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Research Paper

Nutrition management affects cotton (*Gossypium hirsutum*) productivity and leaf reddening for targeted yields

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ABSTRACT

A field experiment was conducted during growing seasons of 2014–15 and 2015–16 at College of Agriculture Farm, University of Agricultural Sciences, Raichur, Karnataka, to study the effect of nutrient management on cotton (*Gossypium Hirsutum* L.) productivity and leaf reddening for targeted yield on medium deep black soil under irrigation. Three yield targets (3, 4 and 5 t *kapas* yield/ha)-based site-specific nutrient management (SSNM) along with 4 leaf- reddening management (LRM) treatments (S_1, vermicompost @ 2.5 t/ha in seed line; S_2, S_1 + $MgSO_4$ 10 kg/ha in seed line; S_3, S_1 + $MgSO_4$ 25 kg/ha in seed line; and S_4, $MgSO_4$ 25 kg/ha in seed line + foliar nutrition of 1% $MgSO_4$ + 19 : 19 : 19 + 1% KNO_3 thrice during flowering, boll development and boll bursting stages) besides recommended control were tested using randomized complete block design. The SSNM for 5 t/ha yield target and supplementary nutrition of $MgSO_4$ both to soil and to foliage and foliar application of major nutrients (19:19:19 and KNO_3) (S_4) resulted in significantly higher plant height (64, 140, 146 and 158 cm, respectively), monopodials (1.90, 3.0, 3.0 and 3.0) and sympodials/plant (10.3, 25.9, 27.5 and 32.3), nodes on main stem (16.4, 29.9, 31.8 and 37.8), leaf area (27.8, 98.0, 131.8 and 99.0 dm^2/plant) and leaf-area index/plant (0.51, 1.82, 2.4 and 1.83) at 45, 90 and 135 DAS and at final picking and dry-matter accumulation in leaves (63.4, 137.2 and 153.2 g/plant), stem (76.3, 146.6 and 161.3 g/plant) and reproductive parts (130.7, 146.3 and 161.0 g/plant) at 90, 135 days after sowing and at final picking. Consequently, the treatment also recorded significantly higher seed-cotton yield (5.35 t/ha), harvest index (0.38 on pooled basis) and benefit: cost ratio (5.32) amongst all targets and LRM approaches, while recommended control fared poorly (2.84 t/ha, 0.37 and 4.14 *kapas* yield, harvest index and B : C ratio, respectively).

Key words: *Bt* cotton, benefit: cost, Growth, Leaf reddening, Site specific nutrient management, Yield

Cotton (*Gossypium* spp.), enjoys a pre-eminent position amongst cash crops in the world and in India as well. In India, it is cultivated in 13.77 million ha, with a production of 36.5 million bales of seed cotton (2018–19), and the country is very close in production to China ranking first in the world. Average productivity of cotton in India, however, is low (460 kg lint/ha) when compared to the world average (762 kg lint/ha) (COCPC, 2021) or the leading producers, viz. Australia (1,781 kg/ha), China (1,719 kg/ha), Brazil (1,522 kg/ha), the USA (974 kg/ha) and Pakistan (699 kg/ha). Particularly, the fall in productivity in potential areas is raising concern. There is great discontent in some quarters about cultivars, as some varieties are becoming vulnerable to bollworm (mostly due to spurious seed/F_2 seed) and/or to many physiological disorders, namely leaf reddening and thereby yielding below par (Venkateshwaralu, 2002) besides poor-quality fibre as reported in Maharashtra and Gujarat (Hebbar and Mayee, 2011). The principle cause of reddening is probably nitrogen and magnesium deficiencies triggered by lower nutrient availability and crop uptake determined by inclement climate and/or poor soil. Supply of nitrogen along with phosphorus and potassium or potassium nitrate and magnesium to the leaf at these stages to reduce the formation of anthocyanin and achieve potential yields is critical (Sathyanarayanrao *et al*., 2014; Honnali and Chittapur, 2017; Basavenneppa *et al*., 2015), and more so when higher targets are set. Hence, an attempt was made in the present investigation to realize set yield targets through adequate nutrition (N, P, K and Mg) to soil and through leaf fortification during growth.

MATERIALS AND METHODS

An experiment was conducted during the growing seasons of 2014–15 and 2015–16 under irrigation. The experiment consisted of 3 main plot treatments, viz. site-specific

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nutrient management (SSNM)-based nutrition, i.e., 3 (M_1), 4 (M_2) and 5 tonnes/ha (M_3) seed-cotton, 4 subplot treatments, viz. nutrient supplementation to manage leaf reddening malady (LRM): S_1, vermicompost @ 2.5 t/ha in seed line; S_2, S_1 + $MgSO_4$ 10 kg/ha in seed line; S_3, S_1 + $MgSO_4$ 25 kg/ha in seed line; and S_4, $MgSO_4$ 25 kg/ha in seed line; + foliar nutrition of 1% $MgSO_4$ + 19 : 19 : 19 + 1% KNO_3 thrice during flowering, boll-development and boll-bursting stages along with recommended fertilizer practice (RDF, 150 kg N, 75 kg P_2O_5 and 75 kg K ha) as outside control for comparison (3 × 4 + 1), laid out in a split-plot design with 3 replications. For the yield targets fertilizers were applied based on the soil test and crop requirement as per Site Specific Nutrient Management (*www.IPNI.com*) (Table 1). In control, the recommended doses of fertilizers were applied as 150 kg N, 75 kg P_2O_5 kg and 75 K kg/ha.

