Original Article

EFFECT OF EXOGENOUS APPLICATION OF MICRONUTRIENTS ON GROWTH AND PRODUCTIVITY OF COTTON (*Gossypium hirsutum* L.) CROP

EFEITO DA APLICAÇÃO EXÓGENA DE MICRONUTRIENTES NO CRESCIMENTO E PRODUTIVIDADE DA CULTURA DE ALGODÃO (Gossypium hirsutum L.)

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ABSTRACT: Micronutrients play a vital role in the growth and productivity of cotton crop. A study was carried out to access the exogenous application of micronutrients on growth and yield of cotton crop. The experiment was comprised of nine treatments as T_0 (control), T_1 (Fe chelated), T_2 (B), T_3 (Mo), T_4 ($CuSo_4 + ZnSo_4 + MnSo_4$), T_5 ($CuSo_4 + ZnSo_4 + MnSo_4 +$ Fe chelated), T_6 ($CuSo_4 + ZnSo_4 + MnSo_4 + B$), T_7 ($CuSo_4 + ZnSo_4 + MnSo_4 + Mo$) and T_8 ($CuSo_4 + ZnSo_4 + MnSo_4 +$ Fe chelated + B). Data on different growth attributes showed that there was significant positive increase with the application of micronutrients. Leaf area was increased after applying micronutrients at 99 days after sowing (DAS) and then a decreasing trend was observed. Chlorophyll contents were increased at 81 DAS and then decreased towards the final harvest. Similarly, different yield components showed that seed cotton yield were significantly increased with the application of Fe, B, Mo, Zn, Cu and Mn compared to control treatment. Earliness index, mean maturity date and production rate index were increased significantly after combined use of foliar spray of Zn, Cu, Mn and Mo.

KEYWORDS: Growth. Yield. Micronutrients. Cotton.

INTRODUCTION

Micronutrients are very essential and their soil application of Zn, B, Fe, Mn, and Cu particularly on calcareous soils is less efficient, as these nutrients remain unavailable to plant roots due to the higher pH of these soils (SAJID et al., 2008). Another approach under such conditions is foliar application of nutrients (RAB; HAQ, 2012) primarily for two reasons. First, it reduces the effects of soil pH on the availability of these nutrients (ALI, 2012) and secondly, it is more efficient and less costly (ALI et al., 2007). The foliar application of nutrients has gained significant interest for agricultural scientist throughout the world as it is successful and cost-effective technology (ALI, 2012; LIEW et al., 2012).

Micronutrients are essential for normal growth and development of plants as zinc is necessary for plants in some of their enzymatic systems. Manganese play role in oxidation reduction reactions in plants especially with iron and nitrogen metabolism as the iron is essential for chlorophyll formation (ABRO et al., 2004). Micronutrients are vital for improvement of both qualitative and quantitative yield in oil seed crop (BAHRANI; POURREZA, 2014).

Foliar application of growth regulators and micronutrients are effective when they were sprayed alone, as boron application increased the seed cotton yield (DONG, 1995; HALLIKERI et al., 2002). Boron is an essential micronutrient for higher plants whose deficiency affects the meristematic development, resulting in stunted growth (MARSCHNER, 1995). Application of zinc to cotton crop promotes boll retention and consequently increases the seed cotton yield (MANGAL; PRASAD, 1998).

Cotton (*Gossypium hirsutum* L.), also known as queen of fibre, is the leading fibre crop of the world and is grown over an area of 3106 thousand hectares, with a production of 12968 thousand bales and average yield of 695 kg per hectare in the year of 2009 to 2010. Cotton is the main cash crop of Pakistan and is grown primarily both for fiber and oilseed. According to annual report of ECONOMIC SURVEY OF PAKISTAN (2009-2010) the cotton production was estimated 12.7 million bales for 2009 to 2010, higher by 7.4% over the last year's production of 11.8 million bales. During these years, cotton contributes 8.6% of the value added in agriculture and approximately 1.8% in GDP.

