



Effect of Foliar Feeding of Gluconate and EDTA Chelated Plant Nutrients on Yield, Chlorophyll Content and Nitrate Reductase Enzyme of Bt Cotton under Rainfed Ecosystem of Marathawada

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

An experiment was conducted to find out the "Effect of foliar feeding of Gluconate and EDTA chelated plant nutrients on yield, Chlorophyll content and Nitrate reductase enzyme activity of Bt-cotton under rainfed ecosystem of Marathawada" at Department of Soil Science and Agril Chemistry, VNMKV, Parbhani. The experiment includes sixteen treatments viz, T₁-control, T₂-ZnGluconate, T₃-Zn EDTA, T₄-Mn gluconate, T₅- Mn EDTA, T₆- Cu Gluconate, T₇- Cu EDTA, T₈-FeGluconate, T₉- Fe EDTA, T₁₀- CaGluconate, T₁₁- Ca EDTA, T₁₂-MgGluconate, T₁₃-MgEDTA, T₁₄-Zn, Mn, Cu, Fe, Ca and Mg Gluconate, T₁₅-Zn, Mn, Cu, Fe, Ca and Mg EDTA and T₁₆- Govt. grade II and replicated twice. The treatments were fertilized with 120:60:60 N,P₂O₅ and K₂O Kg ha⁻¹. Micronutrient sprays of gluconate and EDTA chelated plant nutrients were applied to the crop at the time of flowering i.e. at 55 DAS and second spray was applied at the time of boll development stage i.e. at 75 DAS. The treatment T₂ showed more number of bolls per plant followed by treatment T₃. The maximum boll weight was observed with treatment Zn gluconate. Spraying of Zn gluconate, Zn EDTA and Fe and Mg gluconate nutrients have produced more seed cotton yield. Quantitative analysis of chlorophyll was done by using DMSO as an extractant. Chlorophyll a, chlorophyll b and

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total chlorophyll content in leaves also influenced significantly due to different foliar feeding. The highest chlorophyll a, chlorophyll b and total chlorophyll was registered with the treatment Fe gluconate spray followed by Fe EDTA. Nitrate reductase and acid phosphate activity were improved by the application of T₂ and was found to be significantly superior over control. This study was conducted under rainfed ecosystem.

Keywords: Foliar feeding; gluconate; EDTA; chlorophyll content; anthocyanin content; enzyme activity; Bt-cotton; rainfed ecosystem.

1. INTRODUCTION

Cotton (*Gossypium* spp.) is one of the most important commercial crops playing a key role in economical, political and social status of the world and so has retained its unique fame and name as the “King of fibres” and “White gold” because of its higher economical value among cultivable crops for quite a long period. It was the superiority of Indian cotton fabrics famed as “Web of woven mind” which attracted European countries to seek new trade routes to India. Indian economy continued to receive great support from the cotton industry, is one of the major industries in India contributing [1] 12 per cent to the export basket with improved cotton productivity and other innovations. In the production line, India will be in a position to get more foreign exchange and earned Rs. 10270.21 crores from the export of 83.00 lakh bales in 2009-10 (Cotton Advisory Board).

Plant nutrition have traditionally considered the obvious way to feed plants is through the soil, where plant roots are meant to uptake water and nutrients but in recent years foliar feeding has been developed to supply plants with their nutritional needs. It constitutes one of the important milestones in the progress of agriculture crop production, as a natural phenomenon of nutrient uptake, it has existed with all form of plants life from their beginning (www.groversminral.com). Foliar feeding is the application or feeding of a plant, a liquid plant nutrient or nutrient additive through the leaves instead of via the root. It is a method of plant fertilization which involves applying fertilizer directly to the leaves in the form of solution which is spread on the tiny pores in the leaves allows the fertilizer to pass into the plant providing needed nutrition. Foliar nutrients are mobilized directly into plant leaves which is the goal of fertilization to begin with increasing the rate of photosynthesis in the leaves and by doing so stimulate nutrient absorption by plant roots. When the foliar plant food is sprayed on the leaves, it causes the plant metabolism to speed

up. This causes the plant to demand more water and nutrients from the root system. It is this increase in water and nutrient sent by the roots that provide the potential for higher yield.