The pooled data on growth attributes (plant height, number of monopodials and sympodials/plant, nodes on main stem, leaf area and leaf-area index, dry-matter production), leaf-reddening index (Dastur *et al*., 1952) at different growth stages, number of bolls/plant, seed-cotton yield and benefit: cost ratio (Gross returns/Production cost) obtained from the experiment were subjected to statistical analysis at $P = 0.05$ and means were compared using Duncan's Multiple Range Test (DMRT) using SPSS 16.0 version. Pooled means and third-order interactions were presented and discussed here.

RESULTS AND DISCUSSION

The site-specific nutrient management (SSNM) for yield target of 5 t/ha and supplementary nutrition of $MgSO_4$ both to soil and to foliage and foliar application of major nutrients (19 : 19 : 19 and KNO_3) alone and together (M_3S_4 - 64, 140, 146 and 158 cm at 45, 90 and 135 DAS and at final picking, on pooled basis); resulted in taller plants at all the stages, while M_1S_1 with 3 t/ha target and vermicompost alone to soil had lower plant height amongst all (52, 110, 116, and 132 cm at 45, 90 and 135 DAS and at final picking, on pooled basis); however still it fared better than the recommended control (42, 109, 111 and 126 cm at 45, 90 and 135 DAS and at final picking, on pooled basis) (Table 2). Former treatment (M_3S_4) also resulted in numerically more number of monopodials (1.77, 3.0, 3.0 and 3.0 respectively, at 45, 90 and 135 DAS and at final picking, respectively), while 3 t/ha yield target in combination with application of vermicompost alone (M_1S_1) recorded lower number of monopodials/plant (1.23, 2.0, 2.0 and 2.0 at 45, 90 and 135 DAS and at final picking), but was better than the recommended control (Table 2). Sympodials/plant also differed significantly; M_3 and S_4 faring better than the others alone and among interactions higher count also occurred with M_3S_4 (10.3, 25.9, 27.5 and 32.3 at 45, 90 and 135 DAS and at final picking respectively) and it was on par with yield target 5 t/ha + vermicompost and 25 kg/ha $MgSO_4$ (M_3S_3), while 3 t/ha yield target in combination with application of vermicompost alone (M_1S_1) recorded lower number of sympodials/plant (7.7, 16.6, 19.0 and 21.1 at 45, 90 and 135 DAS and at final picking) but was still superior to the control (Table 2).

Further, nutrition through SSNM and LRM alone and together had significant influence wherein node count was higher with SSNM for 5 t/ha yield target and application of $MgSO_4$ @ 25 kg/ha along with foliar nutrition of 1% each of $MgSO_4$, 19 : 19 : 19 and KNO_3 (M_3S_4); the differences widened as the crop growth advanced (16.4, 29.9, 31.8 and 37.8 plant respectively, at 45, 90 and 135 DAS and at final picking), while the yield target of 3 t/ha in combination with application of vermicompost (M_1S_1) recorded lower number of nodes (11.9, 20.4, 22.3 and 24.8/plant at 45, 90 and 135 DAS and at final picking) amongst all which again was superior to the recommended practice (Table 3). Again 5 t/ha yield target (M_3) and LRM practice of $MgSO_4$ 25 kg/ha in seed line + foliar nutrition of 1% $MgSO_4$ + 19 : 19 : 19 + 1% KNO_3 thrice during flowering, boll development-and boll-bursting stages (S_4) alone and in combination (M_3S_4) resulted in higher leaf area throughout (27.8, 98.0, 131.8 and 99.0 dm^2/plant at 45, 90 and135 DAS and at final picking, with M_3S_4), while the lower leaf area among 2 factor combinations was observed with lower target of 3 t/ha and application of vermicompost (M_1S_1) (18.9, 88.6, 109.6 and 78.8 dm^2/plant at 45, 90 and 135 DAS and at final picking) (Table 3). Consequently, SSNM with 5 t/ha yield target and supplementary nutrition of $MgSO_4$ @ 25 kg/ha to soil along with 1% each of $MgSO_4$, 19 : 19 : 19 and KNO_3 periodically (M_3S_4) resulted in higher LAI (0.51,

Table 1. Soil test value, ratings, nutrient requirement to achieve the target and adjusted nutrients

Yield targets	Soil-test value ($N : P_2O_5 : K_2O$ kg/ha) 2014–15	Soil-test value ($N : P_2O_5 : K_2O$ kg/ha) 2015–16	Nutrient requirement ($N : P_2O_5 : K_2O$ kg/ha)	Final applied ($N : P_2O_5 : K_2O$ kg/ha)
3 t/ha	168 : 72 :184	198 : 74 : 208	192 : 84 : 114	240 : 63 :114
4 t/ha	168 : 72 : 184	198 : 74 : 208	256 : 112 : 152	316 : 84 : 152
5 t/ha	168 : 72 : 184	198 : 74 : 208	320 : 140 : 190	400 : 105 : 190

Source : *www.IPNI.com*

Table 2. Influence of site-specific nutrient-management based yield targets and nutrition for leaf-reddening management on plant height (cm), monopodials and sympodials/plant of cotton at various stages