Keeping in view the role of nutrients in improving the yield of crops, the foliar application of micronutrients has been emphasized these days. Since little information is available on application of micronutrients through foliar sprays and consequently their effect on morphology and yield of cotton, hence, the present study was carried out to evaluate the effect of micronutrients as growth regulator and to determine their effect on growth and yield of cotton crop.

MATERIAL AND METHODS

An experiment was conducted to study the foliar application of micronutrients on the growth and yield of cotton at Cholistan Institute of Desert Studies, Baghdad-ul-Jadeed Campus, The Islamia University of Bahawalpur, Pakistan, during the year 2010-11. The experiment was laid out in randomized complete block design and there were three replications of each treatment.

The experiment was comprised of nine treatments as T_0 (control), T_1 (Fe chelated), T_2 (B), T_3 (Mo), T_4 ($CuSo_4$ + $ZnSo_4$ + $MnSo_4$), T_5 ($CuSo_4$ + $ZnSo_4$ + $MnSo_4$ + Fe chelated), T_6 ($CuSo_4$ + $ZnSo_4$ + $MnSo_4$ + B), T_7 ($CuSo_4$ + $ZnSo_4$ + $MnSo_4$ + Mo), T_8 ($CuSo_4$ + $ZnSo_4$ + $MnSo_4$ + Fe chelated) + B). Copper sulphate, zinc sulphste and manganese sulphate were applied as a source of Cu, Zn and Mn. One percent solution of each micronutrient was applied regularly at 20 days intervals. The seed rate used was 25 kg per hectare and fertilizers (75 kg N, 30 kg P_2O_5 and 50 kg K_2O/ha) was applied at regular intervals of 20 days. Data on growth and yield parameters were recorded from 5 randomly selected plants in each treatment plot measuring 36.45 m^2 (having 78 plants in 6 rows with 67.5 × 75 cm geometry). Seed cotton yield (kg/ha) was calculated from whole plot. All other recommended production and protection practices were uniformly applied. Weeding was performed after regular intervals of 10 days and irrigation was performed by canal water at 15 days interval.

The data on different growth components as plant height was measured with the help of scale from the ground surface to the plant terminal. Number of leaves was taken by counting the total number of leaves of four tagged plants in each plot, and then average of these four tagged plants was calculated. Number of nodes present on the main stem of the four tagged plants was counted, and average was worked out. Leaf area was determined by leaf area meter and

chlorophyll contents in plant leaf were estimated by chlorophyll meter (SPAD-502 value). Number of bolls of tagged plant was also counted regularly and then average was taken. Earliness index was calculated with the help of following formula as proposed by Singh (2003).

$$\text{Earliness Index (\%)} = \frac{\text{Weight of seed cotton from first pick}}{\text{Total seed cotton weight from all picks}}$$

Mean maturity date in cotton was calculated by the formula as proposed by Christidis and Harrison (1955).

$$\text{Mean Maturity Date (MMD)} = \frac{(W_1 \times H_1) + (W_2 \times H_2) + \ldots + (Wn \times Hn)}{W_1 + W_2 + \ldots + Wn}$$

Where W = weight of seed cotton, H = number of days from planting to harvest, 1, 2…n = consecutive periodic harvest number.

Saleem et al. (2010) calculated that production rate index was calculated from total seed cotton weight divided by the mean maturity date.

$$\text{Production Rate Index (g/day)} = \frac{\text{Total seed cotton weight (g)}}{\text{Mean maturity date (day)}}$$

Statistical analysis

Data collected during the course of study were statistically analyzed using MSTAT-C programme (ANONYMOUS, 1986) for analysis of variance and significant means were separated using least significant difference test (LSD) at 5% probability level (STEEL et al., 1997). Regression and correlation analysis was performed using MS Excel program against different variables.