Foliar feeding is a reliable method of feeding plants when soil feeding is inefficient. Almost everything a plant requires to grow and develop is manufactured in the leaves. Hormones, metabolites, proteins, amino-acids the list goes on and they are all manufactured in specialized cells contained within the plants leaves. Most leaves have stomata either only on the underside or on both sides of the leaf. Foliar absorption is through the stomata's which are microscopic pores in the epidermis of the leaf. The leaf with its epidermis can also function as an organ that absorbs and exerts water and substance which may be dissolved in it, when the stomata's are open, foliar absorption is easier.

So, the foliar application assumes greater importance, as the nutrients are brought near the metabolizing area i.e. foliage. Information regarding the effect of foliar feeding of cotton is inadequate, moreover use of chelated nutrients e.g. EDTA chelates and newly developed gluconate chelates required to be tested for their performance.

2. MATERIALS AND METHODS

A research project “Effect of foliar feeding of gluconate and EDTA chelated plant nutrients on yield, Chlorophyll content and Nitrate reductase enzyme activity of Bt-cotton under rainfed ecosystem of Marathwada” was conducted during 2009-10 and 2010-2011 at Vasant Naik Marathwada Krishi Vidyapeeth, Parbhani. It was aimed to find out the influence of foliar feeding of micronutrient through gluconate and EDTA. Gluconate is a salt of gluconic acid, which helps to increase the efficiency of micronutrients and EDTA (Ethylene diamine tetra acetic acid) which has property of forming stable soluble complexes. The foliar application assumes greater importance as the nutrient are brought in

the immediate vicinity of the metabolizing area i.e. foliage and also these nutrients are fast acting nutrients. The field experiments were conducted on TypicHaplusterts at Research Farm of Department of Soil Science and Agricultural Chemistry. The soil is characterized by black colour dominated by montmorillonite clay with high coefficient of expansion and shrinkage leads to deep cracking. The soils are formed from basaltic material. According to 7th approximation, the soils are classified as TypicHaplusterts [2] and are included in Parbhani series. The topography of experimental plot was fairly level. In order to determine the soil properties of experimental soil before sowing the surface (0-22.5 cm depth) soil sample were collected from randomly selected spots covering experimental area. A composite soil sample was prepared and analyzed for its various physico-chemical properties. The experimental soil was fine, Smectitic (Calcareous), Iso-hyperthermic Typic Haplusters. It was slightly alkaline in reaction (8.20 and 8.0), safe in soluble salt concentration (EC 0.117 to 0.113 dSm⁻¹) and medium in organic carbon content (6.70 and 6.50 g kg⁻¹ for cotton crop during the year 2009 and 2010). The free calcium carbonate content was 48.00 to 36.00 g kg⁻¹. The available nitrogen, phosphorus and potassium content of experimental soil of cotton were 147.00 and 139.00 kg ha⁻¹, 8.9 and 10.20 kg ha⁻¹, 887.00 and 670.00 kg ha⁻¹, during 2009 and 2010, respectively and can be categorized as low in available N, medium in P₂O₅ and high in K₂O. Exchangeable Ca and Mg status were 27.30 and 24.48 C mol (p⁺) kg⁻¹ and 16.30 and 14.80 C mol (p⁺) kg⁻¹, respectively. While, the micronutrient status like zinc, iron, manganese and copper content before administration of treatments were 0.56 and 0.53, 2.62 and 2.60, 15.17 and 13.08, 4.39 and 3.57 mg kg⁻¹ during 2009 and 2010, respectively and rated as low in Zn and Fe and high in Mn and Cu. the experiment was laid out in Randomized Block Design comprising sixteen (16) treatments replicated two (2) times in cotton crop. The recommended dose of fertilizer was applied to the crop (120:60:60 kg NPK ha⁻¹). The certified seed of cotton RCH-2 (BG-II) were sown in kharif season by dibbling one seed per hill at 90 x 60 cm distance.

