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Management of leaf reddening through soil and foliar nutrition in irrigated *Bt* cotton (*Gossypium hirsutum* L.)

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ABSTRACT : A field experiment was conducted at Main Agricultural Research Station, Raichur during 2009-2010 to 2011-2012 (three years) to study management of leaf reddening through soil and foliar nutrition in irrigated *Bt* cotton (*Gossypium hirsutum* L.). The pooled results of three years showed that the highest seed cotton yield of 2115 kg/ ha was recorded with combined soil application of NPK 125 per cent and $MgSO_4$ along with foliar sprays of $MgSO_4$ and KNO_3 and closely followed by RDF 125 per cent + $MgSO_4$ soil application along with these treatments were *on par* and significantly superior over RDF alone and along with two foliar sprays of $MgSO_4$. The yield increase with these treatments over check treatment was 16.2 and 14.7 per cent. The extent of reduction in leaf reddening index with these treatments is 28.6 and 27.9 over RDF and 42.8 and 42.2 over check treatment. RDF 125 per cent and $MgSO_4$ along with foliar sprays of $MgSO_4$ and KNO_3 recorded higher net returns.

Key words : *Bt* cotton, foliar application, recommended dose of fertilizers soil application

Cotton (*Gossypium* spp.) is an important commercial fiber crop grown under diverse agro-climatic condition and is called as 'White Gold' and also as 'King of Fiber' crops contributing 85 per cent of raw materials to textile industry. It plays a vital role in the country's economic growth by providing substantial employment and making significant contributions to export earnings (33 %). About 14 per cent of industrial production and 4 per cent of the GDP is contributed by the textile sector and this sector is the second largest provider of employment after agriculture. *Bt* cotton is intensively cultivated in the north eastern dry zone and northern dry zone of the state (Zone 2 and 3) covering partly the Tungabhadra and Upper Krishna irrigation Commands (TBP and UKP) on black soil. The average productivity of *Bt* cotton in these areas is 20 q of seed cotton yield/ha as against potential yield the 30 to 40 q/ha (Satyanarayan Rao and Santhosh, 2016).

At the end of sixth year after *Bt* cotton cultivation was started, rapid survey was made in TBP and UKP command areas with a sample size of 100 respondents to know the real advantages and production constraints with *Bt* cotton cultivation. Among production constraints, leaf reddening has become a major one. Majority of the farmers have opined that *Bt* cotton is more vulnerable to leaf reddening disorder mainly because of retention of more number of opened bolls per plant on account of plant tolerance to boll worm. About 89 per cent sample farmers experienced red leaf disease from peak flowering to boll development stage. Farmers often confused with other foliar diseases and not at all adopted control measures. About 9 per cent farmers not satisfactory even with adoption of existing control measures. Survey report of Hosmath *et al.,* (2012) in other districts of Northern Karnataka also indicated that leaf reddening ranked 1st among the

constraints showing 93 per cent sample farmers facing the problem and higher red leaf index with *Bt* cotton genotypes (1.82) than non *Bt* genotypes (1.63). Survey analysis warranted to research work on management of leaf reddening. With this background, the present study was undertaken.

MATERIALS AND METHODS

A field experiment was conducted during 2009-2010 to 2011-2012 (three years) at Main Agriculture Research Station, Raichur to study management of leaf reddening through soil and foliar nutrition in irrigated *Bt* cotton (*Gossypium hirsutum* L.). Treatments were replicated thrice in RCBD design. There were 11 treatment combinations T_1 : RDF (150 : 75 :75 kg NPK/ha)**,** T_2 : RDF + foliar spray (F.S.) of $MgSO_4$ (1%) at 90 and 110 DAS (Check) , T_3: RDF (125%) + 3 F.S. of 1 % $MgSO_4$, T_4 : RDF (125%) + 3 F.S .of 1.0 (%) 19:19:19 NPK , T_5: RDF (125%) + 3 F.S .of 2.0 % KNO_3 , T_6: RDF (125%) + 3 F.S .of 1.0 (%) $MgSO_4$ + 2.0 % KNO_3 , T_7: RDF (125%) + 3 F.S .of 1.0 (%) $MgSO_4$ + 1.0 (%) 19:19:19 NPK, T_8: RDF (125%) + Soil application (S.A.) of $MgSo_4$ @ 25 kg/ha , T9 : RDF (125%) + S.A .of $MgSO_4$ + 3 F.S. of $MgSO_4$ + 19: 19: 19 NPK, T_{10}: RDF (125%) + S.A .of $MgSO_4$ + 3 F.S. of $MgSO_4$ + KNO_3 , T_{11}: RDF (125%) + 3 F.S. of $MgSO_4$ + Micro nutrient mixture. Three foliar sprays at flowering (75-80 DAS), boll formation (90-95 DAS) and boll development stage (105-110 DAS).