RESULTS

Highest plant height (86.25 cm) was recorded at 117 days after sowing (DAS) in T_8 treatment (Fe + B + Mo + Zn + Cu + Mn), which was closely followed by T_7, T_6 and lowest (63.83 cm) was recorded in control, where no micronutrient was applied (Table 1). Number of leaves in all the treatments continued to increase from 45 DAS up to 108 DAS and then gradually declined towards the final harvest. At 108 days of sowing, highest number of leaves (60.33) was recorded in T_6 treatment, while lowest number of leaves (42.83) was recorded in control (Table 2).

At 72 DAS, treatment T_5 attained the highest number of nodes (14) and in control lowest number of nodes (11.25) was recorded. After 108 DAS, highest number of nodes per plant (15.69) was produced under the application of T_8 treatment and control had the lowest number of nodes i.e. 13.65 (Table 3). The treatment T_8 (Fe + B + Mo + Zn + Cu + Mn) contributed to the maximum leaf area i.e. 55.55 cm^2, and in control (no treatment) showed the minimum leaf area as 44.25 cm^2, at 99 DAS (Table 4). Highest leaf area (50.8 cm^2) was attained by treatment T_8 while least (39.13 cm^2) was recorded in control where no micronutrient was applied at 108 DAS (Table 4).

The Chlorophyll content in all the treatments continued to increase from 45 to 81 DAS, and then gradually declined towards the final harvest. There was significant variation ($p < 0.05$) in chlorophyll contents (SPAD-value) from 54 DAS to onward and at 81 DAS it ranged from 49.35 to 56.77 in control and T_8 treatment (Fe + B + Mo + Zn + Cu + Mn) respectively (Table 5). Data regarding number of bolls per plant, indicate that maximum number of bolls (9.83) was recorded in T_8 treatment (Fe + B + Mo + Zn + Cu + Mn), which was closely followed by T_6 (Cu + Zn + Mn + B). The minimum number of bolls per plant (5.17) was recorded in control where no micronutrient was applied. Treatment T_8 (Fe + B + Mo + Zn + Cu + Mn) yielded the highest number of bolls per plant (9.83) and control treatment had the lowest value (Table 6).

Number of cotton seed per boll increase significantly and in treatment T_8 there was 34.63% increase was recorded comparative to control. Seed cotton yield was highest (2900 kg/ha) in T_8 treatment (Fe + B + Mo + Zn + Cu + Mn) and lowest (2366 kg/ha) in control (T_0) where micronutrient was not applied (Table 7); however, earliness index was minimum (65.50) in T_6 treatment (B + Zn + Cu + Mn) and maximum (66.74) in control treatment (Table 3). Furthermore, mean maturity date was maximum (160.25) in T_6 treatment (B + Zn + Cu + Mn) and minimum (159.99) in T_0 (control). Treatment T_8 had mean maturity date of 160.22, T_7 of 160.18, T_5 of 160.18 and in T_4 was 160.08 (Table 7). Production rate index calculated in treatment T_7 was 32.92 while in T_6; T_4 treatment was 31.70 and 30.61 respectively. Analyzed data (Table 7) indicates that production rate index was maximum (33.64) in T_8 treatment (Fe + B + Mo + Zn + Cu + Mn) which was statistically at par with T_7 treatment and minimum (27.48) in T_0 (control) where micronutrient was not applied.

Linear regression and correlation analysis

Regression analysis suggests the significant dependence of seed cotton yield on plant height ($R^2 = 0.87$; $p \leq 0.01$). Correlation analysis also indicated a positive and linear relationship between plant height and seed cotton yield. Significant positive correlation was noted between number of leaves per plant and seed cotton yield (r = 0.94; $p \leq 0.01$) and regression analysis suggests the significant dependence of seed cotton yield on number of leaves per plant. Regression analysis also depicts the significant dependence of seed cotton yield on number of bolls per plant ($R^2 = 0.82$; $p \leq 0.01$) (Table 8).

