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Influence of Seed Polymer Coating and Foliar Spray with Micronutrients on Yield and Lint Quality of *Bt*–Cotton Hybrid (*Gossypium hirsutum* L.)

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ABSTRACT: A field experiment was conducted during *kharif* 2014 at College of Agriculture, UAS, Raichur with an objective to study the influence of seed polymer coating and foliar spray with micronutrients on yield and lint quality of *Bt* cotton hybrid. The experiment consisted of seventeen different seed polymer coating and foliar spray treatments with micronutrients in three replications laid out in Randomized Block Design. The experimental results revealed that, seed polymer coating with $ZnSO_4$ + $FeSO_4$ + $MgSO_4$ + $MnSO_4$ each @ 4 g kg^{-1} of seed along with two foliar sprays (0.5 % + 0.5 % + 1 % + 0.5 %, respectively, in EDTA form except $MgSO_4$) at an interval of ten days during flowering stage (65 AND 75 DAS) recorded significantly higher plant height (156.2 cm), chlorophyll content (45.20 SPAD values) at 90 DAS, number of bolls (41.57), boll weight (5.54 g), seed index (13.57 g) and seed cotton yield (29.03 q) compared to all other treatments and control (129.5 cm, 38.90 SPAD values, 36.83, 4.35 g, 11.37 g and 24.77 q, respectively). The lint quality parameters did not show any significant difference due to seed polymer coatingand foliar spray with micronutrients in *Bt* cotton hybrid.

Key words: Foliar spray, hybrid *Bt* cotton, lint quality, micronutrients, seed polymer coating, yield

Cotton is one of the important commercial crops playing a key role in the economic, social and political affairs of the country. Globally cotton is cultivated in an area of 29.8 million hectares with a production of 25 million tonnes and productivity of 830 kg ha^{-1} [1]. India ranks first in acreage, with an area of 11.69 million hectare and third in production (36.59 million bales), with productivity of 532 kg per ha^{-1} [2]. In Karnataka, cotton occupies an area of 0.59 million hectare with production of 1.4 million bales and productivity of 401 kg ha^{-1} [2], where all the four cultivated species of cotton *viz., Gossypium arboreum, G. herbaceum, G. hirsutum*and *G. barbadense* are cultivated, with *Gossypium hirsutum* based hybrids occupying the lion share. Cotton is also known as *white gold* and *king of fibre* crops. It is an important cash crop and forms the backbone of textile industries. It is an important raw material, supplying about 65 per cent requirement of the Indian textile industry. It earns about 27 per cent of total foreign exchange [3]. The Indian textile industry thus, occupies a significant place in the country's economy with over 1500 mills, four million handlooms, 1.7 million power looms and thousands of garments hosiery and processing units, providing employment directly or indirectly to about 35 million people [4].

Any crop, for its effective growth and development, requires 17 essential elements. Out of these, the elements which are required in relatively high amount are called macronutrients. The micronutrients are required in relatively smaller quantities by the plants but, they are as important as macronutrients. If any element is

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lacking in the soil or not adequately balanced with other nutrients, plant growth suppression or even complete inhibition may occur [5]. The micronutrients often act as cofactors in enzyme systems and participate in redox reactions, in addition to having several other vital functions in plants such as respiration, meristematic development, chlorophyll formation, photosynthesis, energy release, protein and oil synthesis, gossypol, tannin and phenolic compounds production etc. [6]. Most importantly micronutrients are involved in the key physiological processes of photosynthesis and respiration [5, 7] and their deficiency can impede these vital physiological processes, thus limiting the yield gain.

Improving plant micronutrient status in situations where micronutrient nutrition is inadequately supplied from the soil would increase the yield. This however, requires application of higher doses of fertilizer to soils because of low nutrient-use efficiency [8]. In crop plants, micronutrients may be applied to the soil, foliar sprayed or through seed treatments. Although in most of the cases the required amounts of micronutrients are being supplied by foliar sprays, which have been more effective in yield improvement and grain enrichment, but foliar application occurs at later growth stages when crop stands are already established. However, the micronutrients are also required to secure uniform emergence, rapid seedling growth and healthy plant stand at initial stages [9]. Seed polymer coating is a physiological method of seed invigoration that enriches the endogenous level of newly bioactive substances, whereby better establishment and improved crop productivity can be achieved. This technology helps in precise and uniform application of fungicides, insecticides, micronutrients, colours and other additives [10]. Hence, in the present investigation attempts were made to supply these micronutrients by both seed treatment through seed polymer coating and foliar spray in order to find out its influence on yield and quality of *Bt*-cotton hybrid.