Treatment	Plant height				Monopodials				Sympodials			
	45 DAS	90 DAS	135 DAS	At final picking	45 DAS	90 DAS	135 DAS	At final picking	45 DAS	90 DAS	135 DAS	At final picking
Yield targets (M)												
M_1	53^{c}	117^{c}	121^{c}	136^{c}	1.35^{b}	2.16^{c}	2.16^{c}	2.16^{c}	8.3^{b}	18.1^{b}	20.5^{c}	23.1^{c}
M_2	55^{b}	128^{b}	133^{b}	149^{b}	1.60^{a}	2.37^{b}	2.37^{b}	2.37^{b}	8.9^{b}	23.3^{a}	24.0^{b}	25.9^{b}
M_3	58^{a}	140^{a}	143^{a}	156^{a}	1.75^{a}	2.83^{a}	2.83^{a}	2.83^{a}	9.7^{a}	23.8^{a}	25.5^{a}	29.1^{a}
SEm±	0.5	0.8	1.9	0.9	0.04	0.03	0.03	0.03	0.2	0.2	0.2	0.4
Leaf-reddening management (S)												
S_1	54^{c}	123^{c}	127^{c}	142^{c}	1.52^{c}	2.23^{c}	2.23^{c}	2.23^{c}	8.4^{b}	19.7^{d}	21.4^{d}	23.9^{c}
S_2	54^{c}	126^{b}	131^{b}	146^{bc}	1.46^{bc}	2.41^{b}	2.41^{b}	2.41^{b}	8.9^{ba}	21.3^{c}	22.9^{c}	25.1^{c}
S_3	56^{b}	129^{a}	133^{b}	148^{ba}	1.68^{ba}	2.60^{a}	2.60^{a}	2.60^{a}	9.2^{a}	22.4^{b}	23.9^{b}	26.7^{b}
S_4	58^{a}	131^{a}	136^{a}	152^{a}	1.61^{a}	2.57^{a}	2.57^{a}	2.57^{a}	9.4^{a}	23.5^{a}	25.1^{a}	28.4^{a}
SEm±	0.4	0.4	3.1	0.9	0.03	0.06	0.06	0.06	0.1	0.1	0.1	0.5
Interaction												
M_1S_1	52^{e}	110^{g}	116^{h}	132^{i}	1.23^{f}	2.0^{g}	2.0^{g}	2.0^{g}	7.7^{e}	16.6^{f}	19.0^{f}	21.1^{g}
M_1S_2	53^{ed}	117^{f}	119^{hg}	135^{ih}	1.23^{f}	2.03^{g}	2.03^{g}	2.03^{g}	8.3^{de}	18.1^{e}	20.5^{fe}	22.3^{fg}
M_1S_3	54^{c-e}	121^{fe}	122^{fg}	138^{igh}	1.43^{e}	2.23^{fe}	2.23^{fe}	2.23^{fe}	8.6^{b-e}	18.7^{e}	20.7^{fe}	23.7^{fe}
M_1S_4	54^{ced}	122de	126^{fe}	141^{fgh}	1.50^{ed}	2.37^{de}	2.37^{de}	2.37^{de}	8.7^{b-e}	19.1^{e}	21.9^{de}	25.2^{de}
M_2S_1	53^{ed}	126^{cde}	130de	145^{feg}	1.63^{bcd}	2.17^{gf}	2.17^{gf}	2.17^{gf}	8.4^{d-e}	20.9^{d}	21.8^{be}	23.9^{fe}
M_2S_2	54^{ced}	127^{cd}	132^{dc}	147^{fed}	1.50^{ed}	2.40^{dce}	2.40^{dce}	2.40^{dce}	8.9^{b-c}	22.8^{c}	23.4^{dc}	25.3^{de}
M_2S_3	56^{cbd}	127^{cd}	134^{dc}	149^{edc}	1.70^{bc}	2.57^{c}	2.57^{c}	2.57^{c}	9.2^{a-d}	23.9^{dc}	24.9^{dc}	26.3^{dc}
M_2S_4	57^{cb}	131^{cb}	136^{c}	153^{bcd}	1.57^{ecd}	2.33^{fe}	2.33^{fe}	2.33^{fe}	9.1^{bdc}	25.6^{a}	26.0^{ba}	28.2^{bc}
M_3S_1	55^{b-e}	133^{b}	136^{c}	151^{b-e}	1.70^{bc}	2.53^{dc}	2.53^{dc}	2.53^{dc}	9.1^{bdc}	21.5^{d}	23.2^{dc}	26.8^{dc}
M_3S_2	56^{cbd}	134^{b}	141^{b}	155^{bac}	1.63^{bed}	2.80^{b}	2.80^{b}	2.80^{b}	9.5^{bac}	23.2^{c}	24.9^{bc}	27.6^{dc}
M_3S_3	58^{b}	139^{a}	143^{ba}	158^{ab}	1.90^{a}	3.0^{a}	3.0^{a}	3.0^{a}	9.8^{ba}	24.7^{ba}	26.2^{ba}	30.1^{ba}
M_3S_4	64^{a}	141^{a}	146^{a}	161^{a}	1.77^{ba}	3.0^{a}	2.0^{g}	2.0^{g}	10.3^{a}	25.9^{a}	27.5^{a}	32.3
SEm±	0.8	0.9	5.0	1.7	0.1	0.1	0.1	0.1	0.2	0.3	0.17	0.9
Control	42	109	111	126	1.30	1.90	1.90	1.90	6.4	14.6	16.8	18.5
SEm±	2.2	3.2	4.9	3.3	0.1	0.1	0.1	0.1	0.3	0.7	0.6	1.0
CD (P=0.05)	4.6	9.2	14.2	9.4	0.2	0.30	0.30	0.30	0.9	1.9	1.7	2.7