The soil was deep black with a pH (8.32). The available N, P K were 211, 26.2, 162 kg/ha and Mg 8.40 (C mol/kg), organic carbon 0.49(%), respectively. The cotton hybrid Bunny BG 2 (NCS 145) was sown during all three years by giving a spacing of 90 x 60 cm. The crop received the recommended dose of 150:75:75 kg NPK/ha. The major and secondary nutrients containing fertilizers *viz.,* KNO_3, $MgSO_4$ and 19:19:19 were sprayed in combination as per the treatments. The timely plant protection measures for sucking pests (thrips, aphids, leaf hoppers and whiteflies) were adopted. Three hand weedings (20, 45 and 60 DAS) and 2 inter cultivations were at (15 and 50 DAS) were carried out to keep the plots free from weeds. Chlorophyll content of the green leaves (3rd leaf from top) of each 5 tagged plants was recorded with the help of chlorophyll meter (Modal, SPAD 502). For the quantitative estimation of degree of leaf reddening, an index was worked out. The basis of this method is the number of leaves showing the signs of reddening at a given time. Leaves turned red partly or wholly, were divided into 5 categories as follows: Grade ´zero´-when all the leaves were green or less than 3 leaves showed signs of reddening; Grade ´one´ - when 3 leaves showed reddening ; Grade ´two´ - when more than three leaves were showing signs of reddening but young leaves were green ; Grade ´three´ - when all the leaves were showing reddening in patches and Grade ´four´ - when the whole plant turned red (Santhosh *et al.,* 2015). Boll weight (g) and bolls/ plants were recorded at harvest. The seed cotton yield in kg/ha was computed.

RESULTS AND DISCUSSION

Seed cotton yield and economics: The pooled results of three years showed that the highest seed cotton yield of 2115 kg/ha was recorded with T_{10} *i.e.* combined soil application of NPK (125%) and $MgSO_4$ along with foliar sprays of $MgSO_4$ and KNO_3 and closely followed by RDF (125%)+ $MgSO_4$ soil application along with these treatments were *on par* and significantly superior over RDF alone and along with two foliar sprays of $MgSO_4$. The yield increase with T_{10} and T_9 over check treatment was 16.2 and 14.7

Table 1. Growth and yield components as influenced by nutrient management practices for leaf reddening in *Bt* cotton (Three years pooled data)

Treatments	Plant height (cm)	Harvested bolls/ plant	Boll weight (g)	Seed cotton yield/ plant (g)	Seed cotton yield (kg/ha)
T_1 : RDF	98.82	28.90	3.99	97.54	1773
T_2 : RDF + F.S. of $MgSo_4$ (1%) at 90 and 110 DAS (Check)	102.40	29.17	4.44	103.17	1819
T_3 : RDF (125%) + 3 F.S. of $MgSo_4$ 1%)	106.28	30.88	4.79	108.83	1896
T_4 : RDF (125%) + 3 F.S .of (1%) 19:19:19	104.08	33.40	4.60	117.90	1919
T_5 : RDF (125%) + 3 F.S .of (2%) KNO_3	108.84	30.98	4.79	111.80	1936
T_6 : RDF (125%) + 3 F.S .of (1%) $MgSo_4$ + (2%) KNO_3	107.88	33.26	4.94	117.39	2074
T_7 : RDF (125%) + 3 F.S .of (1%) $MgSo_4$ + (1%) 19:19:19	111.88	30.02	4.74	114.52	1934
T_8 : RDF (125%) + S. A. of $MgSo_4$ (25 kg/ha)	105.55	30.48	4.66	117.85	1966
T_9 : RDF (125%) + S. A. of $MgSo_4$ + 3 F.S. of $MgSo_4$ +19: 19: 19	112.04	33.91	4.79	132.18	2082 (14.7%)
T_{10} : RDF (125%) + S.A .of $MgSo_4$ + 3 F.S. of $MgSo_4$ + KNO_3	113.51	36.37	4.99	130.49	2115 (16.2%)
T_{11} : RDF (125%) + 3 F.S. of (MgSo$_4$ +Micro nutrient mixture)	104.11	29.97	4.66	113.07	1937
S.Em ±	2.80	1.36	0.16	5.05	49
C.D (p=0.05)	8.28	4.02	0.48	14.90	145