MATERIALS AND METHODS

A field experiment was carried out at the Department of Seed Science and Technology farm, College of Agriculture, University of Agricultural Sciences, Raichur to study the influence of seed polymer coating along with foliar spray with micronutrients, on yield and lint quality of *Bt* cotton (*Gossypium hirsutum* L.) hybrid Jadhu (a commercial hybrid of Kaveri Seed Compamy, Hyderabad), during *kharif* 2014. In the present investigation, four different micro nutrients *viz.*, $ZnSO_4$, $FeSO_4$, $MgSO_4$ and $MnSO_4$ were used, both as seed coating (each @ 4 g/kg seed) using polymer (8ml/kg seed) and as folair spray also (0.5 % + 0.5 % + 1 % + 0.5 % respectively, in EDTA form, except $MgSO_4$). These micronutrients were coated to the seed either individually or in combination, as per the below mentioned treatments, by using 8 ml polymer (Disco Agro DC Red L-603 procured from Incotec Pvt. Ltd. Ahmedabad, Gujarat) after dissolving in 30 ml water per kg of seed (standardized in the preliminary experiment) in a rotary seed coating machine. The coated seeds were properly dried in shade and sown in three replications using randomized block design, with spacing of 90 x 60cm. The experiment consisted of total 17 different seed polymer coating along with foliar spray treatments *viz.* T_1 (control), T_2 (only polymer @ 8 ml/kg of seed), T_3 ($ZnSO_4$ @ 4 g kg^{-1} of seed), T_4 ($FeSO_4$ @ 4 g $kg^{-1}$of seed), T_5 ($MgSO_4$ @ 4 g $kg^{-1}$of seed), T_6 ($MnSO_4$@ 4 g kg^{-1} of seed), T_7: (T_3+T_4), T_8: (T_3+T_5), T_9: (T_3+T_6), T_{10}: (T_4+T_5), T_{11}: (T_4+T_6), T_{12}: (T_5+T_6), T_{13}:(T_3+T_4+T_5), T_{14}: (T_3+T_4+T_6), T_{15}: (T_3+T_5+T_6), T_{16}: (T_4+T_5+T_6) and T_{17}: (T_3+T_4+T_5+T_6). Further, during flowering stage (65 and 75 DAS) the micronutrients as mentioned above were sprayed either individually or in combination two times at an interval of 10 days (0.5 % + 0.5 % + 1 % + 0.5 % respectively, in EDTA form, except $MgSO_4$).

The observations on plant height and chlorophyll content (Soil Plant Analytical Device - SPAD) were recorded at 90 days after sowing. The observations on leaf area index (Ceptometer), stomatal conductance and resistance (Leaf Porometer) were recorded at vegetative (45 DAS), flowering (65 DAS) and boll development (90 DAS) stages. The yield attributing parameters *viz.*, number of bolls per plant, boll weight, ginning percentage, seed index and seed cotton yield, were recorded at harvesting stage. The lint from all the treatments (replication wise) after picking, were analyzed for various lint quality parameters *viz.*, 2.5 per cent span length, uniformity ratio, micronaire value and fibre strength, as per the standard procedureusing high volume instrument (HVI) available at ARS, Hebballi Farm, University of Agricultural Sciences, Dharwad, Karnataka. The statistical analysis was done as per the procedure described by Panse and Sukhatme [11].

RESULTS AND DISCUSSION

Among the different treatments, significantly higher plant height (156.2cm) was recorded by T_{17} ($ZnSO_4$+ $FeSO_4$+ $MgSO_4$+ $MnSO_4$each @ 4g per kg of seed) along with two foliar sprays (0.5 % + 0.5 % + 1 % + 0.5 % respectively, in EDTA form, except $MgSO_4$) at an interval of ten days during flowering stage compared to all other treatments and control (129.5 cm), at 90 DAS (Table 1). This might be due to the favorable effect of the above mentioned combination of micronutrients which improved growth through cell elongation and division, enhanced plant growth through development of vigorous and stronger root system thereby enabling the plant to derive available soil moisture and nutrients resulting in better seedling establishment and hence resulted in increased plant height. Similar results were also reported by Zayed *et al.* [12] in rice with Zn (16 %) + Mn (14 %) + Fe (12 %) micronutrient combination as foliar spray. This may be also due to the involvement of zinc in enhancing seedling establishment through various metabolic activities, nitrogen metabolism [13], as well as biosynthesis of plant hormones like IAA and auxin which stimulated the growth as observed by Ponnuswamy and Vijaya [14] in cowpea, Rathinavel and Dharmalingam [15] in cotton due to seed pelleting with the combination of micronutrients, Ramesh and Thirumurugan [16]