*Means with same letters do not differ significantly under DMRT

DAS, Days after sowing; SSNM, site-specific nutrient management

M_1, SSNM for targeted yield of 3 t/ha; M_2 SSNM for targeted yield of 4 t/ha; M_3, SSNM for targeted yield of 5 t/ha; S_1, vermicompost @ 2.5 t/ha in seed line; S_2, S_1 + $MgSO_4$ 10 kg/ha in seed line; S_3, S_1 + $MgSO_4$ 25 kg/ha in seed line; S_4, $MgSO_4$ 25 kg/ha in seed line + foliar nutrition of 1% $MgSO_4$ + 19 : 19 : 19 + 1% KNO_3 (thrice each); Control, recommended dose of fertilizer.

1.82, 2.4 and 1.83 at 45, 90 and 135 DAS and at final picking) throughout (Table 3). Amongst all, 3 t/ha yield target in combination with application of vermicompost (M_1S_1) recorded fairly lower indices at all the stages (0.35, 1.64, 2.03 and 1.46 at 45, 90 and 135 DAS and at final picking). Recommended practice resulted in lower leaf area and leaf-area index.

The improved growth could be attributed to improved photosynthesis with ultimate influence on dry matter (DM) which varied significantly (Table 4). Apart alone SSNM for 5 t/ha yield target and supplementary nutrition with application of $MgSO_4$ @ 25 kg/ha along with foliar nutrition of 1% each of $MgSO_4$, 19 : 19 : 19 and KNO_3 periodically (M_3S_4) resulted in higher DM in leaves (63.4, 137.2 and 153.2 g/plant at 90, 135 DAS and at final picking) among all treatment combinations, while lower DM was observed with 3 t/ha yield target and vermicompost application (M_1S_1) (50.8, 93.1 and 94.8 g/plant respectively, at 90 and 135 DAS and at final picking). Similar was the trend in DM accumulation in stem (M_3S_4 76.3, 146.6 and 161.3 and M_1S_1 64.0, 108.3 and 114.0 g/plant at 90 and 135 DAS and at final picking, respectively) and reproductive parts (M_3S_4 130.7, 146.3 and 161.0 and M_1S_1 109.3, 118.1 and 125.0 g/plant at 90 and 135 DAS and at final picking) (Table 4). Recommended fertilization practice recorded lower values of DM in every plant part at all the stages than SSNM-based nutrition coupled with LRM.

The SSNM basically takes care of plant requirement for a set yield target taking into account soil supply and fertilizer contribution which is the major difference over blanket recommendation. Besides major nutrition, here cotton was supplied with 25 kg/ha $MgSO_4$ to soil and foliar

Table 3. Nodes on main stem /plant leaf-area/plant (dm^2/plant) and leaf-area index of cotton at various stages as influenced by site-specific nutrient management based yield targets and nutrition for leaf-reddening management