Nitrogen was given in two splits. Fifty per cent nitrogen was applied at the time of sowing and the remaining 50 per cent was applied one month after sowing. Entire dose of phosphorus and potassium was applied at the time of sowing.

Micronutrient sprays of gluconate and EDTA chelated plant nutrients were applied to the crop at the time of flowering i.e. at 55 DAS and second spray was applied at the time of boll development stage i.e. at 75 days after sowing. Two plants were randomly selected from two observation line of each plot, tagged and all biometric observations were recorded. Initial and periodical soil samples were collected at 40, 60, 80, 100, 120 DAS and at harvest stage of crop from surface layer (0.15 cm) of each treated plots of the layout. Soils were air dried, ground with wooden mortar and pestle and passed through 2 mm sieve. The sieved samples were stored in polythene bags with proper labelling for further analysis. Nutrient content in cotton plant as influenced by treatment combinations was determined periodically at 20 days interval and after harvest of crop. The samples were washed with the tap water and in detergent solution followed by distilled water. After cleaning, plants were dried in shade and subsequently in the oven at 70°C for 12 hrs. The oven dried sample were ground in electrically operated grinder with stainless steel blade to maximum fineness. The powdered samples were stored in polythene packets with proper labeling and utilized for nutrient content studies. The quantitative analysis of chlorophyll was done by using DMSO as an extractant. The quantification of anthocyanine pigment was done spectrophotometrically by using absorbance of 535 nm wave length. The comparative activities of nitrate reductase activity, acid phosphate, peroxidase and catalyse in cotton plant was used as an index to the active nitrogen, phosphorus and iron in plants. The fresh leaf samples of cotton were collected and made into pieces places at room temperature. So that they could not differ into upper, middle and lower leaves. They were blotted and weighed about 500 mg, crushed with 5 mL of phosphate buffer, pH 6.5 (0.1 M) in already chilled mortar and pestle (4 ± 1°C) and strained through double layered muslin cloth and later through filter paper. The volume was made upto 10 mL with phosphate buffer. This extract was used to determine the enzyme activity.

3. RESULTS AND DISCUSSION

3.1 Yield Attributes of Bt Cotton

The data emerged out from the field experiment were analyzed by analysis of variance and degree of freedom were partitioned into different variance, due to replication and treatments

combinations. Results were statistically analyzed as per the method given in statistical method for agricultural workers by Panse and Sukhatme [3].

3.1.1 Number of bolls

The results presented in Table 1 revealed that treatment difference due to foliar feeding of gluconate and EDTA chelated plant nutrients were significant throughout the growth stages of Bt cotton crop in production of number of bolls plant⁻¹.

The number of bolls plants⁻¹ increased from 51.00 to 78.00 at harvest. The maximum number of bolls plant⁻¹ were observed with treatment T₂ (Zn gluconate) and minimum in treatment T₁ (control). The result concluded that treatment T₂ (Zn gluconate) gave the highest number of bolls, followed treatment T₃, T₈, T₉, T₁₃ and T₁₂ and these treatments were also found at par with each other.

The increase in a number of bolls may be due to micronutrient applications which are involved in the greater diversion of the metabolites to the fruiting parts, culminating in more boll production. This finding is in conformation with earlier reported by Venkatkrishna and Pothiraj (1994). Increasing value of NPK with micronutrients leads to increase number bolls plant⁻¹ might be also due to availability of nutrients for longer period through two foliar sprays. The above findings are in agreement with the finding of Bhaskar (1993) and Malewar et al. [4].

3.1.2 Boll weight

The data on the effect on foliar feeding of gluconate and EDTA chelated plants nutrients on boll weight are presented in Table 1. The boll weight of Bt cotton varied between 2.39 to 3.50 g. The highest boll weight was recorded with T₂ (Zn gluconate) and lowest in control treatment (T₁).

The data revealed that treatment T₂ (Zn gluconate) recorded highest boll weight (i.e. 3.50), which was on par with treatment T₃ (Zn EDTA), T₂ (Zn gluconate), T₈ (Fe gluconate) and T₉ (Fe EDTA) and significantly superior over the control. This might be due to accelerated mobility of photosynthates from source to sink as influenced by the application of zinc and iron. Similar observations were also made by Ahlawat [5], Namdeo et al. [6], Wankhede et al. [7],

Anonymous (1995), Hanumantha Reddy (1999) and Sasthri et al. [8].

