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Higher productivity and sustainability in cotton (*Gossypium hirsutum* L.) through management of leaf reddening by foliar nutrition

S. N. HONNALI* AND B. M. CHITTAPUR

University of Agricultural Sciences, College of Agriculture, Bheemarayanagudi - 585 287

**E-mail:shivanand.honnali@gmail.com,*

ABSTRACT : Leaf reddening in cotton is being a serious disorder limiting productivity of crop an experiment was conducted under irrigation for three consecutive seasons at Agricultural College Farm, Bheemarayanagudi to manage leaf reddening and obtain sustained and higher yields under irrigation. Application of 150:75:75 kg/ha N, P_2O_5 and K_2O along with soil application of 25 kg/ha $MgSO_4$ and thrice foliar sprays each of 1.0 per cent $MgSO_4$ and 19:19:19 at 85, 105 and 130 days after sowing coinciding with square formation, peak flowering and boll development recorded lower scores for leaf reddening (0.67) and higher seed cotton yield (2070 kg/ha), sustainability yield index (90.59 %) and economics (Rs. 73 630 and 2.65 net returns and B:C ratio) in comparison to application of recommended dose of fertilizer (0.87, 1627, 70.41%, Rs. 57 380 and 2.38, respectively).

Key words: *Bt* cotton, foliar nutrition, leaf reddening, yield

With the advent of *Bt* cotton cultivars, no doubt, Indian cotton scenario is witnessing sweeping change and the country is in a position to reach its pre eminence position in natural fibre production and textile fabric. At present, genetically modified cotton is widely accepted by Indian farmer and the crop is grown on 11.13 m ha, of which 88 per cent is occupied by *Bt* hybrids alone, producing 31.20 million bales of seed cotton which is low in comparison to world average (725 kg/ha lint, Anonymous, 2011) in spite of record productivity on many farmers' fields in the irrigation commands. For instance, in Upper Krishna Project irrigation command in Karnataka, many farmers exceed 5.0 t/ha seed cotton yield while the average productivity is around 3.75 t/ ha. Over years these farmers are unable to sustain their yield levels because of delayed planting due to late release of water in the canals or delayed monsoon and consequently increased incidence of leaf reddening syndrome, sucking pest menace etc. Reddening leaf symptoms which appear towards peak flower to boll development result in reddening of leaves and cracking of bolls leading to lower yields; half of the normal yields in uncontrolled situation. Being a complex disorder attributed to many reasons as differential uptake of cations, sudden lowering of night temperature, excessive boll load, low soil nitrogen supply, abiotic stress like water shortage or stagnation, biotic stress due to jassids, synthesis and accumulation of anthocynin pigments etc. resulting in reddening of leaves, petiole, and then stem starting from the lower canopy extending to terminal portion with passage of time. At grand growth phase (flowering and boll development) any hindrance in the assimilate production, translocation and distribution intensifies the leaf reddening effect. Since leaf reddening is an irreversible process occurring at later stages of crop growth in response to growing conditions corrective measures need to be initiated at appropriate stages. Many of the

earlier reports suggest crop nutrition as one of the paramount factor and, therefore, foliar nutrition would be a very handy tool in augmenting the malady (Sangh *et al.,* 2012 and Rajendran *et al.,* 2010). Therefore, the following study on the impact of foliar nutrition on leaf reddening and crop performance was carried out at Agricultural College Farm, Bheemarayanagudi.

