhade *et al*., 1994; Anon., 1995 and Rajarajeshwari, 1996).

In cotton, the seed cotton yield depends on the production and accumulation of photoassimilates and partitioning in to the reproductive parts of the plant. The yield is strongly influenced by the application of macro and micronutrients indicating the role of these chemicals in increasing the yield through their effect on various morphophysiological characters.

In the present investigation, application of calmax resulted in significant improvement in kapas yield of cotton (Table 19). Application of calmax @ 9 l ha^{-1} thrice equally at square formation, flower initiation and peak flowering stages recorded significantly higher seed cotton yield (1406 kg/ha) which was 9.8 per cent higher than the control (water spray) (1280 kg/ha). However, it was on par with calmax spray @ 6 l ha^{-1} thrice equally at square formation, flower initiation and peak flowering stages (1395 kg ha^{-1}), recommended spray of urea + planofix (1373 kg ha^{-1}) and calmax spray @ 9 l ha^{-1} twice equally at square formation and flower initiation stages (1332 kg ha^{-1}).

Similarly seed cotton yield per plant (Table 19) was significantly higher (75.90 g) with application of calmax @ 9 l ha^{-1} thrice equally at square formation, flower initiation and peak flowering stages, which was 11.97 per cent higher than the control (water spray). However, it was on par with calmax spray @ 6 l ha^{-1} thrice equally at square formation, flower initiation and peak flowering stages (75.33 g). Urea + planofix (as per recommendation) (74.15 g) and calmax spray @ 9 l ha^{-1} twice equally at square formation, flower initiation stages (71.94 g).

This may be because of production of more number of harvested bolls per plant, mean boll weight and yield per plant due to marked influence in partitioning of vegetative and reproductive growth. The micronutrients play an important role in the physiology of cotton crop (Anon., 1995). Being a part of enzyme system or as a catalyst in enzymatic reactions, micronutrients are required for plant metabolic activities such as respiration, meristematic development, chlorophyll formation, photosynthesis, energy system, protein and oil synthesis and also these micronutrients helpful for the production of more number of lateral branches, more number of bolls by minimizing dropping of squares, flowers and bolls. These results are in conformity with the finding of Woody *et al*. (1969), Marphy and Lancaster (1971), Ahlawat (1974), Carvalho *et al*. (2001).

Since calmax also contains 10 per cent of nitrogen, foliar application of calmax increased the seed cotton yield compared to control. This might be due to higher kapas yield per plant and other yield related characters. Higher yield due to nitrogen spray may be due to better growth of crop as a result of adequate supply of nitrogen at the critical stages of crop growth. Positive yield response in cotton have been also reported due to nitrogen spray by several workers, Bhoj *et al*. (1969), Ramdas *et al*. (1971) and Elgal *et al*. (1976).

The higher seed cotton yield with calamax spray @ 9 l ha^{-1} thrice equally at square formation, flower initiation and peak flowering stages over other treatments is attributed to higher values of growth and yield components viz., number of squares, number of bolls, number flowers per plant. There was a strong positive and significant correlation between growth components (sympodial branches r=0.85; leaf area r=0.82; leaf area index r=0.83; dry matter accumulation in reproductive parts r=0.99; total dry matter accumulation r=0.97; AGR r=0.74; CGR r=0.74) and yield components (yield per plant r=0.99; harvested bolls per plant r=0.86; mean boll weight r=0.92).

Significant increase in number of squares per plant (Table 16) at peak flowering stage (36.66) was recorded in calmax spray @ 9 l ha^{-1} thrice equally at square formation, flower initiation and peak flowering stages over control (water spray) (23.60). But it was on par with calmax spray @ 6 l ha^{-1} thrice equally at square formation, flower initiation and peak flowering stages (36.33) urea + planofix spray (as per recommendation) (35.20) and calmax spray @ 9 l ha^{-1} twice equally at square formation and flower initiation stage (34.80). Such findings were also reported by Sarour *et al*. (1988) where all the foliage sprayed with micronutrients increased the number of squares per plant significantly and also decreased the squares shedding as compared to control. It was also supported by the findings of Srivastav and Singh (1988).