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Table 1. Effect of different micronutrients on plant height (cm) in cotton

Treatment	45 DAS	54 DAS	63 DAS	72 DAS	81 DAS	90 DAS	99 DAS	108 DAS	117 DAS
T_0	20.33	24.33 c	29.17 c	32.08 e	42.08 d	48.42 d	55.58 c	59.00 e	63.83 d
T_1	23.83	28.25 b	34.75 b	36.25 de	48.83 bcd	55.25 bcd	61.00 bc	65.42 de	69.42 cd
T_2	22.58	29.50 b	37.08 b	43.50 b	51.58 bc	57.75 abc	65.17 abc	68.08 bced	70.58 cd
T_3	22.78	29.17 b	38.42 b	41.67 bc	47.08 cd	53.42 cd	60.42 bc	67.42 cde	74.42 abcd
T_4	22.08	30.42 b	37.17 b	38.08 cd	50.33 bc	60.58 abc	69.92 ab	73.75 abcd	77.92 abc
T_5	24.08	29.58 b	36.58 b	42.33 bc	52.25 bc	56.92 abcd	63.50 abc	68.67 abcde	74.08 bcd
T_6	25.08	28.58 b	37.67 b	41.17 bc	55.50 ab	64.08 ab	73.67 a	79.58 ab	83.92 ab
T_7	24.08	28.50 b	38.33 b	41.67 bc	55.17 ab	63.42 ab	72.25 ab	79.08 abc	85.33 ab
T_8	27.25	34.92 a	44.67 a	48.50 a	60.08 a	65.75 a	73.33 a	80.25 a	86.25 a
LSD at 5%	NS	2.79	4.023	4.686	7.799	9.108	12.08	11.8	11.87

Means sharing the common letter in a column do not differ significantly from each other at p 0.05, N.S = non significant; DAS: Days after sowing; T_0 = Control, T_1 = Fe, T_2 = B, T_3 = Mo, T_4 = $CuSO_4$ + $ZnSO_4$ + $MnSO_4$, T_5 = $CuSO_4$ + $ZnSO_4$ + $MnSO_4$ + Fe, T_6 = $CuSO4$ + $ZnSO_4$; + $MnSO_4$ + B, T_7 = $CuSO_4$ + $ZnSO_4$ + $MnSO_4$ + Mo, T_8 = $CuSO_4$ + $ZnSO_4$ + $MnSO_4$ + Fe + B + Mo.

Table 2. Effect of different micronutrients on number of leaves per plant in cotton

Treatment	45 DAS	54 DAS	63 DAS	72 DAS	81 DAS	90 DAS	99 DAS	108 DAS	117 DAS
T_0	14.50	20.25 d	20.25	24.42 d	27.25	33.58 c	39.33 e	42.83 bc	34.67
T_1	15.17	22.08 cd	24.75	27.25 cd	33.67	38.50 bc	42.75 de	46.50 c	41.00
T_2	15.17	24.08 bc	27.58	31.00 abc	35.92	40.75 ab	44.67 cde	46.08 bc	42.50
T_3	15.83	22.33 cd	25.75	27.17 cd	32.75	39.67 abc	46.00 cd	48.08 abc	46.25
T_4	16.08	26.25 a	26.75	31.92 ab	33.00	41.83 ab	47.42 abcd	50.67 abc	47.17
T_5	15.83	23.17 c	23.92	29.33 bc	33.08	38.00 bc	46.17 bcd	51.00 a	49.42
T_6	13.75	22.58 c	25.00	31.27 abc	34.75	43.50 ab	53.00 a	60.33 ab	60.50
T_7	15.25	23.67 c	28.00	33.42 ab	36.00	44.08 ab	50.92 abc	56.50 a	59.00
T_8	14.92	25.83 ab	25.42	34.50 a	39.50	45.83 a	52.58 ab	59.08 d	62.17
LSD at 5%	NS	2.109	NS	4.548	NS	6.201	6.444	10.12	NS

Means sharing the common letter in a column do not differ significantly from each other at p 0.05, N.S = non significant; DAS: Days after sowing; T_0 = Control, T_1 = Fe, T_2 = B, T_3 = Mo, T_4 = $CuSO_4$ + $ZnSO_4$ + $MnSO_4$, T_5 = $CuSO_4$ + $ZnSO_4$ + $MnSO_4$ + Fe, T_6 = $CuSO4$ + ; $ZnSO_4$ + $MnSO_4$ + B, T_7 = $CuSO_4$ + $ZnSO_4$ + $MnSO_4$ + Mo, T_8 = $CuSO_4$ + $ZnSO_4$ + $MnSO_4$ + Fe + B + Mo.