MATERIALS AND METHODS

The field experiment was conducted at College of Agriculture, Bheemarayanagudi in the Upper Krishna Project irrigation command falling in the north eastern dry zone, with semi arid of climate characterized by short monsoon mild winter and hot summer during the growing seasons of 2009-2010, 2010-2011 and 2011-2012. It is located at 15^0 45' to 17^0 30' North latitude and 75^0 15' to 77^0 31' East longitude and at 411 m mean sea level. The soil of experimental plot was medium black with low available nitrogen (240 kg/ha), medium phosphorus (40 kg/ha) and high potassium (340 kg/ha) contents. There were ten treatments comprising of recommend dose of fertilizer (RDF; 120:60:60 kg/ha N, P_2O_5 and K_2O) and 125 per cent RDF along with soil application 25 kg/ha of $MgSO_4$ and foliar spray of KNO_3 (1.0 or 2.0 %), $MgSO_4$ (1.0 %) and 19:19:19 (1.0 %) either alone or in combination twice or thrice as per treatment. The experiment was laid out using randomized block design with three replications. *Bt* cotton cv (Bunny *Bt* NCS 145) was used for the study and crop was sown during the last week of July after receipt of water in the canal at 90 x 60 cm spacing. Half the dose of nitrogen and full phosphorus and potassium (25 kg/ha $MgSO_4$ according to treatment) were applied at seed dibbling and remaining nitrogen was top dressed in three equal installments at 30, 45 and 60 days of sowing (DAS). Spray of nutrients to foliage was carried out at flowering (85 DAS), boll formation (105 DAS) and boll development (130 DAS) stages either twice or thrice as per treatment. Prophylactic measures were adopted to control the sucking pests. Weeds were controlled by hand weeding and interculture operations. Totally, six irrigations of 10 cm depth each were given during the cropping period based on rainfall occurrence during all the years of study. Leaf scoring for reddening was recorded (0- when all the leaves are green < 3 leaves (>50 % leaf area) are reddened, 1- when 3 leaves show reddening, 2- when >3 leaves (>60 % leaf area) turn red with younger leaves remaining green, 3 - all the leaves in plant show reddening in patches, 4 - whole plant turning reddening. Growth and yield observations were collected and pooled data were subjected to statistical analysis. Further, economics of the experiment was also worked out. Based on the yield data Sustainable Yield index (SYI) was worked out using the formula:

$$SYI = \frac{A - Y}{Y\ max} \times 100$$

A = Mean of particular treatment
Y = Standard deviation of particular treatment
Y max = Potential yield in different years and treatments

RESULTS AND DISCUSSIONS

Cotton growth in terms of plant height, monopodials, sympodials and bolls/plant was not significantly influenced due to any of the treatments, though there was marginal improvement in height and sympodials and bolls/ plant with application of 125 per cent RDF along with soil application of $MgSO_4$ and foliar spray of $MgSO_4$ and 19:19:19 (Table 1). This

variation in growth attributes is on the expected line as there was no variation in plant nutrition except treatment number one till 80 DAS when foliar nutrition treatments were initiated and such a late nutrition is unlikely to result in cognizable changes in growth attributes. In fact, the compositions of the treatments were such that they had impact if any on incidence and intensity of leaf reddening and consequently on seed cotton yield/ plant, total yield and economics of production.

Leaf reddening in cotton scored during 2010 and 2011 though indicated a below normal scores due to either compatible environment, optimum soil nutrient supply situation or use of tolerant cultivars or due to all, still revealed a clear trend of the impact of various treatments with the score ranging from 0.60 to 0.93 (Table 1). Recommended fertilization (T_1) had higher average reddening score (0.87) among all the treatments. Even increase in fertilization up to 125 per cent of RDF coupled with three sprays of 1 per cent 19:19:19 (T_4) or soil application of $MgSO_4$ (T_8) was also ineffective with next higher scores (0.77 each). However, application of 125 per cent RDF and three foliar sprays of 2.0 per cent KNO_3 (T_5), and application of 125 per cent RDF along with soil application of 25 kg /ha $MgSO_4$ and three foliar sprays of both $MgSO_4$ (1 %) and19:19:19 (1 %) (T_9) recorded the

Table 1. Growth, yield attributes and leaf scoring characters as influenced by foliar nutrition in *Bt* cotton

(Pooled data of three years)