Treatment	Nodes on main stem				Leaf area/plant				Leaf-area index			
	45 DAS	90 DAS	135 DAS	At final picking	45 DAS	90 DAS	135 DAS	At final picking	45 DAS	90 DAS	135 DAS	At final picking
Yield targets (M)												
M_1	13.2^{c}	22.0^{b}	23.8^{c}	26.2^{c}	20.2^{c}	89.7^{b}	113.8^{c}	81.3^{b}	0.37^{c}	1.66^{b}	2.11^{b}	1.50^{b}
M_2	14.2^{b}	27.4^{a}	26.6^{b}	28.1^{b}	23.2^{b}	92.7^{ba}	119.1^{b}	83.5^{b}	0.43^{b}	1.72^{ba}	2.21^{ba}	1.55^{b}
M_3	15.1^{a}	28.1^{a}	29.2^{a}	33.8^{s}	26.9^{a}	96.1^{a}	125.6^{a}	95.1^{a}	0.50^{a}	1.78^{a}	2.33^{a}	1.76^{a}
SEm±	0.2	0.4	0.2	0.4	0.2	0.7	0.9	0.7	0.004	0.01	0.02	0.01
Leaf reddening management (S)												
S_1	12.8^{c}	23.9^{c}	24.8^{b}	27.3^{c}	22.0^{c}	90.9^{b}	113.9^{d}	82.9^{c}	0.41^{b}	1.68^{b}	2.11^{c}	1.54^{b}
S_2	13.8^{bc}	25.3^{b}	25.8^{b}	28.2^{c}	23.3^{ba}	90.9^{b}	117.1^{c}	86.3^{b}	0.43^{ba}	1.68^{b}	2.17^{bc}	1.60^{ba}
S_3	14.6^{ba}	26.3^{b}	27.1^{a}	29.9^{b}	24.2^{a}	94.1^{a}	122.0^{b}	87.8^{ba}	0.45^{a}	1.74^{a}	2.26^{ba}	1.63^{a}
S_4	15.5^{a}	27.7^{a}	28.4^{a}	32.1^{a}	24.2^{a}	95.4^{a}	124.9^{a}	89.5^{a}	0.45^{a}	1.77^{a}	2.31^{a}	1.66^{a}
SEm±	0.1	0.1	0.1	0.6	0.2	0.9	1.1	0.5	0.003	0.02	0.02	0.01
Interaction												
M_1S_1	11.9^{e}	20.4^{g}	22.3^{f}	24.8^{f}	18.9^{f}	88.6^{de}	109.6^{g}	78.8^{e}	0.35^{f}	1.64^{de}	2.03^{d}	1.46^{c}
M_1S_2	12.5^{de}	21.5^{fg}	23.1^{fe}	25.5^{f}	20.0^{ef}	85.1^{e}	111.2^{g}	80.4^{de}	0.37^{ef}	1.58^{e}	2.06^{dc}	1.49^{c}
M_1S_3	13.7^{b-e}	22.3^{fe}	24.5^{dc}	26.6^{fe}	21.1^{efd}	91.7^{bdc}	116.5^{fe}	82.2^{cde}	0.39^{efd}	1.70^{bdc}	2.16^{bdc}	1.52^{cb}
M_1S_4	14.6^{a-d}	23.6^{e}	25.4^{de}	28.0^{e}	20.8^{efd}	93.2a^{-d}	117.9^{be}	83.6^{cd}	0.38^{efd}	1.73^{a-d}	2.18^{bdc}	1.55^{cb}
M_2S_1	12.9^{dec}	25.3^{d}	25.0^{de}	26.5^{fe}	21.8^{ecd}	90.4^{dec}	112.1^{gf}	81.1^{de}	0.40^{ecd}	1.67d^{ec}	2.08^{dc}	1.50^{c}
M_2S_2	13.9^{b-e}	26.9^{de}	26.1^{dc}	27.0^{fe}	23.2^{bcd}	91.8^{bdc}	117.5^{e}	82.6^{cde}	0.43^{bdc}	1.70b^{dc}	2.18^{bdc}	1.53^{cb}
M_2S_3	14.4^{a-d}	27.7^{bc}	27.1^{dc}	28.6^{de}	23.9^{bc}	93.9^{a-d}	121.6^{dce}	84.2^{cd}	0.44^{bc}	1.74^{a-d}	2.25^{a-d}	1.56^{cb}
M_2S_4	15.5^{ba}	29.7^{a}	28.2^{bc}	30.5^{dc}	23.9^{bc}	94.9^{ba}c	125.1^{bc}	85.8^{cb}	0.44^{bc}	1.76^{bac}	2.32^{ba}	1.59^{cb}
M_3S_1	13.5^{b-e}	26.1^{dc}	27.0^{dc}	30.8^{dc}	25.4^{ba}	93.8^{a-d}	119.9^{de}	88.8^{b}	0.47^{ba}	1.74^{a-d}	2.22^{a-d}	1.64^{b}
M_3S_2	15.1^{bac}	27.6^{bc}	28.3^{dc}	32.1^{c}	26.8^{a}	95.6^{bac}	122.7^{de}	95.9^{a}	0.50^{a}	1.77^{bac}	2.27^{bac}	1.78^{a}
M_3S_3	15.6^{ba}	28.8^{ba}	29.7^{ba}	34.4^{b}	27.6^{a}	96.8^{ba}	128.0^{ba}	96.9^{a}	0.51^{a}	1.79^{ba}	2.37^{ba}	1.79^{a}
M_3S_4	16.4^{a}	29.9^{a}	31.8^{a}	37.8^{a}	27.8^{a}	98.0^{a}	131.8^{a}	99.0^{a}	0.51^{a}	1.82^{a}	2.4^{a}	1.83^{a}
SEm±	0.22	0.5	0.2	1.0	0.4	1.4	1.9	1.0	0.01	0.03	0.04	0.02
Control	9.5	17.9	19.9	21.0	16.4	71.0	85.2	54.0	0.30	1.32	1.58	1.0
SEm±	0.6	0.8	0.8	0.5	1.3	3.2	3.3	3.4	0.03	0.04	0.05	0.05
CD (P=0.05)	1.8	2.4	2.4	1.4	4.6	9.2	9.5	9.9	0.09	0.13	0.16	0.15

*Means with same letters do not differ significantly under DMRT

DAS, Days after sowing; SSNM, site-specific nutrient management

M_1, SSNM for targeted yield of 3 t/ha; M_2, SSNM for targeted yield of 4 t/ha; M_3, SSNM for targeted yield of 5 t/ha; S_1, vermicompost @ 2.5 t/ha in seed line; S_2, S_1 + $MgSO_4$ 10 kg/ha in seed line; S_3, S_1 + $MgSO_4$ 25 kg/ha in seed line; S_4, $MgSO_4$ 25 kg/ha in seed line + foliar nutrition of 1% $MgSO_4$ + 19 : 19 : 19 + 1% KNO_3 (thrice each); Control, recommended dose of fertilizer.

supplementation through 1 per cent spray of $MgSO_4$, 19 : 19 : 19 and KNO_3 thrice. Latter treatment being LRM package, helped greatly to alleviate leaf reddening (0.23, 0.37, 0.68 and 1.10 at 90, 105, 120 and 135 DAS on pooled basis, Fig. 1) and its consequent negative impact on yield. Foliar application of KNO_3 which is a source of both N and K, is highly beneficial in increasing the seed-cotton yield (Brar *et al*., 2009). Soil and foliar application of $MgSO_4$ also influenced seed-cotton yield because of magnesium which is an integral part of chlorophyll, which increased chlorophyll content and its stability and thereby photosynthesis and seed-cotton yield. The results are in conformity with the findings of Brar *et al*., (2009) and Hosmath (2011). Further, potassium deserves special attention in cotton nutrition because of its high uptake rates and relative inefficiency of potash uptake mechanism compared to many other crops (Kerby and Adams, 1985). Probably, SSNM-based nutrition could able to take care of this issue and hence any benefits that accrued owing to LRM were marginal in the present investigation.