Significantly higher number of flowers per plant (Tale 17) at peak flowering stage (11.86) was recorded in calmax spray @ 9 l ha^{-1} thrice equally at square formation, flower initiation and peak flowering stages over control (water spray) (7.20). But it was on par with calmax spray @ 6 l ha^{-1} thrice equally at square formation, flower initiation and peak flowering stages (11.40). This may be due to efficient translocation of sugars within the plant and also production of growth promoting hormones, carbohydrates and synthesis of nucleic acid. Such effect on flowering was also noticed by Silva *et al*. (1982) and Ullagadi (2000).

Further the results strengthened by probing into total number of bolls produced per plant and harvested bolls per plant. Among various treatments calmax spray @ 9 l ha^{-1} thrice equally at square formation, flower initiation and peak flowering stages recorded significantly higher number of total bolls produced per plant (33.86) and harvested bolls per plant (31.66) over control (water spray).

It was due to increased leaf area and leaf area index with adequate supply of micronutrients *viz*., Fe, Mn and B. Fe is believed to be essential for the synthesis of chlorophyll and biological nitrogen fixation and primary photochemical reaction in photosynthesis. These results are in conformity with the results of Verma (1973). Thus it could be reasoned out that foliar application of Fe was better for increasing the number of harvested bolls per plant and mean boll weight and thereby increased the yield per plant. Mn also plays role in the synthesis of chlorophyll and transfer of electrons from water to photo-oxidized chlorophyll in photosynthesis. Several workers have shown that boron is necessary for fruiting in cotton (Eaton, 1932, Holley and Dulin, 1939, McConnel *et al*., 1992).

Increased boll number and mean boll weight with nitrogen which is also present in calmax is due to increased production of fruiting points and reduced shedding of floral parts as a result of increased meristmatic activity and production of auxin as reported by Gardner and Jucker (1967), Mathur *et al*. (1968), Singh *et al*. (1970) and Sarour *et al*. (1988).

Also in chilli Sureshbabu (2001) reported that S and Fe application resulted in higher dry fruit of chilli yield. It might be attributed to favourable effect of S (essential constituent of aminoacids, cystein, methionine) and Fe (plays an important role in biosynthesis of auxins which reduced the flower and fruit drop) resulting in better growth and yield components. Similar positive response of increase in number of dry fruit of chilli yield due to application of Ca has been reported by Evans and Troxler (1953), Roychoudhury *et al*. (1990) and Hamsaveni (2002).

Further, calmax spray @ 9 l ha^{-1} thrice equally at square formation, flower initiation and peak flowering stages recorded significantly higher mean boll weight (5.56 g) over control (water spray) (3.80 g). But it was on par with calmax spray @ 6 l ha^{-1} thrice equally at square formation, flower initiation and peak flowering stages (5.49 g), urea + planofix spray (as per recommendation) (5.23 g) and calmax spray @ 9 l ha^{-1} equally twice at square formation flower initiation stages (5.09 g).

This might be due to increased plant metabolic activity, meristematic development, energy system and protein synthesis, which improved translocation of photosynthesis and directly influenced the boll weight of cotton (Stoyanow and Gikov, 1990 and Hanumanthareddy, 1999).

Significantly higher harvest index (34.78%) was recorded with calmax sprayed @ 9 l ha^{-1} thrice equally at square formation, flower initiation and peak flowering stages compared to control (water spray (25.34%). But it was on par with calmax spray @ 6 l ha^{-1} thrice equally at square formation, flower initiation and peak flowering stages (34.50%), urea + planofix (as per recommendation) spray (33.59%) and calmax spray @ 9 l ha^{-1} twice equally at square formation and flower initiation stages (33.18%) while other parameters such as seed index and ginning percentage were not influenced significantly by foliar application of calmax. Significant variations in yield and yield components can be traced back to the variations in different growth components.

5.3 EFFECT OF FOLIAR APPLICATION OF CALMAX ON GROWTH PARAMETERS OF COTTON

Various growth characters of cotton such as plant height, number of monopodial branches, number of sympodial branches, leaf area, leaf area index and total dry matter production influenced significantly with calmax spray. Among the various treatments, the response was maximum with calmax spray @ 9 l ha^{-1} thrice equally at square formation, flower initiation and peak flowering stages followed by calmax spray @ 6 l ha^{-1} thrice equally at square formation, flower initiation and peak flowering stages, urea + planofix spray as per recommendation and calmax spray @ 9 l ha^{-1} twice equally at square formation and flower initiation stages.