Table 3. Effect of different micronutrients on number of nodes per plant in cotton

Treatment	45 DAS	54 DAS	63 DAS	72 DAS	81 DAS	90 DAS	99 DAS	108 DAS	117 DAS
T_0	6.00	9.25	10.75 c	11.25 f	12.33 c	13.58 d	13.58	13.58 e	13.58
T_1	8.75	9.92	11.17 c	12.17 de	13.50 b	14.58 cd	14.58	14.58 de	14.58
T_2	7.67	10.00	11.42 abc	12.67 cd	14.08 ab	14.75 bc	14.75	14.75 de	14.75
T_3	8.17	9.50	11.17 c	11.83 ef	14.08 ab	15.67 a	15.67	15.67 cd	15.67
T_4	8.33	10.50	11.33 bc	11.92 def	13.42 b	14.50 c	14.50	14.50 cd	14.50
T_5	7.08	10.17	12.17 ab	13.83 a	14.00 ab	14.50 c	14.50	14.50 cd	14.50
T_6	7.92	10.00	11.25 c	13.58 ab	14.08 ab	15.08 abc	15.08	15.08 bc	15.08
T_7	8.58	11.00	12.25 a	13.25 abc	14.42 a	15.50 ab	15.50	15.50 ab	15.50
T_8	7.92	10.08	11.50 abc	13.17 bc	14.50 a	15.75 a	15.75	15.75 a	15.75
LSD at 5%	NS	NS	0.85	0.78	0.70	0.80	NS	1.16	NS

Means sharing the common letter in a column do not differ significantly from each other at p 0.05, N.S = non significant; DAS: Days after sowing; T_0 = Control, T_1 = Fe, T_2 = B, T_3 = Mo, T_4 = $CuSO_4$ + $ZnSO_4$ + $MnSO_4$, T_5 = $CuSO_4$ + $ZnSO_4$ + $MnSO_4$ + Fe, T_6 = $CuSO_4$ + $ZnSO_4$ + ; $MnSO_4$ + B, T_7 = $CuSO_4$ + $ZnSO_4$ + $MnSO_4$ + Mo, T_8 = $CuSO_4$ + $ZnSO_4$ + $MnSO_4$ + Fe + B + Mo.

Table 4. Effect of different micronutrients on leaf area (cm^2) in cotton

Treatment	45 DAS	54 DAS	63 DAS	72 DAS	81 DAS	90 DAS	99 DAS	108 DAS	117 DAS
T_0	17.29	21.18	22.87 abc	30.03 d	33.88 c	40.33 c	44.25	39.13 d	33.80 d
T_1	21.67	23.59	27.84 ab	33.39 c	37.64 bc	43.24 bc	47.12	42.77 bcd	37.29 cd
T_2	21.12	24.60	31.65 bc	36.76 b	44.27 a	48.02 ab	52.47	45.83 abc	38.18 c
T_3	19.98	26.81	29.80 a	37.11 b	42.08 ab	47.26 ab	51.54	45.76 abc	38.59 bc
T_4	20.16	26.36	30.78 c	36.09 bc	44.01 a	51.49 a	51.47	42.11 cd	38.76 bc
T_5	24.15	27.73	29.94 bc	38.19 ab	43.39 a	52.19 a	52.18	49.41 a	40.57 bc
T_6	20.57	26.18	32.30 a	40.52 a	44.03 a	52.68 a	52.89	48.32 ab	39.76 bc
T_7	20.97	24.92	26.95 bc	35.69 bc	45.63 a	51.85 a	52.94	47.78 abc	42.00 b
T_8	23.98	29.91	34.77 ab	40.91 a	46.33 a	53.49 a	55.55	50.80 a	45.98 a
LSD at 5%	NS	NS	5.96	3.25	4.48	6.69	NS	5.88	3.81