Further, enhanced leaf area, concomitant lower reddening and dry-matter production with M_3S_4 owing to need-based nutrition for the set target (400 : 105 : 190 kg N : P : K/ha) enabled higher photosynthesis and further sustenance of greenness for prolonged period because of supply of soluble form of nutrients, particularly N and Mg, during critical stages of crop growth which coincided with limiting climatic factors such as lower temperature and drier weather which occurred during latter part of reproductive stage. Further, during this period efficient translocation to developing bolls was facilitated because of foliar nutrition of potassium (19 : 19 : 19 and KNO_3). The N and Mg

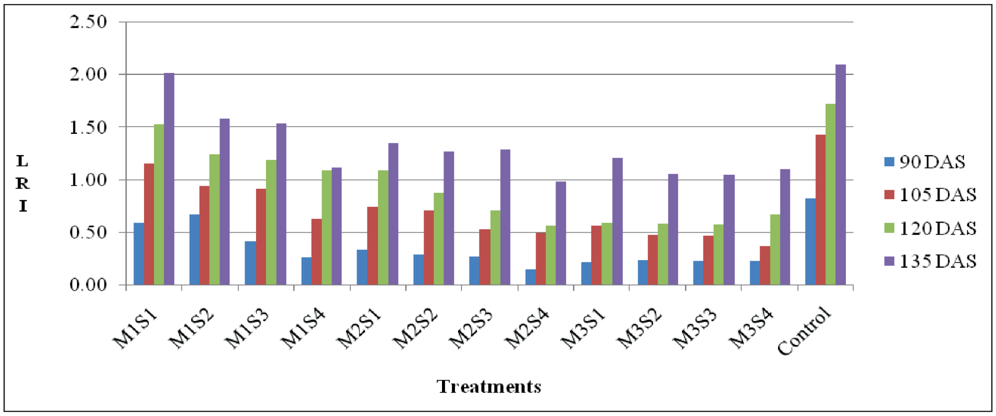

Fig. 1. Leaf reddening index (LRI) of cotton at various stages as influenced by site-specific nutrient management (SSNM)-based yield targets and nutrition for leaf reddening management yield target (M): M_1, SSNM for targeted yield of 3 t/ha; M_2, SSNM for targeted yield of 4 t/ha; and M_3, SSNM for targeted yield of 5 t/ha, Leaf reddening management (S): S_1, Vermicompost @ 2.5 t/ha in seed line; S_2, S_1+$MgSO_4$ 10 kg/ha in seed line; S_3, S_1 + $MgSO_4$ 25 kg/ha in seed line; and S_4, $MgSO_4$ 25 kg/ha in seed line + foliar nutrition of 1% $MgSO_4$ +19 : 19 : 19 + 1% KNO_3 (thrice each); Control, recommended dose of fertilizer with recommended practice.

Table 4. Effect of site-specific nutrient management-based yield targets and nutrition for leaf-reddening management on dry-matter accumulation in leaves (g/plant) of cotton at various stages