3.1.3 Cotton yield (kg ha⁻¹)

The data regarding effect foliar feeding of gluconate and EDTA chelated plant nutrients on yield of cotton are presented in Table 1.

The application of varied levels of foliar feeding of micronutrients significantly influenced the cotton yield. The yield was ranged from 1498.14 to 2709.67 kg ha⁻¹.

The data showed that application of Zn gluconate increases the cotton yield which was to the tune of 2709.67 kg ha⁻¹. However, it was on par with the application of treatment T₃ (Zn EDTA) however, significantly superior over control (T₁). From the above results, it can be concluded that due to foliar application of micronutrient there was an increase in cotton yield.

In cotton, the yield depends on the accumulation of photoassimilates and its partitioning in different parts of the plant. The yield is strongly influenced by the application of foliar micronutrient indicating the role of these micronutrients in increasing the yield through their effect on various morpho-physiological traits. Foliar micronutrients in known to increase the yield of cotton crop [7,8].

Sharma et al. [9] obtained the foliar spray of multi-micronutrient proved highly beneficial for increasing yield and yield attributes. It may be due to the sufficient availability of micronutrients by foliar feeding, which was not only an additional channel of nutrition but also means of regulating root uptake. Sharma et al. [10] observed that foliar application of Zn (0.5 per cent) on 50 and 65 DAS gave seed cotton yield of 14.69 ha⁻¹ compared with 11.82 q ha⁻¹ without Zn. Application of zinc and iron enhanced seed cotton yield. This might be due to improved growth and yield attributing characters. Similar results were recorded by Chhabra et al. [11] in cotton. Rajendran [12] also concluded that foliar application of nutrient in alone or in combination has a great effect in improving the efficiency of utilization of nutrients and thereby improves the growth and seed cotton yield.

3.1.4 Nitrate reductase

The data regarding the effect of foliar feeding of gluconate and EDTA chelated plant nutrient on

nitrate reductase activity at flowering stage of Bt cotton are presented in Table 1.

The assimilatory nitrate reductase enzyme converts nitrate into nitrite which is further reduced to ammonia by nitrite reductase. Thus, in nitrate reduction process, conversion of nitrate is a rate limiting step. Hence, nitrate reductase enzyme has a very important role in regulation of nitrate assimilation in higher plants. Nitrate is reduced to nitrite by nitrate reductase which is a key enzyme in nitrate assimilatory pathway [13]. Maximum nitrate reductase activity was noticed with treatment T₂ (Zn gluconate) at flowering stage of Bt cotton crop and it was found to be distinctly superior over control. The treatment T₂ (Zn gluconate) was found to be significantly superior over control and other treatments. The treatment T₃ (Zn EDTA), T₈ (Fe gluconate) and T₉ (Fe EDTA) were at par with the Zn application treatments.

Similar findings also observed by Nehra et al. [14] and Asad and Rafique [15], Chaubey et al. [16] emphasized the role of Zn in starch formation due to its influence on the activity of enzyme starch synthetize which could be attributed as a possible reason for increase in enzyme activity. There are many references

quoting involvement of 'N' in nitrate reductase activity, Nazirkar and Adsule, [17] responded that the nitrate reductase activity found to be increased with N application. Nitrogen application (280 g N ha⁻¹) significantly increased nitrate reductase activity. Nitrogen applied plants on the average had a 20 per cent higher activity over the control throughout the growing season [18]. However, in present investigation it was noted that Zn, Fe were also involved in nitrate reductase activity.

3.2 Chlorophyll Content of Bt- Cotton

3.2.1 The effect of foliar feeding of gluconate and EDTA chelated plant nutrients on chlorophyll content of Bt cotton

3.2.1.1 Chlorophyll 'a'

The data on chlorophyll 'a' content in cotton leaves, as influenced by foliar feeding of chelated plant nutrients at different time intervals for two consecutive years 2009-10 and 2010-11 and pooled and presented in Table 2.