Plant height differed significantly due to foliar application of calmax. The highest plant height (123.87 cm) at harvest (Table 3) was recorded with calmax spray @ 9 l ha^{-1} thrice equally at square formation, flower initiation and peak flowering stages. But it was on par with calmax spray @ 6 l ha^{-1} equally thrice at square formation, flower initiation and peak flowering stages (120.13 cm), urea + planofix spray as per recommendation (119.91 cm) and calmax spray @ 9 l ha^{-1} equally twice at square formation and flower initiation stages (117.48 cm). This might be due to the application of micro and macronutrients which increased the plant height. Such effect was due to stimulation of stem elongation, cell elongation and promotion of cell division (Shukla *et al*., 1997).

Berger *et al*. (1945) mentioned that boron is very important and plays a positive role in cell division, cell elongation and forms an essential component of cell wall. Similarly, Tusi (1948) has given convincing evidence of the importance of Zn in the production of growth promoting hormones. Similar results were reported by Sawan *et al*. (1997).

Calmax spray significantly influenced the sympodial branches but not the monopodial branches (Table 4 and 5). Application of calmax @ 9 l ha^{-1} equally thrice at square formation, flower initiation and peak flowering stages recorded significantly higher number of sympodial branches per plant (32.20) at harvest over control (water spray) (22.53). But it was on par with calmax spray @ 6 l ha^{-1} equally thrice at square formation, flower initiation and peak flowering stages (31.26), urea + planofix spray as per recommendation (31.20) and calmax spray @ 6 l ha^{-1} equally twice at square formation and flower initiation stages (30.90). This might be due to active participation of micronutrients in plant metabolism by activating the enzymes, increasing photosynthetic activity, efficient translocation, assimilation of photosynthates and increase in both cell division and cell elongation in apical meristem in growing parts leading to increased length of internodes. Similar results were reported by Basavarajappa *et al*. (1997).

In the present study, the leaf area and leaf area index increased upto boll formation stage and declined thereafter due to senescence and ageing of leaves. The application of calmax exhibited a profound effect on these parameters at all the stages. This is in accordance with Patel (1993) who reported that with foliar application of NAA (10 ppm) there was an increase in leaf area index in cotton.

Leaf area fairly gives a good idea of the photosynthetic capacity of the plant. In the present study, it was observed that leaf area (Table 6) increased significantly upto boll formation stage with the application of calmax @ 9 l ha^{-1} equally thrice at square formation, flower initiation and peak flowering stages (135.17 dm^2) over control (water spray) (95.25 dm^2). It was on par with calmax spray @ 6 l ha^{-1} equally thrice at square formation, flower initiation and peak flowering stages (132.69 dm^2), recommended spray of urea + planofix (131.21 dm^2) and calmax spray @ 9 l ha^{-1} equally twice at square formation and flower initiation stages (129.72 dm^2). These results are inconformity with the findings of Sarour *et al*. (1988), where foliar application of 4 per cent urea either alone or incombination with mixture of micronutrients produced the higher leaf area per plant and LAI. This might be due to higher uptake of NPK by the plant and cell division, cell elongation and reduction in the abscission of leaves by regulatory senescence. Leaf area being the photosynthetic surface, plays an important role in determining the total biomass production and the amount of photosynthates availability for production of economic yield. Therefore it is hypothised that higher nutrient status in leaves due to sprays might have improved the CO_2 exchange rate resulting in increased photosynthesis and yield (Nataraj *et al*., 1972).

Growth parameters like AGR, CGR, RGR and NAR have been extensively used for better understanding the physiological basis for yield variations in crop plant.