Treatment	DMP in leaves			DMP in stem			DMP reproductive parts		
	90 DAS	135 DAS	At final picking	90 DAS	135 DAS	At final picking	90 DAS	135 DAS	At final picking
Yield targets (M)									
M_1	53.5^{c}	100.8^{c}	105.3^{c}	66.7^{c}	115.0^{c}	118.5^{c}	114.6^{c}	125.3^{c}	132.6^{c}
M_2	56.4^{b}	111.5^{b}	120.6^{b}	69.2^{b}	126.8^{b}	135.9^{b}	121.1^{b}	132.3^{b}	139.0^{b}
M_3	59.1^{a}	128.2^{a}	136.7^{a}	72.6^{a}	134.3^{a}	145.8^{a}	125.0^{a}	137.8^{a}	148.5^{a}
SEm±	0.4	1.1	1.0	0.4	0.7	0.8	0.4	0.6	1.4
Leaf reddening management (S)									
S_1	53.3^{c}	104.6^{d}	108.4^{d}	66.6^{c}	114.5^{d}	121.9^{d}	115.0^{d}	124.0^{d}	130.2^{d}
S_2	55.1^{cb}	109.0^{c}	115.5^{c}	67.9^{c}	121.2^{c}	129.4^{c}	118.3^{c}	129.6^{c}	138.1^{c}
S_3	57.0^{b}	117.2^{b}	124.1^{b}	70.4^{b}	129.4^{b}	136.8^{b}	122.1^{b}	134.7^{b}	142.5^{b}
S_4	59.9^{a}	123.1^{a}	135.4^{a}	73.0^{a}	136.4^{a}	145.6^{a}	125.5^{a}	138.9^{a}	149.4^{a}
SEm±	0.3	0.7	0.6	0.5	1.1	0.3	0.2	0.2	1.1
Interaction									
M_1S_1	50.8^{d}	93.1^{h}	94.8^{g}	64.0^{f}	108.3^{g}	114.0^{g}	109.3^{f}	118.1^{h}	125.0^{h}
M_1S_2	52.4^{cd}	94.6^{h}	100.6^{g}	65.3^{fe}	110.0^{gf}	115.6^{fg}	112.7^{ef}	123.7^{g}	131.6^{fg}
M_1S_3	53.9^{cd}	105.3^{gf}	110.8^{f}	67.3^{fed}	119.0^{ed}	120.0^{fe}	116.8^{ecd}	127.4^{fg}	133.6^{fg}
M_1S_4	56.9^{bc}	110.2^{ef}	115.2^{ef}	70.4^{bdc}	122.9^{d}	124.5^{e}	119.6^{cd}	132.2^{fdc}	140.4^{ced}
M_2S_1	53.2^{cd}	100.0^{gh}	108.4^{f}	66.6^{fed}	114.9^{ef}	121.1^{fe}	116.4^{ed}	124.3^{g}	128.5^{hg}
M_2S_2	55.6^{bcd}	107.7^{f}	114.7^{ef}	67.8^{c-f}	123.0^{d}	131.2^{d}	119.4^{cd}	130.8^{fdc}	138.1^{fcd}
M_2S_3	57.2^{bc}	116.5^{ed}	121.1^{ecb}	70.0^{b-c}	129.8^{c}	140.4^{c}	122.3^{bcd}	135.8^{cd}	143.5^{ced}
M_2S_4	59.4^{ba}	122.0^{cd}	138.1^{b}	72.4^{bae}	139.6^{b}	150.9^{b}	126.3^{ba}	138.3^{cb}	146.0^{cb}
M_3S_1	55.9^{bc}	120.8^{cd}	122.3^{d}	69.1^{b-e}	120.5^{ed}	130.5^{d}	119.1^{cd}	129.5^{fe}	137.3^{fe}
M_3S_2	57.4^{bc}	124.7^{cb}	131.1^{c}	70.8^{bdc}	130.7^{c}	141.4^{c}	122.9^{bc}	134.3^{cde}	144.5^{cbd}
M_3S_3	59.8^{ba}	129.9^{b}	140.4^{b}	74.0^{ba}	139.5^{b}	150.0^{b}	127.2^{ba}	140.9^{b}	150.^{4b}
M_3S_4	63.4^{a}	137.2^{a}	153.2^{a}	76.3^{a}	146.6^{a}	161.3^{a}	130.7^{a}	146.3^{a}	161.9^{a}
S.Em±	0.5	1.6	1.3	0.9	1.7	0.9	0.5	0.7	2.2
Control	41.4	75.9	81.1	49.9	85.0	89.0	81.9	87.8	93.5
SEm±	3.2	3.4	3.1	3.2	3.2	3.2	2.9	3.1	4.8
CD (P=0.05)	9.3	9.9	9.2	9.4	9.3	9.4	8.5	9.3	14.0

*Means with same letters do not differ significantly under DMRT

DAS, Days after sowing; SSNM, site-specific nutrient management

M_1, SSNM for targeted yield of 3 t/ha; M_2 SSNM for targeted yield of 4 t/ha; M_3, SSNM for targeted yield of 5 t/ha; S_1, vermicompost @ 2.5 t/ha in seed line; S_2, S_1 + $MgSO_4$ 10 kg/ha in seed line; S_3, S_1 + $MgSO_4$ 25 kg/ha in seed line; S_4, $MgSO_4$ 25 kg/ha in seed line + foliar nutrition of 1% $MgSO_4$ + 19 : 19 : 19 + 1% KNO_3 (thrice each); Control, recommended dose of fertilizer.

enabled extended greenness of leaf and thereby extended utilization of radiant energy into chemical energy which ultimately helped obtain higher seed cotton yield (Basavanneppa *et al*., 2011 and Honnali and Chittapur 2013).

This significant increase in all the growth parameters with adequate fertilization for higher yields in combination with foliar spray of major nutrients for LR alone and together resulted in higher assimilates production and their translocation to sink; bolls and seed-cotton yield. Higher boll count (66.2–66.9 on pooled basis) was observed with higher yield target and different subplots being comparable ($M_3S_{1–4}$), while the lower yield target had lower count; different subplots being at par again ($M_1S_{1–4}$) (54.4–55.3 on pooled basis) (Table 5). Further M_3S_4 comprising 5 t/ha yield target coupled with soil application of $MgSO_4$ combined with foliar application of 1% each of $MgSO_4$, 19 : 19 : 19 and KNO_3 (thrice each) at flowering, boll development and boll bursting fared better (66.4) and differed significantly from all the treatment combination involving lower yield targets ($M_1S_{1–4}$) and also from M_2S_1.