Application of various micronutrients and their combinations has profound influence on chlorophyll 'a' content. Application of treatment T₈

Table 1. Effect of foliar feeding of gluconate and EDTA chelated plant nutrient on number of bolls plant⁻¹, boll weight (g boll⁻¹), yield (Kg ha⁻¹) and nitrate reductase enzyme activity of Bt cotton

| Treatment | Number of bolls plant ⁻¹ | Boll weight (g boll ⁻¹) | Yield (Kg ha ⁻¹) | Nitrate reductase activity (moles) NO ₂ ⁻ /g fresh wt. hr ⁻¹ |
|--|-------------------------------------|-------------------------------------|------------------------------|---|
| T ₁ -Control | 51.00 | 2.39 | 1498.14 | 0.121 |
| T ₂ -Zn gluconate | 78.00 | 3.50 | 2709.67 | 0.194 |
| T ₃ -Zn EDTA | 77.00 | 3.47 | 2515.95 | 0.188 |
| T ₄ -Mn gluconate | 65.50 | 3.05 | 2114.96 | 0.151 |
| T ₅ -Mn EDTA | 67.25 | 3.10 | 2157.13 | 0.158 |
| T ₆ -Cu gluconate | 59.25 | 2.84 | 1683.37 | 0.133 |
| T ₇ -Cu EDTA | 56.75 | 2.78 | 1643.51 | 0.132 |
| T ₈ -Fe gluconate | 72.25 | 3.29 | 2323.93 | 0.181 |
| T ₉ -Fe EDTA | 71.75 | 3.23 | 2259.57 | 0.173 |
| T ₁₀ -Ca gluconate | 54.75 | 2.55 | 1610.47 | 0.126 |
| T ₁₁ -Ca EDTA | 53.50 | 2.48 | 1552.76 | 0.123 |
| T ₁₂ -Mg gluconate | 69.50 | 3.13 | 2191.83 | 0.162 |
| T ₁₃ -Mg EDTA | 71.25 | 3.16 | 2228.79 | 0.165 |
| T ₁₄ -Zn, Mn, Cu, Fe, Ca and Mg gluconate | 65.00 | 3.00 | 1919.59 | 0.139 |
| T ₁₅ - Zn, Mn, Cu, Fe, Ca and Mg EDTA | 63.75 | 2.88 | 1760.00 | 0.137 |
| T ₁₆ -Government grade 2 | 65.75 | 2.89 | 2077.95 | 0.144 |
| SE ± | 2.61 | 0.08 | 94.91 | 0.005 |
| CD at 5% | 9.15 | 0.29 | 332.84 | 0.017 |

Table 2. Effect of foliar feeding of gluconate and EDTA chelated plant nutrient on chlorophyll 'a' (mg g⁻¹) of Bt cotton

