J. Cotton Res. Dev. **32** (1) 77-83 (January, 2018) **ISSN No. 0972-8619**

Enhancing productivity of *Bt* cotton through foliar fertilization under humid southern plain zone of Rajasthan

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ABSTRACT : An experiment was conducted at Agricultural Research Station, Borwat Farm, Banswara during *kharif,* -2010, 2011 and 2012 to find out the suitable nutrient for increasing productivity of *Bt* cotton under various nutrients foliar sprays. Significantly higher seed cotton yield (2893 kg/ha) was recorded under foliar sprays of $MgSO_4$ @ 0.5 per cent + $ZnSO_4$@ 0.5 per cent over control and foliar spray of Boron @ 0.1 per cent, $ZnSO_4$@ 0.5 per cent, $MnSO_4$@ 1.0 per cent, $MgSO_4$@ 1.0 per cent and $FeSO_4$@ 0.5 per cent. However, it was found at par with foliar spray of $FeSO_4$@ 0.5 per cent + $ZnSO_4$ @ 0.5 per cent seed cotton yield (2812 kg/ha) and spray of 2 per cent urea at flowering and 2 per cent DAP at boll formation stage seed cotton yield (2780 kg/ha),respectively.

Key words : *Bt* cotton, foliar spray, nutrients, seed cotton yield

Cotton is known as white gold and queen of fibers. It is an important cash crop of global significance which plays a dominant role in world agriculture and industrial economy. India is important grower of cotton on a global scale. The cotton productivity in 2016-2017 has 568 kg/ha with an area of 105 lakh ha and production 351 lakh bales each 170 kg (*http://cotcorp.gov.in/statistics.aspx#area* CCI,2017).Cotton plant has an indeterminate growth pattern, so the use of balanced micro and macro nutrients is essential for the optimum vegetative and reproductive growth to obtain maximum yield. The reasons for decreasing productivity are due to decreasing soil fertility especially micronutrients, imbalanced use of fertilizer and occurrences of physiological disorders like square dropping, square drying, leaf reddening *etc*. Among these, imbalanced use of major and micro nutrients is the major problem. These nutrients are more important because in *Bt* cotton synchronized boll development altered the source sink relationship due to rapid translocation of saccharides and nutrients from leaves to the developing bolls (Hebbar *et al.*, 2007). To overcome these constraints, additional nutrition through foliar feeding is required over and above the normal fertilizer recommendation. This is one of the most efficient ways of supplying essential nutrients to a growing crop.The increased use of foliar fertilizers in crop production in the last decade is due to the changes in production philosophy. However, an alternative approach under such circumstances is foliar application of nutrients (Rab and Haq 2012) primarily for two reasons. First, it eliminates the effects of soil pH on the availability of these nutrients (Ali 2012). Researchers showed that adding foliar nutrition to supplement soil applied fertilizers is used to correct its deficiency, to maintain optimum nutrition of a particular nutrient, to give the crop a nutritional boost at a critical juncture in it's life. Foliar fertilizers support leaf nutrient levels that are drained as the plant shifts growth towards the bolls (Errington *et al.*, 2007). Newly released, high yielding transgenic cotton cultivars are said to have a higher nutrient demand during the boll development period (between flowering and maturity) due to their higher boll retention rate and larger boll load than conventional cultivars. During this period, nutrients are translocated from leaves to bolls, leading to speculation that foliar fertilization could be used as an effective tool for raising the nutrient status of the leaves at this critical period, and ultimately increase the yield of the cotton crop (Sawan *et al.*, 2008). So, the foliar application assumes greater importance, as the nutrients are brought in the immediate vicinity of the metabolizing area *i.e.* foliage. Therefore, supplying optimal quantities of mineral nutrients and using balanced macro and micronutrient doses to growing crop plants is one way to improve crop yields.