The SSNM for yield target of 5 t/ha and supplementary nutrition of $MgSO_4$ both to soil and to foliage and foliar fortification (M_3S_4) resulted in significantly higher (higher by 6.98% over set target) seed-cotton yield (5.35 t/ha), while M_1S_1 with 3 t/ha target and vermicompost alone to soil registered lower seed-cotton yield amongst all (3.40 t/ha) (Table 5), whereas the yield with the recommended control (2.84 t/ha) was lower than SSNM + LRM combination, being lower by 53% compared to M_3S_4 and by 11.9% from M_1S_1. Hosmani *et al*. (2013) and Parminder Kaur *et al*. (2010) also reported improved growth parameters and consequently cotton yield with adequate nutrition through soil in addition to foliar spray of liquid soluble fertilizers over the recommended practice.

Harvest index due to the interaction effect of SSNM and

Table 5. Effect of site-specific nutrient management based yield targets and nutrition for leaf-reddening management on bolls/plant, seed-cotton yield (t/ha), harvest index and benifit: cost ratio of cotton

Treatment	Bolls/plant	Yield (t/ha)	Harvest index	Benefit: cost ratio
Yield targets (M)				
M_1	54.5^{c}	3.48^{c}	0.35^{c}	4.32^{c}
M_2	60.6^{b}	4.49^{b}	0.39^{b}	4.97^{b}
M_3	66.4^{a}	5.25^{a}	0.41^{a}	5.32^{a}
SEm±	0.70	0.77	0.004	0.01
Leaf reddening management (S)				
S_1	61.4^{a}	4.32^{b}	0.39^{a}	4.87^{a}
S_2	60.9^{b}	4.38^{a}	0.39^{a}	4.88^{a}
S_3	60.7^{a}	4.43^{a}	0.38^{b}	4.86^{a}
S_4	60.3^{ba}	4.50^{a}	0.38^{b}	4.87^{a}
SEm±	0.30	0.40	0.004	0.02
Interaction				
M_1S_1	54.8^{d}	3.40^{i}	0.36^{fe}	4.31^{d}
M_1S_2	55.3^{d}	3.45^{hi}	0.36^{fg}	4.32^{d}
M_1S_3	55.1^{d}	3.51^{hg}	0.35^{g}	4.31^{d}
M_1S_4	54.4^{d}	3.57^{g}	0.35^{g}	4.33^{d}
M_2S_1	62.6^{b}	4.41^{f}	0.41^{b}	4.97^{b}
M_2S_2	61.1^{cb}	4.49^{e}	0.39^{ed}	4.99^{b}
M_2S_3	60.1^{c}	4.52^{ed}	0.40^{d}	4.96^{cb}
M_2S_4	59.4^{c}	4.57^{d}	0.39^{e}	4.96^{b}
M_3S_1	67.2^{a}	5.15^{c}	0.43^{a}	5.32^{a}
M_3S_2	66.7^{a}	5.21^{cb}	0.41^{b}	5.33^{a}
M_3S_3	66.9^{a}	5.27^{b}	0.40^{cb}	5.32^{a}
M_3S_4	66.4^{a}	5.35^{a}	0.38^{d}	5.32^{a}
SEm±	0.70	0.86	0.007	0.04
Control	55.0	2.84	0.37	4.14
SEm±	0.70	0.16	0.01	0.03
CD (P=0.05)	2.1	0.47	0.02	0.10

*Means with same letters do not differ significantly under DMRT

DAS, Days after sowing; SSNM, site-specific nutrient management

M_1, SSNM for targeted yield of 3 t/ha; M_2, SSNM for targeted yield of 4 t/ha; M_3, SSNM for targeted yield of 5 t/ha; S_1, vermicompost @ 2.5 t/ha in seed line; S_2, S_1 + $MgSO_4$ 10 kg/ha in seed line; S_3, S_1 + $MgSO_4$ 25 kg/ha in seed line; S_4, $MgSO_4$ 25 kg/ha in seed line + foliar nutrition of 1% $MgSO_4$ + 19 : 19 : 19 + 1% KNO_3 (thrice each); Control, recommended dose of fertilizer.

nutrient supplementation for leaf reddening also varied significantly but followed different trend. Lower yield target of 3 t/ha coupled with 25 kg/ha $MgSO_4$ along with foliar nutrition of 1% each of $MgSO_4$, 19 : 19 : 19 and KNO_3 (M_1S_4) had significantly lower HI (0.35) while 5 t/ha yield target coupled with application of vermicompost alone (M_3S_1) had consistently higher HI (0.43 on pooled basis) among all. Recommended control was comparable with crop nutrition for 3 t/ha yield target irrespective of LRM practices. Again combinations of SSNM-based yield targets and nutrient supplementation for leaf reddening influenced benefit: cost ratio during both the years and on pooled basis as well. Overall, SSNM for yield target of 5 t/ha irrespective of the LRM practice resulted in higher benefit: cost ratio among all (5.32 to 5.33), while lower yield target of 3 t/ha irrespective of LRM practices recorded lower benefit: cost ratio (4.31–4.33) which, however was superior to blanket recommendation (4.14). Results are in conformity with those of Gawade and Bhalerao (2012) and Giri *et al*. (2013).

Thus, SSNM-based nutrition for a 5 t/ha yield target, soil application of $MgSO_4$ @ 25 kg/ha, and foliar sprays of 1% each of $MgSO_4$, 19 : 19 : 19, and KNO_3 thrice at flower initiation, boll development, and boll bursting and sowing could be beneficially followed in Tunga Bhadra Project irrigation command.

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