Table 1. Influence of seed polymer coating with micronutrients and foliar spray on plant height, chlorophyll content, number of bolls, boll weight and ginning percentage in *Bt* cotton hybrid

Treatments	Plant height (cm)	Chlorophyll content (SPAD reading)	No. of bolls/ plant	Boll weight (g)	Ginning (%)
T_1: Control	129.5	38.90	36.83	4.35	36.83
T_2: Only polymer	132.8	40.77	37.43	4.43	36.89
T_3: $ZnSO_4$ @ 4g per kg of seed	136.9	41.63	38.07	4.53	36.62
T_4: $FeSO_4$ @ 4g per kg of seed	131.7	39.57	37.73	4.41	36.46
T_5: $MgSO_4$ @ 4g per kg of seed	135.7	41.60	37.97	4.49	36.53
T_6: $MnSO_4$ @ 4g per kg of seed	134.1	41.03	37.90	4.48	36.61
T_7: T_3+T_4	137.1	41.83	38.33	4.60	36.28
T_8: T_3+T_5	139.7	42.33	39.93	4.75	36.93
T_9: T_3+T_6	139.5	42.23	39.50	4.73	36.97
T_{10}: T_4+T_5	137.5	41.82	38.47	4.63	36.22
T_{11}: T_4+T_6	138.3	41.87	38.83	4.66	36.35
T_{12}: T_5+T_6	139.1	42.05	39.17	4.68	37.18
T_{13}: $T_3+T_4+T_5$	141.3	43.23	40.27	4.86	36.50
T_{14}: $T_3+T_4+T_6$	140.3	42.90	40.13	4.79	36.99
T_{15}: $T_3+T_5+T_6$	149.9	43.80	40.73	5.01	35.61
T_{16}: $T_4+T_5+T_6$	142.3	43.33	40.50	4.99	35.59
T_{17}: $T_3+T_4+T_5+T_6$	156.2	45.20	41.57	5.54	36.14
Mean	138.9	42.01	39.02	4.70	36.50
SEm±	1.9	0.38	0.29	0.17	0.66
CD @ 5%	5.4	1.10	0.83	0.17	NS

NS : Non-significant

in soybean due to application of combinations of ammonium molybdate (250 mg/kg of seed) + $FeSO_4$ (500 mg/kg of seed), Ratna Kumari and Hema [17] in cotton due to foliar spray of $MnSO_4$ at 0.2 per cent or 0.4 per cent and Arunakumar [18] in sesame due to seed pelleting with $ZnSO_4$ at 300 mg per kg of seed.

Leaf area index (LAI) is one of the most important and commonly used indices to analyze the growth of any crop plant. It depends on the percent of expansion of crop canopy to utilize the sunlight for photosynthesis. In the present investigation, significantly higher LAI (2.171, 5.024 and 4.550) was recorded in T_{17} compared to all other treatments and control (0.906, 3.812 and3.483) at 45 DAS, 65 DAS and 90 DAS, respectively (Fig. 1). This might be due to the involvement of micronutrients in chloroplast formation, nitrogen and carbohydrate metabolism which had stimulatory effect on photosynthesis [13], because of which the canopy established in a better way and ultimately led to more LAI. Similar results were reported by Zayed *et al.* [12] in rice with Zn +Mn + Fe micronutrient fertilization at (16, 14 AND 12 %) respectively and Soleymani and Shahrajabian [19] in sorghum due to foliar application of Zn + Fe + Mn at10, 12 and5 % respectively.