The growth indices AGR and CGR differed significantly at various growth stages (Table 8 and 9). Differential response of treatments at various growth stages were noticed with respect to growth indices *viz*., AGR and CGR, it was observed that both the parameters increased from 45-75 DAS to 75-105 DAS which could be attributed to greater accumulation of photosynthates with growth advancement. The computation of AGR and CGR at different growth stages indicated that they were maximum at 75-105 DAS. Similarly, Brar *et al*. (1982) showed that the foliar application NAA (20 ppm) markedly increased both AGR and CGR in cotton. Sharma (1995) also reported that the foliar application of micronutrients significantly increased the AGR and CGR in blackgram.

Between 75-105 DAS (Table 21), calmax spray @ 9 l ha^{-1} equally thrice at square formation, flower initiation and peak flowering stages showed higher AGR (r=0.74) and CGR (r=0.74), which had significantly positive correlation with the seed cotton yield (kg ha^{-1}). However, there was no significant correlation of RGR and NAR with yield.

Application of calmax had no significant influence on RGR at any growth stage. These results are inconfirmity with Baghel and Yadav (1992).

Yield improvement in any crop could be attributed to the higher production of assimilates and better partitioning of photoassimilates towards reproductive or economic sinks. The rate of dry matter accumulation may also have an influence on dry matter partitioning and it is difficult to establish a cause and effect of relationship between the partitioning and growth rate.

In the present study, it was found that, dry matter production and its distribution to different plant parts *viz*., leaf, stem and reproductive parts was significantly increased (Table 15) with application of calmax. At harvest, the total dry matter production was significantly higher with calmax spray @ 9 l ha^{-1} equally thrice at square formation, flower initiation and peak flowering stages (145.21 g) over control (water spray) (122.23 g). But it was on par with calmax spray @ 6 l ha^{-1} equally thrice at square formation, flower initiation and peak flowering stages (143.72 g), urea + planofix spray as per recommendation (141.23 g) and calmax spray @ 9 l ha^{-1} at equally twice at square formation and flower initiation stages (135.74 g). Similar results were reported by Hunsagi and Katarki (1974). This may be due to higher production of assimilates and better partitioning of photo-assimilates and increased metabolic activity as a result of increased leaf area index. Such results were also obtained by Sarour *et al*. (1988) where higher dry matter production was recoded with foliar application of mixture of macro micronutrients (urea+calcium super phosphate + trace elements).

PRACTICAL UTILITY OF RESULTS

1. Application of calmax @ 9 l ha^{-1} in three equal splits at square formation, flower initiation and peak flowering stages recorded significantly higher seed cotton yield which was 9.8 per cent higher than the control (water spray).

2. Calmax sprayed @ 6 l ha^{-1} in three equal splits at square formation, flower initiation and peak flowering stages, recommended practice of urea + planofix and clamax spray @ 9 l ha^{-1} in two equal splits at square formation and flower initiation can be used as an alternative to the calmax @ 9 l ha^{-1} in three equal splits at square formation, flower initiation and peak flowering stages.

FUTURE LINE OF WORK

1. There is a need to findout the critical limits of the essential micronurients both in soil and plant for micronutrient management in cotton in different soil conditions

2. There is a need to study the micronutrient management on long term basis using organics and other sources through integrated management system.

VI. SUMMARY

A field experiment was conducted at Main Agricultural Research Station, Dharwad on *vertisols* during *kharif* season of 2005-06 to study the effect of calmax a foliar micronutrient fertilizer on hybrid cotton (DHH-11) under rainfed condition. The experiment was laid out in a randomized block design with 14 treatments and three replications. The results of the investigations are summarized below.