Means sharing the common letter in a column do not differ significantly from each other at p 0.05, N.S = non significant; DAS: Days after sowing; T_0 = Control, T_1 = Fe, T_2 = B, T_3 = Mo, T_4 = $CuSO_4$ + $ZnSO_4$ + $MnSO_4$, T_5 = $CuSO_4$ + $ZnSO_4$ + $MnSO_4$ + Fe, T_6 = $CuSO_4$; + $ZnSO_4$ + $MnSO_4$ + B, T_7 = $CuSO_4$ + $ZnSO_4$ + $MnSO_4$ + Mo, T_8 = $CuSO_4$ + $ZnSO_4$ + $MnSO_4$ + Fe + B + Mo.

Table 5. Effect of different micronutrients on chlorophyll content (SPAD-502 value) in cotton

Treatment	45 DAS	54 DAS	63 DAS	72 DAS	81 DAS	90 DAS	99 DAS	108 DAS	117 DAS
T_0	37.96	39.25 c	41.29 f	44.06 e	48.14 abc	45.42 e	42.02 bcd	40.02 c	37.81 bc
T_1	36.56	40.75 c	42.86 def	44.58 de	48.80 ab	48.78 cd	44.63 bcd	43.52 b	39.83 bc
T_2	37.58	40.74 c	42.69 ef	45.67 cd	49.22 a	48.79 cd	45.26 ab	44.14 ab	39.77 bc
T_3	40.99	42.70 b	43.58 cde	46.01 c	50.86 c	48.00 d	45.59 a	43.87 ab	40.73 ab
T_4	39.47	43.16 ab	44.34 bcde	46.55 c	51.80 bc	49.50 cd	46.76 d	42.94 bc	40.81 ab
T_5	40.40	44.03 ab	44.40 bcd	46.22 c	52.35 c	49.96 cd	45.98 bcd	43.41 b	41.10 a
T_6	38.28	42.53 b	45.46 ab	49.01 b	53.09 bc	50.76 bc	47.03 cd	43.65 b	42.63 c
T_7	40.70	44.08 ab	45.21 abc	51.00 a	54.75 bc	52.67 ab	49.80 bcd	46.10 ab	42.84 c
T_8	40.90	44.63 a	46.11 a	51.98 a	56.77 abc	53.14 a	51.47 abc	47.23 a	44.22 bc
LSD at 5%	NS	1.59	1.70	1.41	4.13	2.13	3.95	3.37	2.73

Means sharing the common letter in a column do not differ significantly from each other at p 0.05, N.S = non significant; DAS: Days after sowing; T_0 = Control, T_1 = Fe, T_2 = B, T_3 = Mo, T_4 = $CuSO_4$ + $ZnSO_4$ + $MnSO_4$, T_5 = $CuSO_4$ + $ZnSO_4$ + $MnSO_4$ + Fe, T_6 = $CuSO_4$ + $ZnSO_4$; + $MnSO_4$ + B, T_7 = $CuSO_4$ + $ZnSO_4$ + $MnSO_4$ + Mo, T_8 = $CuSO_4$ + $ZnSO_4$ + $MnSO_4$ + Fe + B + Mo.

Table 6. Effect of different micronutrients number of bolls per plant in cotton

Treatment	72 DAS	81 DAS	90 DAS	99 DAS	108 DAS	117 DAS
T_0	0.75 d	0.73 d	1.67 c	1.67 c	3.58 d	5.17
T_1	1.25 abc	0.89 cd	3.00 b	3.00 bc	4.50 cd	6.08
T_2	1.33 ab	1.92 a	3.17 b	3.17 bc	4.92 cd	6.00
T_3	1.58 a	2.00 a	3.58 b	3.58 b	5.83 bc	7.25
T_4	0.92 bcd	1.17 bc	3.33 b	3.33 b	5.50 bc	7.42
T_5	1.08 bcd	1.33 b	3.33 b	3.33 a	7.33 bc	7.50
T_6	1.00 bcd	1.25 b	3.42 b	3.42 a	7.67 ab	8.75
T_7	0.83 cd	1.33 b	3.17 b	3.17 b	5.50 bc	7.42
T_8	0.67 d	1.83 a	4.42 a	4.42 a	8.33 a	9.83
LSD at 5%	0.45	0.30	0.60	1.43	1.85	NS