Chlorophyll content, stomatal conductance and stomatal resistance were significantly influenced due to seed polymer coating with micronutrients and foliar spray. Among the different treatments, T_{17} recorded higher chlorophyll content (45.20 SPAD values) at 90 DAS (Table 1), higher stomatal conductance (837.3, 351.3 and 309.5 M mol/m^2s) (Fig. 2) and lower stomatal resistance (1.18, 2.86 and 3.24 m^2s/mol) at 45 DAS, 65 DAS and 90 DAS (Fig. 3) compared to control, which recorded the lowest chlorophyll content (38.90 SPAD value), lowest stomatal conductance (615.0, 137.5 and 113.8 M mol/m^2s) and higher stomatal resistance (2.73, 6.57 and 7.41 m^2s/mol). This variation in chlorophyll content due to micronutrients might be due to decreased chlorophyll degradation and increased chlorophyll biosynthesis because of combined effect of micronutrients [20]. Further, the micronutrients also act as main component of some antioxidant enzymes which are involved in the protection of chloroplasts from free radicals [17]. It may also be due to the action of iron which is constituent of the heme group that acts as a precursor of chlorophyll [21], thereby increasing the chlorophyll content, which further might have increased the photosynthetic activity with higher intake of carbon dioxide due to higher stomatal conductance and reduced resistance. Similar results were reported by John *et al.* [22] in maize with micronutrient mixture (0.1 % of zinc, manganese and iron, and 0.5 % copper, boron and molybdenum per kg of seed), Srimathi *et al.* [23] in green gram due to hardening with 1 per cent *Prosopis* leaf extract + pelleting with DAP (40 g) + $MnSO_4$ (100 mg) + $FeSO_4$ (100 mg) + ammonium molybdate (250 mg) per kg of seed and Zayed *et al.* [12] in rice with Zn + Mn + Fe micronutrient fertilization at (16, 14 and 12 %) respectively.

Significantly higher number of bolls (41.57 $plant^{-1}$) were recorded due to seed polymer coating

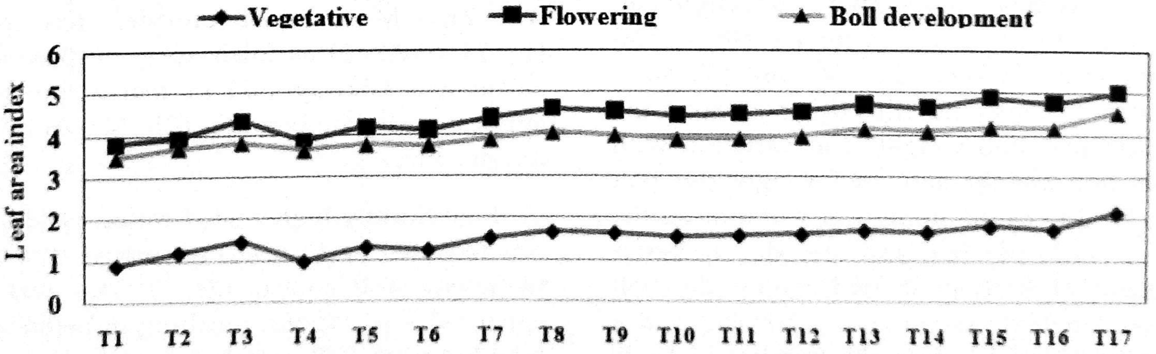

Fig. 1. Influence of seed polymer coating with micronutrientsand foliar spray on leaf area index at different growth stages of *Bt* cotton hybrid

with $ZnSO_4$+ $FeSO_4$+ $MgSO_4$+ $MnSO_4$each @ 4g per kg of seed along with two foliar sprays (0.5 % + 0.5 % + 1 % + 0.5 % respectively, in EDTA form, except $MgSO_4$) at an interval of ten days during flowering stage, compared to all other treatments and control (26.30 plant^{-1}) (Table 1). This might be due to better utilization of all the micronutrients leading to increased translocation of photosynthates from source and sink [24]. The micronutrients act as a catalyst in enzymatic reactions and are required for plant metabolic activities such as respiration, meristematic development, chlorophyll formation, photosynthesis, energy system functions, protein synthesis and oil content. Similar results were reported in cotton by Ahlawat [25] due to foliar application of $MgSO_4$, Rathinavel *et al.* [26] due to soil application of zinc sulphate (50 kg/ha) and borax (10 kg/ha), Yallappa [27] due to application of $MgSO_4$ (1%) at 60 DAS in combination with Boron (0.1%) at 75 DAS, Basavarajappa *et al.* [24] due to soil and foliar fertilization with $FeSO_4$ at 20 and 5 kg per hectare respectively and Ratna Kumari and Hema [17] due to foliar spray of $MgSO_4$ at 0.5 and 1.0 per cent and $MnSO_4$ at 0.2 per cent.