MATERIALS AND METHODS

The field experiment was conducted for three consecutive crop season *kharif,* 2010 to 2012 at Agricultural Research Station, Banswara. Nine treatments comprised *i. e.* (T_1- foliar spray of Boron @ 0.1 per cent, T_2- $ZnSO_4$@ 0.5 per cent, T_3-$MnSO_4$@ 1.0 per cent,T_4-$MgSO_4$@ 1.0 per cent,T_5-$FeSO_4$@ 0.5 per cent, T_6-$MgSO_4$ @ 0.5 per cent + $ZnSO_4$@ 0.5 per cent,T_7-$FeSO_4$@ 0.5 per cent + $ZnSO_4$ @ 0.5 per cent, T_8-2 per cent urea at flowering and 2 per cent DAP at boll formation stage and T_9-control water spray) in randomized block design with three replications. Experimental field was well prepared by two ploughing followed by harrowing and cultivator and one planking for uniform levelling were performed for sowing of cotton. The soil was medium in available nitrogen (248 kg/ha) and phosphorus (47.90 kg/ha) and high in available potassium (321 kg/ha) during crop season. Available micronutrient of experimental soil i.e. boron 8.57 mg/kg, zinc 0.84 mg/kg, sulphur 7.86 mg/kg, ferrous 10.12 mg/kg, manganese 9.36 mg/kg and magnesium 9.77 mg/kg soil. The *Bt* cotton variety NCS138 was sown in first week of June by dibbling 2-3 seeds/hills. Sprays of nutrients were done at flowering (50 DAS) and boll development stage (70 DAS). Full dose of phosphorus and potash were applied before sowing, while nitrogen dose was given in two splits *i.e.* first half dose after thinning (20 DAS) and remaining half at flowering stage (50 DAS). All production and protection measures were applied as per package and practices of the humid southern plain zone of Rajasthan.

RESULTS AND DISCUSSION

Plant population: It is evident from pooled data of three years (Table.1) shows that the plant population of *Bt* cotton was found not significant under all the treatments of foliar sprays of nutrients.

Growth parameters: Three years pooled data (Table.2) shows that the foliar sprays of nutrients significantly influences plant growth parameters. The maximum plant height (100.60

Table 1. Effect of foliar spray of nutrients on plant population of *Bt* cotton

Treatment	Plant population ('000)			
	2010	2011	2012	**Pooled**
Boron (0.1 %)	24380	24350	24348	**24359**
$ZnSO_4$ ((0.5 %)	24397	24341	24347	**24362**
$MnSO_4$ (1.0 %)	24356	24357	24365	**24359**
$MgSO_4$ (1.0 %)	24351	24332	24340	**24341**
$FeSO_4$ (0.5 %)	24370	24378	24385	**24378**
$MgSO_4$ (0.5 %) + $ZnSO_4$ (0.5 %)	24390	24359	24367	**24372**
$FeSO_4$ (0.5 %) + $ZnSO_4$ (0.5 %)	24400	24365	24370	**24378**
(2%) urea at flowering and (2%) DAP at boll formation stage	24378	24378	24381	**24379**
Control (water spray)	24352	24372	24375	**24366**
SEm+	57	45	49	**46**
CD (p=0.05)	NS	NS	NS	**NS**