Treatments	Plant height (cm)	Monopods/ plant	Sympods/ plant	Bolls/ plant	Leaf reddening score
T_1 - RDF (120:60:60 kg NPK /ha)	106	2.03	18.09	36.04	0.87*(0.80 – 0.93)
T_2 - RDF + 2 foliar sprays of $MgSO_4$ (1%)	106	2.00	17.80	38.56	0.67(0.60 – 0.73)
T_3 - RDF (125%) + 3 foliar sprays of $MgSO_4$ (1 %)	110	2.00	18.16	38.38	0.70(0.67 – 0.73)
T_4 - RDF (125%) + 3 foliar sprays of 19:19:19 (1 %)	113	1.80	17.82	38.13	0.77(0.73 -0.80)
T_5 - RDF (125%) + 3 foliar sprays of KNO_3 (2 %)	110	2.00	17.93	37.71	0.67(0.73 -0.60)
T_6 - RDF (125%) + 3 foliar sprays of $MgSO_4$ (1%) and KNO_3 (1 %)	111	2.00	18.69	37.73	0.73(0.67 – 0.80)
T_7 - RDF (125%) + 3 foliar sprays of $MgSO_4$ (1 %) and 19:19:19 (1 %)	113	2.00	18.93	37.41	0.700.60 -0.80)
T_8 - RDF (125%)+ Soil application of $MgSO_4$ 25 kg /ha	111	2.00	18.58	40.47	0.77(0.73 -0.80)
T_9 - RDF (125%) + Soil application of $MgSO_4$ 25 kg/ ha + 3 foliar sprays of $MgSO_4$ (1 %) and 19:19:19 (1 %)	114	2.03	19.93	42.49	0.67(0.60 -0.73)
T_{10}- RDF (125%) + Soil application of $MgSO_4$ 25 kg/ ha + 3 foliar sprays of $MgSO_4$ (1 %) and KNO_3 (2 %)	114	2.10	18.93	41.64	0.70(0.60 – 0.80)
S.Em. +	2.38	0.08	0.62	1.52	0.12
C D (p=0.05)	NS	NS	NS	NS	NS

Note : 2 foliar sprays at 90 and 110 DAS, 3 sprays at flowering (85 DAS), boll formation (105 DAS) and boll development (130 DAS) stages, NS - Not significant, * Range of leaf reddening score

lowest leaf reddening score (0.67) among all. Similarly, Praharaj and Sankaranarayanan (2010) reported that the low leaf N and potash resulting in reddening of leaves could be augmented through combined spray of $MgSO_4$ (1%), urea (1 %) and zinc sulphate (1 %) at 50th and 80th days. This emphasizes the importance of application of basic elements namely Mg and K in the present study in spite of soil being alkaline. Besides, balanced application of primary elements namely N, P and K along with soil and foliar nutrition of Mg is equally effective than sole application of any of these compounds.

This beneficial effect of nutrition of basic elements and primary elements consequent upon reduced reddening was also visible on seed cotton yield/ plant (Table 2). Seed cotton yield/ plant was the highest with 125 per cent RDF along with soil application of $MgSO_4$ at 25 kg/ha and three foliar sprays of $MgSO_4$ and 19:19:19 each at 1 per cent each. Treatments T_8, T_{10}, T_6 and T_5 were *on par* with each other. While, RDF or 125 per cent RDF alone or in combination with either of $MgSO_4$ and 19:19:19 failed to produce comparable performances. Consequent upon improved seed cotton weight/ plant, the seed cotton yield was the highest with T_9 (2070 kg/ ha) closely followed by T_7 (1999 kg/ha) and T_{10} (1972 kg/ha). The yield improvement with T_9 over the treatment receiving only recommended

Table 2. Seed cotton yield and economics as influenced by foliar nutrition in *Bt* cotton (Pooled data of three years)

Treatment	Seed cotton yield		Sustainable yield index (%)	Gross returns (₹/ha)	Net returns (₹/ha)	B : C ratio
	Weight (g/plant)	Yield (kg/ha)				
T_1 - RDF (120:60:60 kg NPK /ha)	114.8	1627	70.4	73863	57380	2.38
T_2 - RDF + 2 foliar sprays of $MgSO_4$ (1 %)	114.0	1767	76.8	80291	62906	2.57
T_3 - RDF (125%) + 3 foliar sprays of $MgSO_4$ (1 %)	117.7	1843	80.0	83614	66156	2.56
T_4 - RDF (125%) + 3 foliar sprays of 19:19:19 (1%)	118.3	1878	81.9	84541	65873	2.51
T_5 - RDF (125%) + 3 foliar sprays of KNO_3 (2 %)	124.2	1868	81.4	84132	64749	2.38
T_6 - RDF (125%) + 3 foliar sprays of $MgSO_4$ (1 %) and KNO_3 (1 %)	121.8	1848	80.5	83694	65347	2.43
T_7 - RDF (125%) + 3 foliar sprays of $MgSO_4$ (1 %) and 19:19:19(1 %)	120.0	1999	87.4	90456	71713	2.67
T_8 - RDF (125%)+ Soil application of $MgSO_4$ (25 kg /ha)	123.7	1867	81.4	84681	65718	2.47
T_9 - RDF (125%) + Soil application of $MgSO_4$ (25 kg/ ha)+3 foliar sprays of $MgSO_4$ (1 %) and 19:19:19 (1 %)	127.4	2070	90.6	93435	73630	2.65
T_{10}- RDF (125%) + Soil application of $MgSO_4$ (25 kg/ ha)+3 foliar sprays of $MgSO_4$ (1 %) and KNO_3 (2 %)	123.4	1972	86.0	88787	68964	2.42
S.Em. +	2.32	34	-	1682	1757	0.07
C D (p=0.05)	6.90	101	-	4998	5220	0.20