Increased seed cotton yield is mainly achieved through improvement in yield attributing characters like boll weight. The boll weight was significantly increased (5.54 g) by seed polymer coating with the combination of $ZnSO_4$+ $FeSO_4$+ $MgSO_4$+ $MnSO_4$ each @ 4g per kg of seed along with two foliar sprays (0.5 % + 0.5 % + 1 % + 0.5 % respectively, in EDTA form, except $MgSO_4$) at an interval of ten days during flowering stage compared to all other treatments and control (4.35) (Table 1). This may be due to increase in the plant metabolic activities, meristematic development, energy system function and protein synthesis [28] which improved mobilization of photosynthates from source to sink and directly influenced the seed weight and boll weight. The variation with respect to boll weight and seed weight per boll may also be due to the numerical variation in the number of seeds per boll and also due to better development of individual seed within the boll (higher seed index). Yadav *et al.* [29] observed a positive correlation between the number of seeds per boll and seed weight per boll. Similar results were made in cotton by Rathinavel *et al.* [26] due to soil application of zinc sulphate (50 kg/ha) and borax (10 kg/ha), Hanumanthareddy [30] with foliar of application of NAA in combination with $MgSO_4$ and Yallappa [27] with foliar of application of $MgSO_4$ (1%) at 60 DAS in combination with Boron (0.1%) at 75 DAS (3.02g), Basavarajappa *et al.* [24] due to soil and foliar fertilization with $FeSO_4$ at 20 and 5 kg per hectare, respectively and Gokhale *et al.* [31] with application of RDF + Zn, Fe and B.

Ginning percentage (Table 1) did not show significant influence due toseed polymer coating with micronutrients and foliar spray. The results are in agreement with the findings of Suresh and Kumar [32] with application of magnesium and zinc and Ratna Kumari and Hema [17] due to foliar application of $MgSO_4$ at 0.5 and 1.0 per cent and $MnSO_4$ at 0.2 per cent in cotton. Seed index (Table 2) was significantly higher (13.57 g) in T_{17} compared to all other treatments and control (11.37 g). The increased seed index might be due to increased amino acid synthesis by activating a number of enzymes, particularly decarboxylases and dehydrogenases of the tricarboxylic acid cycle [7, 33] translocation of photoassimilates from source to sink and conversion of sugars from complex form to simpler form due to the involvement of micronutrients. The results are in line with the findings of Ashoub *et al.* [34] in maize by seed coating with Mn, Rathinavel *et al.* [26] in cotton due to foliar spray of zinc sulphate @ 0.5 per cent, Ananda and Patil [35] in wheat with application of RDF + FYM + Zn at 25 kg per hectare + Fe at 25 kg per hectare, Masuthi *et al.* [36] in cowpea due to seed pelleting with $ZnSO_4$ + borax + arappu leaf powder at (250 mg, 100 mg and 250 g/kg of seeds), Zayed *et al.* [12] in rice with Zn + Mn + Fe micronutrient fertilization at (16, 14 and12 %) as folair spray respectively and Salem and Gizway [37] in maize due to foliar application in combination (Zn, Mn and Fe) at 85 mg per litre.

Significantly higher seed cotton yield (Table 2) was recorded by T_{17} (29.03 q) compared to all other treatments and control (24.77). This was due to enhanced seed vigour, resulting in better seedling establishment [22] which led to increased plant height, better leaf canopy and thereby, leading to increased leaf area index. Due to the higher leaf area index, there might have been increased photosynthetic activity and with enhanced stomatal conductance, the uptake of carbon dioxide might be more leading to higher production of carbohydrates and better translocation of these metabolites to reproductive parts. Due to translocation of carbohydrates from photo synthetically active leaf (source) to boll and inturn accumulation of these carbohydrates in seed (sink), there was increased seed index, which further might have increased the boll weight and finally increased the seed cotton yield. Nageshwara Rao [38] reported an increase in seed cotton yield to an extent of 26, 16 and 21 percentage with soil application of B, Zn and Fe over control and the results were also supported by Dastur and Singh [39], Anderson and Fred [40], Matocha and Sorenson [41] in cotton with application of Fe, Zn

Table 2. Influence of seed polymer coating with micronutrients and foliar spray on seed index, seed cotton yield, 2.5 % span length, uniformity ratio, micronaire and fibre strength of *Bt* cotton hybrid