| Treatments | Chlorophyll 'a' (mg g ⁻¹) | | | | | |
|--|---------------------------------------|--------|--------|---------|---------|------------|
| | 40 DAS | 60 DAS | 80 DAS | 100 DAS | 120 DAS | at harvest |
| T ₁ -Control | 0.369 | 0.451 | 0.666 | 0.827 | 0.746 | 0.582 |
| T ₂ -Zn gluconate | 0.647 | 0.748 | 1.015 | 1.245 | 1.086 | 0.905 |
| T ₃ -Zn EDTA | 0.580 | 0.684 | 0.890 | 1.183 | 1.000 | 0.825 |
| T ₄ -Mn gluconate | 0.555 | 0.664 | 0.863 | 1.162 | 0.977 | 0.852 |
| T ₅ -Mn EDTA | 0.621 | 0.723 | 0.989 | 1.219 | 1.056 | 0.875 |
| T ₆ -Cu gluconate | 0.536 | 0.640 | 0.847 | 1.130 | 0.952 | 0.788 |
| T ₇ -Cu EDTA | 0.603 | 0.698 | 0.911 | 1.199 | 1.030 | 0.853 |
| T ₈ -Fe gluconate | 0.807 | 0.873 | 1.209 | 1.402 | 1.195 | 1.064 |
| T ₉ -Fe EDTA | 0.772 | 0.846 | 1.182 | 1.380 | 1.164 | 1.045 |
| T ₁₀ -Ca gluconate | 0.406 | 0.485 | 0.702 | 0.858 | 0.790 | 0.628 |
| T ₁₁ -Ca EDTA | 0.388 | 0.464 | 0.688 | 0.838 | 0.769 | 0.609 |
| T ₁₂ -Mg gluconate | 0.747 | 0.826 | 1.157 | 1.352 | 1.143 | 0.974 |
| T ₁₃ -Mg EDTA | 0.722 | 0.804 | 1.079 | 1.322 | 1.115 | 0.953 |
| T ₁₄ -Zn, Mn, Cu, Fe, Ca and Mg gluconate | 0.460 | 0.532 | 0.745 | 0.951 | 0.851 | 0.663 |
| T ₁₅ - Zn, Mn, Cu, Fe, Ca and Mg EDTA | 0.477 | 0.554 | 0.772 | 0.974 | 0.872 | 0.693 |
| T ₁₆ -Government grade 2 | 0.493 | 0.574 | 0.796 | 1.051 | 0.891 | 0.722 |
| SE ± | 0.009 | 0.01 | 0.008 | 0.009 | 0.01 | 0.009 |
| CD at 5% | 0.03 | 0.36 | NS | 0.03 | 0.05 | 0.03 |
| Grand mean | 0.57 | 0.66 | 0.91 | 1.131 | 0.977 | 0.814 |

(Fe gluconate) and T₉ (Fe EDTA) significantly increased the chlorophyll 'a' content which was 0.830 and 0.793 mg g⁻¹ at 40 DAS. Further, the same treatments showed significantly higher chlorophyll 'a' at different growth stages of observation of Bt cotton over the control (T₁). Similarly, foliar application of Mg also helped to improve the chlorophyll content at all growth stages in both the years and in pooled.

It is to be noted here that even at harvesting stage application of Fe and Mg maintained higher chlorophyll concentration in the leaves of Bt cotton. This might be the reason of less reddening observed in these treatments.

Among the two salts used in the present investigation gluconate complexed nutrient had showed superiority over EDTA complexed nutrients.

3.2.1.2 Chlorophyll 'b'

The results on chlorophyll 'b' in Bt cotton leaves as influenced by foliar feeding of chelated plant nutrient are presented in Table 3.

Chlorophyll b content in leaves of Bt cotton on an average was highest at 100 DAS (1.13 mg g⁻¹) and found to be decreased with growth of cotton

crop. Maximum chlorophyll b content was observed in treatment T₈ (Fe gluconate), which was distinctly superior over control (T₁) and other treatments.

The periodical synthesis of chlorophyll b indicated the trend of its increase from 40 to 100 DAS and thereafter its rate was found to be dropped till at harvest.

The result on total chlorophyll content in cotton leaves as influenced by application of foliar feeding of chelated plant nutrients are compiled in Table 3.

Application of Fe gluconate significantly influenced on total chlorophyll content at 40, 60, 80 and 100 DAS during both the experimental years. Similarly, the pattern of total chlorophyll synthesis showed that it increased up to 100 DAS and later on declined with advancement in age of the crop.

It was observed from pooled data of 40, 60, 80 and 100DAS, the maximum total chlorophyll content and it was recorded in treatment T₈ (Fe gluconate) and minimum in treatment T₁ (control). Treatment T₈ (Fe gluconate) was found to be significantly superior over the control and at par with treatment T₉ (Fe EDTA).