cm) and sympodial branches/plant (24.26) were observed under foliar spray of T_6-$MgSO_4$@ 0.5 per cent + $ZnSO_4$@ 0.5 per cent over T_9-control and foliar spray of T_1-Boron @ 0. per cent, T_2-$ZnSO_4$@ 0.5 per cent, T_3-$MnSO_4$@ 1.0 per cent, T_4-$MgSO_4$@ 1.0 per cent and T_5-$FeSO_4$@ 0.5 per cent. However, it was found *at par* with foliar spray of T_7-$FeSO_4$@ 0.5 per cent + $ZnSO_4$ @ 0.5 per cent and T_8-spray of 2 per cent urea at flowering and 2 per cent DAP at boll formation stage. Significantly higher monopodial branches/plant (1.50) was recorded under foliar spray of T_6-$MgSO_4$ @ 0.5 per cent + $ZnSO_4$@ 0.5 per cent over control (1.27) in the pooled analysis, but it was found *at par* with rest of foliar spray treatments. The sufficient supply of micro and macronutrients results in efficient hormonal activity. Higher uptake of boron and zinc promote the synthesis of growth promoting hormones, especially the production of auxins resulting in enhanced growth and increased the number of internodes that promoted the development of main shoot as well as growth of sympodial branches. The reason for increase in growth components might be due to additional application of micro (magnesium, boron, zinc and iron) and along with macro nutrients (N, P and K) which might have increased the photosynthetic activity, enzyme activity and other biochemical process. Higher growth and growth attributes were reported in *Bt* cotton with three foliar sprays of micronutrient along with RDF by Ravikiran *et al.,* (2012) and Rajendran *et al.,* (2011).

Yield attributes: It is evident from pooled data (Table.3) that yield attributes of *Bt* cotton were significantly influence by foliar spray of nutrients. The maximum bolls/plant (39.26) and boll weight (4.12 g) were observed under T_6-foliar spray of $MgSO_4$@ 0.5 per cent + $ZnSO_4$@ 0.5 per cent over T_9-control and T_1-foliar spray of Boron @ 0.1 per cent, T_2-$ZnSO_4$@ 0.5 per cent, T_3-$MnSO_4$@ 1.0 per cent, T_4-$MgSO_4$@ 1.0 per cent and T_5-$FeSO_4$@ 0.5 per cent but it was found *at par* with T_7-foliar spray of $FeSO_4$@ 0.5 per cent + $ZnSO_4$ @ 0.5 per cent bolls $plant^{-1}$ (38.72) and boll weight (4.10 g) and T_8- spray of 2 per cent urea at flowering and 2 per cent DAP at boll formation stage bolls/plant (37.89) and boll weight (4.07g) ,respectively during both the years as well as in

Table: 2. Effect of foliar spray of nutrients on growth parameters of *Bt* cotton

Treatment	Plant height (cm)				Monopodial branches / plant				Sympodial branches / plant			
	2010	2011	2012	**Pooled**	2010	2011	2012	**Pooled**	2010	2011	2012	**Pooled**
Boron (0.1 %)	88.70	90.75	90.46	**89.97**	1.38	1.41	1.41	**1.40**	18.60	19.42	19.40	**19.14**
$ZnSO_4$ (0.5 %)	89.98	91.05	90.58	**90.76**	1.41	1.46	1.44	**1.44**	19.08	20.38	19.72	**19.73**
$MnSO_4$ (1.0 %)	90.31	91.25	91.28	**90.95**	1.45	1.44	1.46	**1.45**	19.70	21.13	21.12	**20.65**
$MgSO_4$ (1.0 %)	91.78	92.97	93.50	**92.75**	1.44	1.44	1.48	**1.45**	18.17	21.45	21.39	**20.33**
$FeSO_4$ (0.5 %)	90.50	91.44	92.54	**92.49**	1.45	1.46	1.48	**1.46**	17.61	20.53	20.96	**19.70**
$MgSO_4$ (0.5 %)+$ZnSO_4$ (0.5 %)	98.67	100.92	102.25	**100.60**	1.47	1.52	1.51	**1.50**	23.05	24.90	24.84	**24.26**
$FeSO_4$ (0.5 %)+$ZnSO_4$ (0.5 %)	97.90	98.41	99.52	**98.56**	1.45	1.51	1.50	**1.49**	22.72	24.02	24.49	**23.74**
(2%) urea at flowering and (2%) DAP at boll formation stage	95.08	97.20	98.15	**96.81**	1.45	1.51	1.48	**1.48**	22.28	23.97	24.32	**23.52**
Control	82.97	84.51	83.57	**83.68**	1.26	1.28	1.28	**1.27**	13.95	16.81	16.75	**15.84**
SEm+	1.78	1.70	1.85	**1.63**	0.05	0.06	0.05	**0.049**	0.85	0.78	0.84	**0.76**
CD (p=0.05)	5.39	5.12	5.51	**4.98**	0.16	0.20	0.16	**0.15**	2.52	2.36	2.49	**2.34**