Treatments	Seed index (g)	Seed cotton yield (q/ha)	2.5 % span length (mm)	Uniformity ratio (%)	Micronaire ($inch^{-1}$)	Fibre strength ($g\ tex^{-1}$)
T_1: Control	11.37	24.77	31.40	46.00	5.10	20.53
T_2: Only polymer	11.60	24.97	31.47	46.00	4.97	21.00
T_3: $ZnSO_4$ @ 4g per kg of seed	12.10	25.48	31.70	45.33	5.10	20.43
T_4: $FeSO_4$ @ 4g per kg of seed	11.53	25.33	31.37	46.33	5.00	21.17
T_5: $MgSO_4$ @ 4g per kg of seed	12.00	25.47	31.03	46.33	5.07	20.67
T_6: $MnSO_4$ @ 4g per kg of seed	11.67	25.40	31.37	46.67	5.07	20.90
T_7: $T_3 + T_4$	12.07	25.63	31.03	46.67	5.03	21.30
T_8: $T_3 + T_5$	12.80	26.70	31.20	46.00	4.93	21.30
T_9: $T_3 + T_6$	12.60	26.52	31.70	45.00	5.13	20.60
T_{10}: $T_4 + T_5$	12.07	25.80	31.27	45.33	5.30	20.47
T_{11}: $T_4 + T_6$	12.10	26.00	31.13	46.33	5.33	20.47
T_{12}: $T_5 + T_6$	12.17	26.35	31.03	46.00	4.90	21.27
T_{13}: $T_3 + T_4 + T_5$	13.07	27.00	31.20	46.00	4.63	21.70
T_{14}: $T_3 + T_4 + T_6$	13.03	26.60	31.37	45.67	4.83	21.73
T_{15}: $T_3 + T_5 + T_6$	13.37	27.17	31.00	46.33	4.93	21.13
T_{16}: $T_4 + T_5 + T_6$	13.31	27.13	31.10	46.33	5.10	20.87
T_{17}: $T_3 + T_4 + T_5 + T_6$	13.57	29.03	31.30	45.00	5.13	20.50
Mean	12.38	26.20	31.27	45.96	5.03	20.94
SEm±	0.40	0.63	0.35	0.43	0.12	0.38
CD @ 5%	1.16	1.81	NS	NS	NS	NS

NS : Non-significant

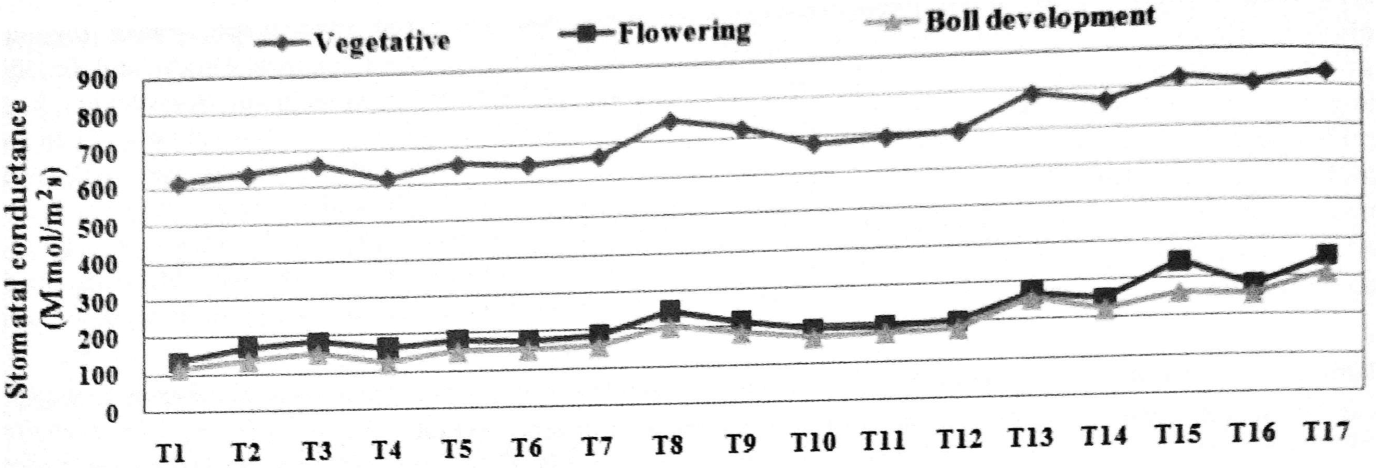

Fig. 2. Influence of seed polymer coating with micronutrients and foliar spray on stomatal conductance (M mol/ m^2s) at different growth stages of *Bt* cotton hybrid