Table 3. Effect of foliar feeding of gluconate and EDTA chelated plant nutrient on chlorophyll 'b' (mg g⁻¹) of Bt cotton

| Treatments | Chlorophyll 'b' (mg g ⁻¹) | | | | | |
|--|---------------------------------------|-----------|-----------|------------|------------|---------------|
| | 40 DAS | 60 DAS | 80 DAS | 100 DAS | 120 DAS | at harvest |
| T ₁ -Control | 0.197 | 0.235 | 0.436 | 0.471 | 0.302 | 0.171 |
| T ₂ -Zn gluconate | 0.297 | 0.361 | 0.569 | 0.580 | 0.450 | 0.259 |
| T ₃ -Zn EDTA | 0.288 | 0.342 | 0.551 | 0.564 | 0.423 | 0.232 |
| T ₄ -Mn gluconate | 0.296 | 0.337 | 0.548 | 0.562 | 0.413 | 0.226 |
| T ₅ -Mn EDTA | 0.289 | 0.356 | 0.560 | 0.576 | 0.442 | 0.250 |
| T ₆ -Cu gluconate | 0.289 | 0.333 | 0.543 | 0.554 | 0.403 | 0.224 |
| T ₇ -Cu EDTA | 0.294 | 0.346 | 0.556 | 0.572 | 0.433 | 0.242 |
| T ₈ -Fe gluconate | 0.358 | 0.407 | 0.597 | 0.621 | 0.498 | 0.307 |
| T ₉ -Fe EDTA | 0.345 | 0.405 | 0.591 | 0.610 | 0.485 | 0.292 |
| T ₁₀ -Ca gluconate | 0.244 | 0.258 | 0.468 | 0.498 | 0.329 | 0.180 |
| T ₁₁ -Ca EDTA | 0.244 | 0.252 | 0.453 | 0.486 | 0.316 | 0.176 |
| T ₁₂ -Mg gluconate | 0.320 | 0.393 | 0.587 | 0.599 | 0.475 | 0.283 |
| T ₁₃ -Mg EDTA | 0.306 | 0.387 | 0.582 | 0.591 | 0.468 | 0.275 |
| T ₁₄ -Zn, Mn, Cu, Fe, Ca and Mg gluconate | 0.271 | 0.280 | 0.499 | 0.522 | 0.352 | 0.200 |
| T ₁₅ - Zn, Mn, Cu, Fe, Ca and Mg EDTA | 0.271 | 0.289 | 0.509 | 0.531 | 0.363 | 0.208 |
| T ₁₆ -Government grade 2 | 0.279 | 0.304 | 0.521 | 0.538 | 0.375 | 0.214 |
| SE ± | 0.008 | 0.007 | 0.01 | 0.009 | 0.01 | 0.01 |
| CD at 5% | 0.02 | 0.02 | 0.04 | 0.03 | 0.03 | 0.04 |
| Grand mean | 0.286 | 0.330 | 0.536 | 0.555 | 0.408 | 0.234 |

Table 4. Effect of foliar feeding of gluconate and EDTA chelated plant nutrient on total chlorophyll (mg g⁻¹) of Bt cotton

| Treatments | Total chlorophyll (mg g ⁻¹) | | | | | |
|--|---|-----------|-----------|------------|------------|---------------|
| | 40 DAS | 60 DAS | 80 DAS | 100 DAS | 120 DAS | at harvest |
| T ₁ -Control | 0.552 | 0.682 | 1.320 | 1.672 | 1.261 | 0.786 |
| T ₂ -Zn gluconate | 0.932 | 1.146 | 1.647 | 2.037 | 1.631 | 1.189 |
| T ₃ -Zn EDTA | 0.855 | 1.076 | 1.576 | 1.971 | 1.560 | 1.099 |
| T ₄ -Mn gluconate | 0.824 | 1.054 | 1.553 | 1.941 | 1.532 | 1.080 |
| T ₅ -Mn EDTA | 0.904 | 1.123 | 1.619 | 2.015 | 1.603 | 1.155 |
| T ₆ -Cu gluconate | 0.803 | 1.027 | 1.538 | 1.915 | 1.506 | 1.057 |
| T ₇ -Cu EDTA | 0.884 | 1.104 | 1.595 | 1.993 | 1.586 | 1.130 |
| T ₈ -Fe gluconate | 1.166 | 1.266 | 1.771 | 2.203 | 1.794 | 1.346 |
| T ₉ -Fe EDTA | 1.140 | 1.245 | 1.754 | 2.180 | 1.769 | 1.316 |
| T ₁₀ -Ca gluconate | 0.605 | 0.723 | 1.385 | 1.727 | 1.327 | 0.837 |
| T ₁₁ -Ca EDTA | 0.576 | 0.705 | 1.354 | 1.708 | 1.293 | 0.816 |
| T ₁₂ -Mg gluconate | 1.110 | 1.227 | 1.730 | 2.151 | 1.740 | 1.297 |
| T ₁₃ -Mg EDTA | 1.084 | 1.203 | 1.709 | 2.122 | 1.710 | 1.269 |
| T ₁₄ -Zn, Mn, Cu, Fe, Ca and Mg gluconate | 0.672 | 0.866 | 1.469 | 1.783 | 1.369 | 0.921 |
| T ₁₅ - Zn, Mn, Cu, Fe, Ca and Mg EDTA | 0.701 | 0.890 | 1.483 | 1.805 | 1.396 | 0.955 |
| T ₁₆ -Government grade 2 | 0.725 | 0.912 | 1.504 | 1.830 | 1.422 | 0.977 |
| SE ± | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| CD at 5% | 0.04 | 0.03 | NS | 0.04 | 0.05 | 0.06 |
| Grand mean | 0.846 | 1.016 | 1.563 | 1.941 | 1.531 | 1.077 |