Note : 2 foliar sprays at 90 and 110 DAS, 3 sprays at flowering (85 DAS), boll formation (105 DAS) and boll development (130 DAS) stages, NS - Not significant.

dose of fertilizer (T_1) was to the tune of 27 per cent. Foliar application of urea, DAP and MOP also increased bolls, boll weight/plant and yield/plant because newly released transgenic cotton cultivars need higher and continuous supply of nutrients especially during boll filling period Madaan *et al.,* (2014). It is interesting to point here that though yield variations mostly followed trend in leaf reddening but the impact of foliar nutrition was beyond the effect on the stability of leaf greenness. Waraich *et al.,* (2011) reported that the foliar application of potassium resulted in increased bolls, boll weight and yield/plant. The yield variation at same leaf score in the study for reddening confirms the fact. In other words, application of Mg as well as N, P and K also improved boll weight or lint yield due to their beneficial effect on photosynthesis, efficient translocation and efficient enzymatic activity under hot day and cool night situations prevailing during peak flowering to boll development stage in the months of November to December in peninsular region. Brar *et al.,* (2008) opined that foliar application of water soluble complex fertilizers will act as a source of all major and micro nutrients, which helps in increasing the seed cotton yield. The parent results are in consonance with the findings of Aladakatti *et al.,* (2011). Improved growth and growth attributes were reported in *Bt* cotton with three foliar application of micronutrient along with RDF by Rajendran *et al.,* (2011). The reason for increase in growth components might be due to additional application of secondary (magnesium) and macro nutrients (N, P_2O_5 and K_2O) which might have increased the photosynthetic activity, enzyme activity and other biochemical process and also helped in better partitioning of dry matter. Similar results were reported by Shivamurthy and Biradar, (2014).

The high sustainable yield indices with afore mentioned treatments further substantiate the fact that extra addition of 25 per cent RDF (30:15:15 kg/ha N, P_2O_5 and K_2O) along with soil and foliar nutrition of $MgSO_4$ and foliar nutrition of NPK in equal concentration also helped in achieving sustainability in yield in spite of continuous cultivation of cotton on the same field for three years (Table 2). In other words, it can be suggested that under economic considerations the farmer can postpone change of crop at least for three years in leaf reddening endemic areas.

Further, the economics of the experiment revealed higher gross returns (Rs. 93435 /ha) and net returns (Rs. 73630 /ha) with application of 125 per cent RDF and $MgSO_4$@ 25 kg/ha along with three foliar sprays of $MgSO_4$ (1 %) and 19:19:19 (1 %), owing to higher seed cotton yield (Table 2). B: C ratio was also the highest with soil application 125 per cent RDF along with three foliar sprays of $MgSO_4$ (1 %) and 19:19:19 (1 %) due to higher efficiency of water soluble nutrients and lower cost/unit of nutrient with latter compound.

Thus, though, earlier recommendations suggest single application of either $MgSO_4$, urea, DAP or KNO_3 to augment leaf reddening the present study strongly favours the application of $MgSO_4$ as well as three major nutrients namely N, P and K @ 1.0 per cent thrice at 85, 105 and 130 DAS in traditional cotton belt of peninsular India for effective management of leaf reddening for sustained and higher seed cotton yield.

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