Table 3. Effect of foliar spray of nutrients on yield attributes and seed cotton yield of *Bt* cotton

Treatment	Boll/plant				Boll weight (g)				Seed cotton yield (kg/ha)			
	2010	2011	2012	**Pooled**	2010	2011	2012	**Pooled**	2010	2011	2012	**Pooled**
Boron (0.1 %)	24.09	34.01	35.05	**31.05**	3.43	3.66	3.62	**3.57**	1478	2519	2498	**2165**
$ZnSO_4$(0.5 %)	24.89	34.67	35.16	**31.57**	3.44	3.81	3.70	**3.65**	1522	2554	2571	**2216**
$MnSO_4$(1.0 %)	26.41	38.06	38.67	**34.38**	3.51	3.90	3.76	**3.72**	1583	2785	2800	**2389**
$MgSO_4$(1.0 %)	26.42	38.13	38.33	**34.29**	3.52	3.93	3.80	**3.75**	1600	2869	2863	**2444**
$FeSO_4$(0.5 %)	26.38	38.00	38.24	**34.21**	3.50	3.88	3.78	**3.72**	1578	2788	2819	**2395**
$MgSO_4$(0.5 %)+ $ZnSO_4$(0.5 %)	31.41	42.33	44.05	**39.26**	3.86	4.30	4.22	**4.12**	2012	3358	3308	**2893**
$FeSO_4$(0.5 %) + $ZnSO_4$ (0.5 %)	30.86	42.10	43.21	**38.72**	3.84	4.27	4.19	**4.10**	1956	3249	3227	**2812**
(2%) urea at flowering and (2%) DAP at boll formation stage	30.35	41.24	42.09	**37.89**	3.81	4.26	4.15	**4.07**	1945	3202	3194	**2780**
Control	20.22	28.08	28.60	**25.63**	3.34	3.46	3.39	**3.40**	1331	2133	2135	**1866**
SEm+	1.12	1.20	1.15	**1.06**	0.10	0.09	0.12	**0.09**	115	120	118	**108**
CD (p=0.05)	3.38	3.62	3.50	**3.22**	0.31	0.28	0.35	**0.29**	348	358	355	**327**

Table 4. Effect of foliar spray of nutrients on economics of *Bt* cotton

Treatment	Net return (Rs./ha)				B:C ratio			
	2010	2011	2012	**Pooled**	2010	2011	2012	**Pooled**
Boron (0.1 %)	22296	55608	54936	**44280**	0.89	2.22	2.20	**1.77**
$ZnSO_4$(0.5 %)	23704	56728	57272	**45901**	0.95	2.27	2.29	**1.84**
$MnSO_4$(1.0 %)	25656	64120	64600	**51459**	1.03	2.56	2.58	**2.06**
$MgSO_4$(1.0 %)	26200	66808	66616	**53208**	1.05	2.67	2.66	**2.13**
$FeSO_4$(0.5 %)	25496	64216	65208	**51640**	1.02	2.57	2.61	**2.07**
$MgSO_4$ (0.5 %) + $ZnSO_4$(0.5 %)	39384	82456	80856	**67565**	1.58	3.30	3.23	**2.70**
$FeSO_4$(0.5 %) + $ZnSO_4$ (0.5 %)	36592	77968	77264	**63941**	1.41	3.00	2.97	**2.46**
(2%) urea at flowering and (2%) DAP at boll formation stage	36240	76464	76208	**62971**	1.39	2.94	2.93	**2.42**
Control	19092	44756	44820	**36223**	0.81	1.90	1.91	**1.54**
SEm+	1350	2455	1725	**1692**	0.08	0.13	0.11	**0.10**
CD (p=0.05)	3934	7403	5178	**5087**	0.25	0.40	0.34	**0.29**