Figures in parenthesis indicate % increase over check (T2)

percent (Table 1). Even in individual years also (two out of three years), these treatments are found promising. Higher yields with these treatments may be attributed to optimum canopy as a result of lower leaf reddening index which may be again due to the higher leaf N, Mg and chlorophyll contents. Higher nutrients contents in the leaf led to higher photosynthetic efficiency. The beneficial effect of $MgSO_4$ was higher when spraying was taken up with 19:19:19 and KNO_3 as a result of growth promoting effect of NPK nutrients supplied through these sources at critical growth stages which might have also led to better distribution of dry matter. Several workers have reported increased in seed cotton yields because of development of optimum canopy as a result of lower leaf reddening index which was attributed due to higher leaf nitrogen, magnesium and chlorophyll contents and thus leading to higher photosynthetic efficiency with spraying of $MgSO_4$ (Kumar and Yadav, 2010), $MgSO_4$ + KNO_3, $MgSO_4$ + DAP and soil application of $MgSO_4$ with foliar spray of $MgSO_4$ and soil application of NPK with foliar sprays of KNO_3, DAP and KNO_3 + 19:19:19 (Santhosh *et al.,* 2015). The higher yield levels with nutrient management practices are due to the higher growth and yield components. Acceptance of new technology depends upon the economics involved in the crop production. Combined application of RDF (125 %) and $MgSO_4$ along with foliar sprays of $MgSO_4$ and KNO_3 recorded higher net returns. The higher net returns with T_8 and T_6 were mainly due to lower cost of cultivation compared to the treatments which recorded higher returns. Higher net returns were because of higher seed cotton yields. The T_9 and T_{10} are far superior than RDF and RDF with foliar spray of $MgSO_4$ treatments. Data on economics revealed that treatments T_{10} and T_9 fetched 12.64 and 12.12 per cent higher net returns over check treatment (T_2)

(Rs.61,028/ha) (Table 2).

Leaf reddening index (LRI) and chlorophyll content (SPAD value): All the nutrient management practices have recorded lower LRI values compared to RDF and RDF with foliar spray of $MgSO_4$.There was significant reduction in leaf reddening index values in treatments T_9 and T_{10} compared to check treatments. The extent of reduction in leaf reddening index with these treatments is 28.6 and 27.9 over RDF and 42.8 and 42.2 over check treatment (Table 2). Further not only they recorded lower LRI values but also higher leaf chlorophyll contents when compared to the other nutrient management practices and check treatments. Higher leaf chlorophyll contents in nutrient management practices might be due to higher leaf N and Mg contents. Soil and foliar application of nutrients, higher yields due to combined initial soil application of $MgSO_4$ with foliar sprays of $MgSO_4$ + KNO_3, $MgSO_4$ + 19:19:19 and $MgSO_4$ might be attributed to the development of optimum canopy as a result of lower leaf reddening index (LRI) which was attributed due to higher leaf nitrogen, magnesium and chlorophyll contents and thus leading to higher photosynthetic efficiency. Foliar spraying of $MgSO_4$+ KNO_3, $MgSO_4$ + 19:19:19 and $MgSO_4$ combined with initial soil application of $MgSO_4$ resulted in significantly lower leaf reddening index. The beneficial effect of $MgSO_4$ was higher when foliar spray was combined with KNO_3 and 19:19:19 NPK. This might be due to growth promoting effect of N, P and K nutrients supplied through KNO3 and 19:19:19 sprays might has promoted the retention and development of the bolls on account of adequate supply of the nutrients (N and K) at critical stages resulted into better growth of the crop besides the role of magnesium in growth and development of the plant with minimizing the leaf reddening incidence results in better growth and yield attributes like plant height, harvested bolls/plant, boll weight (g) and seed cotton yield/plant (g) (Table 1). Further, it might