- The seed cotton yield differed significantly due to calmax spray at different doses and times.
- Spraying calmax @ 9 l ha^{-1} three equal splits at square formation, flower initiation and peak flowering stages recorded the highest seed cotton yield (1406 kg ha^{-1}) which was 9.8 per cent higher over control.
- Among the various treatments, application of calmax @ 6 l ha^{-1} in three equal splits at square formation, flower initiation and peak flowering stages, calmax @ 9 l ha^{-1} in two equal splits at square formation and flower initiation stages and foliar spray of urea along with planofix recorded on par kapas yield (1395 kg ha^{-1}, 1332 kg ha^{-1} and 1373 kg ha^{-1}, respectively) were on par with calmax @ 9 l ha^{-1} in three equal splits at square formation, flower initiation and peak flowering stages (1406 kg ha^{-1}).
- Control (water spray) treatment recorded the lowest seed cotton yield (1280 kg ha^{-1}).
- Higher seed cotton yield with calmax spray @ 9 l ha^{-1} in three equal splits at square formation, flower initiation and peak flowering stages was due to higher yield components *viz.*, mean boll weight, number of bolls per plant and kapas yield per plant.
- Mean boll weight (5.56 g), harvested bolls per plant (31.66) and yield per plant (75.90 g plant^{-1}) were highest with calmax spray @ 9 l ha^{-1} in three equal splits at square formation, flower initiation and peak flowering stages.
- The effect of yield components on seed cotton yield was due to variations in growth components like sympodial branches per plant, leaf area per plant, LAI and dry matter production and distribution in different plant parts.
- At harvest, the total dry matter production (145.21 g plant^{-1}) significantly higher with the application of calmax @ 9 l ha^{-1} in three equal splits at square formation, flower initiation and peak flowering stages compared to control (water spray) (122.65 g plant^{-1}). The dry matter distribution in stem, leaf and reproductive parts also followed the same trend.
- Similar trend was also noticed with respect to other growth components *viz.*, sympodial branches per plant, leaf area per plant, LAI, AGR and CGR.
- Correlation between yield and yield components indicated that the seed cotton yield had a significant and positive correlation with yield components *viz.*, yield per plant (r=0.99), harvest bolls per plant (r=0.86) and mean boll weight (r=0.92). Also the growth components *viz.*, sympodial branches (r=0.85), leaf area (r=0.82), leaf area index (r=0.83), dry matter accumulation in reproductive parts (r=0.99), total dry matter production (r=0.97) had significant and positive correlation with seed cotton yield.

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APPENDIX I

Weekly distribution of rainfall (mm), relative humidity (%), maximum and minimum temperature (℃) during cropping year 2005-06 recorded at the Meteorological Observatory, Main Agricultural Research Station, University of Agricultural Sciences, Dharwad

Sl. No.	Standard weeks	Period	Rainfall (mm)	Relative humidity (%)	Temperature (℃)	
					Max.	Min.
1	14	2 April-8 April	0.0	48.5	36.8	21.8
2	15	9 April-15 April	37.0	52.0	36.4	20.6
3	16	16 April-22 April	21.4	62.0	35.3	21.3
4	17	23 April-29 April	16.6	51.5	36.1	22.0
5	18	30 April-6 May	0.0	53.0	36.1	20.4
6	19	7 May-13 May	0.0	51.0	36.6	21.5
7	20	14 May-20 May	0.0	42.0	39.5	21.3
8	21	21 May-27 May	22.4	61.0	38.2	22.7
9	22	28 May-3 June	8.2	70.5	31.7	21.6
10	23	4 June-10 June	25.6	64.0	34.2	21.8
11	24	11 June-17 June	24.6	70.5	33.2	21.9
12	25	13 June-24 June	22.6	84.5	28.6	20.9
13	26	25 June-1 July	92.2	88.5	26.8	21.3
14	27	2 July-8 July	53.6	82.5	27.2	21.3
15	28	9 July-15 July	11.0	75.5	29.4	21.1
16	29	16 July-22 July	61.2	84.5	28.8	21.0
17	30	23 July-29 July	130.4	91.0	25.3	20.5
18	31	30 July-5 August	54.8	89.0	25.4	20.3
19	32	6 Aug. -12 Aug.	18.8	86.5	26.1	20.5
20	33	13 Aug.-19 Aug.	27.4	88.5	26.4	20.5
21	34	20 Aug.-26 Aug.	96.0	79.5	27.8	19.7
22	35	27 Aug.-2 Sep.	109.0	80.0	30.0	20.6
23	36	3 Sep.-9 Sep.	30.4	86.0	28.5	21.2
24	37	10 Sep.-16 Sep.	19.6	86.5	26.7	20.3

Appendix I. Contd…..