pooled analysis.The increase in bolls may be due to micronutrient applications which are involved in greater diversion of the metabolites to the fruiting parts, culminating in more boll production. Increasing value of NPK with micronutrients leads to increase bolls/plant, boll weight 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 Sasthri *et al.*, (2000). Sankaranarayanan *et al.,* (2010) has also reported that foliar application of MgSO4 0.5 per cent at 60, 75 and 90 days after planting significantly influenced the leaf area index, bolls/ plant and dry weight at 90 days after planting by 26, 30 and 27 per cent over the control.

Seed cotton yield: Pooled data of three years shows that (Table.3) the seed cotton yield was significantly increasing by spray of T_6-$MgSO_4$@ 0.5 per cent + $ZnSO_4$@ 0.5 per cent. Among the treatments, foliar spray of T_6-$MgSO_4$ @ 0.5 per cent + $ZnSO_4$@ 0.5 per cent seed cotton yield (2893 kg/ha), T_7-$FeSO_4$@ 0.5 per cent + $ZnSO_4$ @ 0.5 per cent seed cotton yield (2812 kg/ ha) and T_8-spray of 2 per cent urea at flowering and 2 per cent DAP at boll formation stage seed cotton yield (2780 kg/ha) were found *at par* with each other but these treatment gave significantly higher seed cotton yield over T_9-control (1866 kg/ha) and foliar spray of T_1-Boron @ 0.1 per cent (2165 kg/ha), T_2-$ZnSO_4$@ 0.5 per cent (2216 kg/ha), T_3-$MnSO_4$@ 1.0 per cent (2389 kg/ha), T_4-$MgSO_4$@ 1.0 per cent (2444 kg/ha) and T_5- $FeSO_4$@ 0.5 per cent (2395 kg/ha),during may be in all three years. The sufficient supply of micro and macro nutrients result in efficient hormonal activity. Higher uptake of boron and zinc promote the synthesis of growth promoting hormones, especially the production of auxins resulting in enhanced growth and increased the number of internodes that promoted the development of main shoot as well as growth of sympodial branches. The increased yield attributed to the increased boronic acid mediated carbohadrate transport through cell mambranes

Boron and zinc fertilization also significantly improved phosphorus accumulation in seeds that enhance the protein contents resulting in the higher seed yield as reported by (Aref, 2007). Several previous studies had determined the positive effect of boron and zinc along with NPK fertilizers on growth, yield and nutrient uptake of *Bt* cotton (Aslam *et al.,* 2013).

Economics: Pooled data of three years shows that (Table.4) the net returns and B:C ratio was significantly influence by foliar fertilization of nutrients. Among the treatments, foliar spray of T_6-$MgSO_4$@ 0.5 per cent + $ZnSO_4$@ 0.5 per cent gave maximum net return (Rs. 67565/ha) and B:C ratio (2.70) over rest of the foliar spray of nutrients. However, it was found at par with foliar spray of T_7-$FeSO_4$@ 0.5 per cent + $ZnSO_4$ @ 0.5 per cent and T_8-spray of 2 per cent urea at flowering and 2 per cent DAP at boll formation stage .

CONCLUSION

This study revealed that judicious and balanced use of micro and macro nutrients in *Bt* cotton substantially improved the growth, boll weight, bolls/plant and seed cotton yield. It can be concluded that the foliar spray of $MgSO_4$@ 0.5 per cent + $ZnSO_4$@ 0.5 per cent gave higher seed cotton yield, but it was found *at par* with $FeSO_4$@ 0.5 per cent + $ZnSO_4$ @ 0.5 per cent and spray of 2 per cent urea at flowering and 2 per cent DAP at boll formation stage.

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Received for publication : May 22, 2017
Accepted for publication : November 6, 2017