Means sharing the common letter in a column do not differ significantly from each other at p 0.05, N.S = non significant, DAS: Days after sowing; T_0 = Control, T_1 = Fe, T_2 = B, T_3 = Mo, T_4 = $CuSO_4$ + $ZnSO_4$ + $MnSO_4$, T_5 = $CuSO_4$ + $ZnSO_4$;+ $MnSO_4$ + Fe, T_6 = $CuSO_4$ + $ZnSO_4$ + $MnSO_4$ + B, T_7 = $CuSO_4$ + $ZnSO_4$ + $MnSO_4$ + Mo, T_8 = $CuSO_4$ + $ZnSO_4$ + $MnSO_4$ + Fe + B + Mo

Table 7. Effect of different micronutrients on number of cotton seeds per boll, seed cotton yield, earliness index (EI), mean maturity date (MMD), and production rate index (PRI) in cotton.

Treatment	Number of cotton seeds per boll	Seed cotton yield (Kg/ha)	Earliness index (%)	Mean maturity date (days)	Production rate index (g/day)
T_0	14.10e	2366.21e	66.74	159.99	27.48e
T_1	16.27d	2407.48e	66.26	160.09	27.94e
T_2	17.07cd	2509.73d	66.55	160.03	29.14d
T_3	17.17cd	2561.75cd	66.19	160.10	29.73cd
T_4	17.40bcd	2637.10bc	66.27	160.08	30.61bc
T_5	18.17bc	2681.95b	65.82	160.18	31.11b
T_6	18.43b	2733.97b	65.50	160.25	31.70b
T_7	21.53a	2838.02a	65.80	160.18	32.92a
T_8	21.57a	2900.81a	65.62	160.22	33.64a
LSD at 5%	1.24	99.29	2.03 (N.S)	0.43 (N.S)	1.13

Means sharing the common letter in a column do not differ significantly from each other at p 0.05, N.S = non significant; T_0 = control, T_1 = Fe, T_2 = B, T_3 = Mo, T_4 = $CuSO_4$ + $ZnSO_4$ + $MnSO_4$, T_5 = $CuSO_4$ + $ZnSO_4$ + $MnSO_4$ + Fe, T_6 = $CuSO_4$ + $ZnSO_4$ + $MnSO_4$ + B, T_7 = $CuSO_4$ + $ZnSO_4$ + $MnSO_4$ + Mo, T_8 = $CuSO_4$ + $ZnSO_4$ + $MnSO_4$ + Fe + B + Mo.

Table 8. Linear regression (R^2) and correlation coefficient (r) between seed cotton yield (SCY) versus selected growth and yield components of cotton.

Characters	Coefficient of determination (R^2)	Linear correlation coefficient (r)
SCY vs. plant height	0.87[*]	0.94**
SCY vs. number of leaves per plant	0.88[*]	0.94**
SCY vs. chlorophyll content	0.96[**]	0.98**
SCY vs. number of bolls per plant	0.82[*]	0.91**
SCY vs. number of cotton seeds per boll	0.90[**]	0.95**

* and; ** significant at 0.05 and 0.01 levels, respectively. vs = versus.

DISCUSSION

The results of present investigation indicate that plant height significantly increased in treatment compared to control (Table 1). Dordas (2009) in his experiment found that plant height was increased by an average of 9 to 10% compared with the control after the application of micronutrients in cotton crop. In another study, Tahir et al. (2009) also recorded that application of chelated zinc improved the plant height significantly. Foliar application of zinc, copper, manganese, iron, boron and molybdenum have key role in increasing the number of leaves per plant (PADMA et al., 1989).