3.2.1.3 Total Chlorophyll

The results on total chlorophyll in Bt cotton leaves as influenced by foliar feeding of chelated

plant nutrient are presented in Table 4. The second best treatments were foliar application of Mg through gluconate and EDTA. So, it was very clear from the data recorded on chlorophyll

content that chlorophyll 'a' 'b' and total chlorophyll synthesis was more in the treatment received Fe and Mg.

Bt cotton crop treated with Fe gluconate (T₈) and Fe EDTA (T₉) treatment showed maximum synthesis of total chlorophyll and the minimum total chlorophyll was recorded with treatment T₁ (control). The treatments T₁₂(Mg gluconate) and T₁₃ (Mg EDTA) were found at par with superior treatment at all the stages.

The highest chlorophyll content in leaves recorded with the supply of micronutrient treatment particularly T₈ (Fe gluconate) and T₉ (Fe EDTA) is in accordance with the results reported by Jadhav *et al.* (2004). Patil and Malewar [19] also observed highest content of total chlorophyll in cotton leaves with the supply of nitrogen, iron and Zn. The higher values of total chlorophyll recorded with supply of Mg in the present study confirm the findings of Jaylalita and Narayanan [20]. Further, Akarte *et al.* [21], Jaylalitha and Narayanan [20] observed that Mg deficient cotton plant shows purplish red and orange interveinal pigmentation in older leaves as well as chlorophyll content drastically reduced due to Mg deficiency. Dhoble *et al.* [22] observed the high total chlorophyll concentration at grand growth stages of wheat and cotton.

4. CONCLUSION

- 1) The foliar feeding of gluconate and EDTA chelated plant nutrients found to be effective in increasing the biometric parameters growth and yield attributes *viz.*, height of plant, number of leaves, leaf area fresh weight and dry weight number of sympodia, number of bolls, boll weight and seed cotton yield. Among the chelated nutrient sprays gluconate complexed nutrients found superior over EDTA chelated nutrients and government grade 2.
- 2) Chlorophyll a, chlorophyll b and total chlorophyll content in leaves also influenced significantly due to different foliar feeding. The highest chlorophyll a, chlorophyll b and total chlorophyll was registered with the treatment Fe gluconate spray followed by Fe EDTA. The a, b and total chlorophyll showed increasing trend up to 100 DAS and decreased thereafter.
- 3) The foliar feeding of Fe gluconate showed significant increase in plant pigments like chlorophyll 'a', chlorophyll 'b' and total

chlorophyll and anthocyanin content overall the treatments except Fe EDTA, Mg gluconate in leaves of Bt cotton. Spraying of Zn gluconate improvement in the enzymatic activity *viz.*, nitrate reductase acid, phosphatase. While, Zn EDTA, Fe gluconate and Fe EDTA showed significant increase in catalase and peroxidase activity and on par with Mg gluconate and Mg EDTA.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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