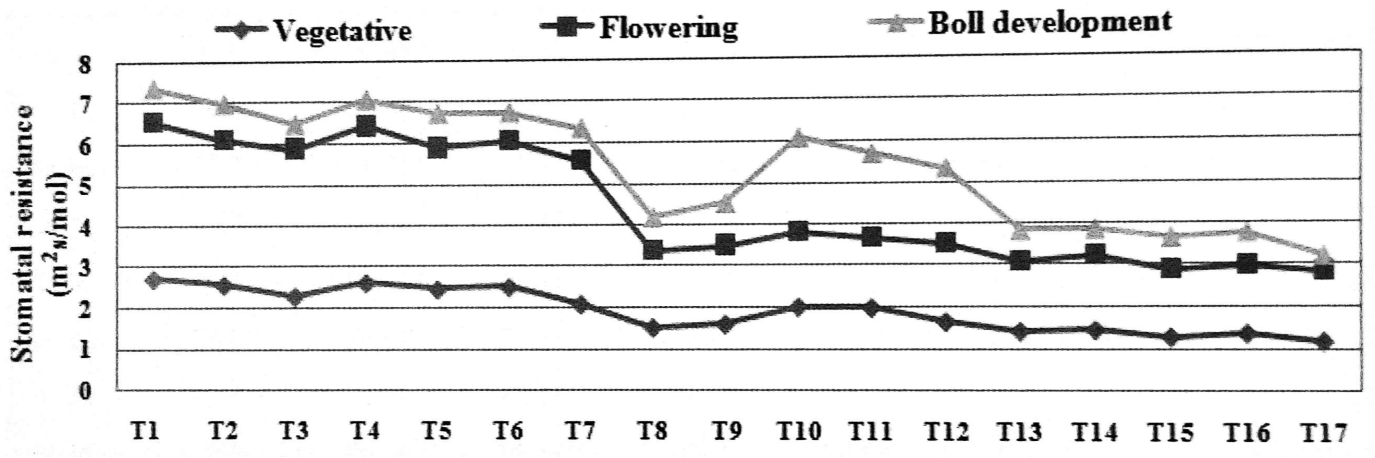

Fig. 3. Influence of seed polymer coating with micronutrients and foliar spray on stomatal resistance (m^2s/mol) at different growth stages of *Bt* cotton hybrid

and Mn, Hanumanthareddy [30] with foliar of application NAA in combination with $MgSO_4$ (1 %), Rathinavel *et al.* [26] due to soil application of zinc sulphate (50 kg/ha) and borax (10 kg/ha), Ratna Kumari and Hema [17] due to foliar application of $MgSO_4$ at 0.5 and 1.0 per cent and $MnSO_4$ at 0.2 per cent, Nayarain Jazy and Naderidarbaghshahi [42] with foliar application of micronutrients (Zn 4% + Fe 4% + Mn 3% + Cu 0.5% + B 1.5% + Mo 0.05% + Mg 1.3% + S 1.3%).

The lint quality parameters *viz.*, 2.5 per cent span length, uniformity ratio, micronaire value and fibre strength of lint had no significant variationdue to seed polymer coating with micronutrients and foliar spray (Table 2). The results were in line with the findings of Anderson and Fred [40] in cotton due to soil application of Manganese (2.23 kg/ha) along with Boron (0.45 kg/ha), Matocha and Sorenson [41] with application of Fe, Zn and Mn, Suresh and Kumar [32] with magnesium and zinc fertilization and Ratna Kumari and Hema [17] due to foliar application of $MgSO_4$ at 0.5 and 1.0 per cent and $MnSO_4$ at 0.2 per cent, who also did not reportany significant difference with respect to lint quality parameters due to application of micronutrients.

CONCLUSION

Seed polymer coating with $ZnSO_4$+ $FeSO_4$+ $MgSO_4$+ $MnSO_4$ each @ 4g/kg of seed along with two foliar sprays (0.5 % + 0.5 % + 1 % + 0.5 % respectively, in EDTA form, except $MgSO_4$) at an interval of ten days during flowering stage (65 and 75 DAS) resulted in maximum growth, yield and yield attributing characters in *Bt* cotton hybrid without any influence on lint quality parameters.

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