Table 2. Leaf reddening index (LRI), SPAD (Chlorophyll) values and economics as influenced by nutrient management practices for leaf reddening in *Bt* cotton (Three years pooled data)

Treatments	120 DAS		Gross returns (Rs/ha)	Cost of culti-vation (Rs/ha)	Net returns (Rs/ha)
	LRI (0-4 Scale)	SPAD values			
T_0 : RDF	1. 61	42.51	82,778	22,741	60,037
T_1 : RDF + F.S. of $MgSo_4$ (1%) at 90 and 110 DAS (Check)	1. 29	43.72	84,876	24,781	61,028
T_2 : RDF (125%) + 3 F.S. of (1%) $MgSo_4$	1. 03	45.64	88,474	25,629	62,845
T_3 : RDF (125%) + 3 F.S. of (1%) 19:19:19	0. 96	46.93	89,539	26,743	62,796
T_4 : RDF (125%) + 3 F.S. of (2%) KNO_3	1. 03	45.22	90,348	27,969	62,379
T_5 : RDF (125%) + 3 F.S. of (1%) $MgSo_4$ + KNO_3 (2%)	1.01	46.15	96,739	28,894	67,845
T_6 : RDF (125%) + 3 F.S. of (1%) $MgSo_4$ + (1%) 19:19:19	1. 01	46.56	90,261	27,486	62,774
T_7 : RDF (125%) + S.A of $MgSo_4$ (25 kg/ha)	1. 11	45.53	91,724	25,203	66,521
T_8 : RDF (125%) + S.A. of $MgSo_4$ +3 F.S. of $MgSo_4$ +19: 19: 19	0.93	47.80	97,134	28,707	68,427
T_9 : RDF (125%) + S.A. of $MgSo_4$ + 3 F.S. of $MgSo_4$ + KNO_3	0. 92	48.13	98,704	29,958	68,746
T_{10} : RDF (125%) + 3 F.S. of $MgSo_4$ +Micro nutrient mixture)	0. 97	46.10	90,360	28,270	62,090
$S.Em_{11}$ ±	0. 11	0.85	2,294	-	2,006
C.D (p=0.05)	0. 32	2.53	6,728	-	5,885

be due to the fact that nutrients (N and K) supplied through KNO_3 and 19:19:19 sprays might have helped in redistributing dry matter within the plant thus bringing an improvement in yield. Similar results of beneficial effect of nitrogen, phosphorus and potassium along with magnesium on plant growth and development of the crop plants were reported by Upperi and Kuligoud (2011). Even in individual years also the promising treatments had higher leaf chlorophyll contents. Seed cotton yield and leaf reddening index values with different treatments. Both are inversely proportional. Higher LRI and lower will be the yield level and vice-versa. The higher beneficial effects inturns leaf reddening management, yield and monetary returns were pronounced when foliar spray of $MgSO_4$ was taken in combination with KNO_3 and 19:19:19 along with soil application of $MgSO_4$ and 25per cent additional NPK dose. Magnesium being associated with maintaining healthy green leaves and higher photosynthesis occurred in centre part of chlorophyll molecule. The foliar nutrition played important role in physiology of crop. In another related study at same location Santhosh (2012) and Santhosh *et al.,* (2015) observed lower LRI values and higher cotton leaf N, Mg content in nutrient management studies.

On the basis of this study, it could be inferred that for effective control of leaf reddening and also to get higher seed cotton yields under irrigation, It is advocated to follow RDF (125%) application with $MgSO_4$@ 25 kg/ha and 3 foliar sprays of $MgSO_4$ (1.0%) + KNO_3 (2.0%) or $MgSO_4$ (1.0%) + (1.0%) 19:19:19 NPK at flowering, boll formation and boll development stages is advocated.

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