Sl. No.	Standard weeks	Period	Rainfall (mm)	Relative humidity (%)	Temperature (°C)	
					Max.	Min.
25	38	17 Sep.-23 Sep.	51.5	89.0	26.3	20.1
26	39	24 Sep.-30 Sep.	33.0	79.0	27.6	19.4
27	40	1 Oct.-7 Oct.	1.8	68.5	30.1	19.5
28	41	8 Oct.-14 Oct.	21.6	72.5	30.7	19.5
29	42	15 Oct.-21 Oct.	53.4	76.0	29.1	19.9
30	43	22 Oct.-28 Oct.	8.0	65.2	29.6	17.6
31	44	29 Oct.-4 Nov.	42.0	68.5	28.6	18.7
32	45	5 Nov.-11 Nov.	0.0	51.5	29.4	14.9
33	46	12 Nov.-18 Nov.	0.0	39.0	29.9	11.7
34	47	19 Nov.-25 Nov.	0.0	51.0	29.5	15.7
35	48	26 Nov.-2 Dec.	0.0	51.5	29.0	14.7
36	49	3 Dec.-9 Dec.	0.0	63.5	29.2	15.1
37	50	10 Dec.-16 Dec.	0.0	54.0	29.1	13.0
38	51	17 Dec.-23 Dec.	0.0	50.0	29.3	12.7
39	52	24 Dec.-31 Dec.	0.0	50.0	27.9	11.6
40	1	1 Jan.-7 Jan.	0.0	61.0	28.0	11.3
41	2	8 Jan.-14 Jan.	0.0	61.5	30.0	14.5
42	3	15 Jan.-21 Jan.	0.0	50.5	31.8	14.3
43	4	22 Jan.-28 Jan.	0.0	42.5	29.9	12.3
44	5	29 Jan.-4 Feb.	0.0	41.0	30.4	11.7
45	6	5 Feb.-11 Feb.	0.0	39.5	30.7	13.0
46	7	12 Feb.-18 Feb.	0.0	44.0	31.9	15.6
47	8	19 Feb.-25 Feb.	0.0	33.5	34.9	16.9
48	9	26 Feb.-4 Mar.	0.0	50.0	34.3	18.1
49	10	5 Mar.-11 Mar.	5.2	49.5	33.3	16.8
50	11	12 Mar.-18 Mar.	0.0	48.0	31.4	15.3
51	12	19 Mar.-25 Mar.	0.0	35.5	35.4	19.7
		Total	1011.5			

EFFECT OF CALMAX, A FOLIAR MICRONUTRIENT FERTILIZER ON GROWTH AND YIELD OF HYBRID COTTON UNDER NORTHERN TRANSITIONAL ZONE OF KARNATAKA

RAGHAVENDRA C. DESHPANDE **2006** **Dr. S. I. HALIKATTI MAJOR ADVISOR**

ABSTRACT

A field experiment on effect of calmax, a foliar micronutrient fertilizer on growth and yield of hybrid cotton under northern transitional zone of Karnataka was conducted at Main Agricultural Research Station, University of Agricultural Sciences, Dharwad under rainfed condition on black clay loam soil during 2005. Experiment was laid out in a randomised complete block design with 14 treatments comprising three doses of calmax (3, 6 and 9 l ha^{-1}) and three stages of cotton (square formation, flower initiation and peak flowering stages), planofix + urea as per recommendation with a control treatment (water spray).

In the present investigation, application of calmax resulted in significant improvement in kapas yield of cotton. Application of calmax @ 9 l ha^{-1} in three equal splits at square formation, flower initiation and peak flowering stages recorded significantly higher seed cotton yield (1406 kg ha^{-1}) which was 9.8 per cent higher than the control (water spray). However, it was on par with other treatments, calmax spray @ 6 l ha^{-1} in three equal splits at square formation, flower initiation and peak flowering stages (1395 kg ha^{-1}), recommended spray of urea + planofix (1373 kg ha^{-1}) and calmax spray @ 9 l ha^{-1} in two equal splits at square formation and flower initiation stage (1332 kg ha^{-1}).

The yield increase was attributed to higher number of harvested bolls per plant (31.66), mean boll weight (5.56 g), yield per plant (75.90 g $plant^{-1}$) and harvest index (34.78) which was mainly due to beneficial effect on partitioning of vegetative and reproductive growth and these parameters showed a significant and positive correlation with seed cotton yield per hectare.

The seed index and ginning percentage were not affected significantly by calmax spray.