It has been observed that increase in the number of node plant might be due to the application of manganese, which plays a beneficial role in this regard (DORDAS, 2009). Application of zinc and boron significantly increased leaf area in treatment T_8 compared to control (Table 4). These results are similar with the finding of Tahir et al. (2009) who found that maximum leaf area was noted in $ZnSO_4$-DTPA followed by $ZnSO_4$ Fulvate, and $ZnSO_4$-EDTA, while minimum was recorded in control, where no treatment was applied. In the present study, highest leaf area (50.8 cm) produced

in T_8 treatment may be due to the application of Zinc sulphate (Table 4).

Dordas (2009) noted that chlorophyll content was increased by application of Mn and deficiency of Mn cause decline in chlorophyll content that may lead to problems of boll abscission (SILVERTOOTH et al., 1999). Application of Mn during anthesis in cotton significantly increased the number of bolls retained in the plant (DORDAS, 2009). It is therefore observed that application of zinc, iron and boron significantly increased number of bolls per plant and consequently better yield.

It has been observed previously by Ratinavel et al. (1999) that number of bolls per plant and number of cotton seeds per boll were increased in plants given combined soil application of $ZnSO_4$ and boron. Our results are also in conformity with those of Hallikeri et al. (2002) who found that application of $ZnSO_4$ + $FeSO_4$ significantly increased the seed cotton yield. Singh et al. (2015) also found that foliar application of combined micronutrient on cotton benefits to realize the higher yield. The results of present study (Table 7) are similar to those of Yaseen et al. (2013) who indicated a significant improvement in seed cotton yield with foliar application of Zn, B, Mn, Cu, and

Fe on cotton grown on calcareous soils with the recommended soil applied NPK fertilizers in Pakistan. In the present study, the increase in earliness index in treatment T_8 and T_7 (Table 7) may be due to application of Zn and K (ZAKARIA et al., 2008).

CONCLUSION

It is inferred that foliar application could be a viable option to break the yield barrier and it might be exploited by farmers to enhance cotton productivity. The application of $CuSO_4$ + $ZnSO_4$ + $MnSo_4$ + Fe + B fertilization increases the seed cotton yield and yield contributing parameters particularly iron and molybdenum improved yield by increasing the number of bolls per plant.

RESUMO: Os micronutrientes desempenham um papel vital no crescimento e produtividade da cultura do algodão. Um estudo foi realizado para acessar a aplicação exógena de micronutrientes no crescimento e produção de cultura de algodão. O experimento foi composto de nove tratamentos como T_0 (controle), T_1 (Fe quelatado), T_2 (B), T_3 (Mo), T_4 ($CuSO_4$ + $ZnSo_4$ + $MnSo_4$), T_5 ($CuSO_4$ + $ZnSo_4$ + $MnSo_4$ + Fe quelatado) T_6 ($CuSO_4$ + $ZnSo_4$ + $MnSo_4$ + B), T_7 ($CuSO_4$ + $ZnSo_4$ + $MnSo_4$ + Mo) e T_8 ($CuSO_4$ + $ZnSo_4$ + $MnSo_4$ + Fe quelados + B). Dados sobre diferentes atributos de crescimento mostraram aumento significativo positivo com a aplicação de micronutrientes. A área foliar foi aumentada após aplicação de micronutrientes aos 99 dias após a semeadura (DAS), observando - se, então, uma tendência decrescente. Os teores de clorofila foram aumentados em 81 DAS e depois diminuíram para a colheita final. De forma semelhante, diferentes componentes de rendimento mostraram que o rendimento de algodão de sementes aumentou significativamente com a aplicação de Fe, B, Mo, Zn, Cu e Mn em comparação com o tratamento de controlo. O índice de precocidade, a data média de maturidade eo índice de taxa de produção aumentaram significativamente após o uso combinado de pulverização foliar de Zn, Cu, Mn e Mo.

PALAVRAS-CHAVE: Crescimento. Produção. Micronutrientes. Algodão.

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