



Leaf Reddening in Bt Hybrid Cotton



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Introduction

Mahyco Monsanto Biotech Co (MMB) had commercially introduced Bt cotton hybrids directly under its supervision in 2002 with selected farmers under supplemental irrigations Mohan & Manjunath [1]. Bt hybrid cotton had initial hiccups like lower seed cotton yield, poor micronaire, leaf reddening besides lower price realization by the early innovative farmers under rainfed and irrigated conditions except boll worm protection Ramanujam and Kuraganti, 2004 Stone [2]. Bt hybrid cotton was well adopted by small and marginal farmers under rainfed conditions into shallow to medium deep soils in Maharashtra state reached 65% of the cotton area in 2007 due to reduced expenditure on boll worms, synchronized boll bursting with seed cotton yield advantage of 5 q ha⁻¹ with 30% more boll retention and 20 days earliness over non bt hybrid cotton Ramasundaram [3]; Hebbar et al. [4].

Reddening of leaves is a physiological disorder in early Bt hybrid cotton genotypes except medium and late duration hybrids with Cocker 312 background, induced by different biotic, abiotic and nutritional stresses at peak boll development stage, with strong accumulation of anthocyanins and drop of chlorophyll content, increase of proline content and peroxidase activity Edreva et al. [5]; Kumar & Swamy [6], Prakash et al. [7]. Earliest report of leaf reddening was reported by NGOs as early as 2003-04, however it went unheard by public and private sectors Raju & Thakare [8], later it was confirmed by many authors about increase in management costs of sucking pests and foliar diseases besides decline in yield Raju & Thakare [9]; Better crops [10]. Seed cotton yield reduction due to leaf reddening was estimated and reported by different authors around 15-20% further aggravated by foliar diseases and unfavourable rainfall distribution reaching a yield reductions up to 50% Raju & Thakare [9]. Bt hybrid cotton profitability had also eroded after the record highest prices in year 2011 with further increase in labour costs and reduction of imports by China Raju & Thakare [9].

Forgotten better management practices (BMPs)

Surveys conducted by the investigators found no application of animal manures, tank silt animal penning etc due to the higher

cost or short supply. Commercial cultivation of Bt hybrid cotton-soybean-gram /wheat system under imbalanced nutrition in the absence of K, S, Mg, Mn, Zn, B application resulted in permanent replacement of soybean due to viral disease (YMV) and partial replacement of Bt hybrid cotton by leaf reddening. Farmers returns were still compensated up to 40% from stripcropped pigeon pea (6-8:1/2). BMPs remained on paper itself as the gulf between technology developers and users was widened with poor extension linkages and lack of interest of technology developers to go in for participatory mode.

Role of genotypes

Leaf reddening incidence was more pronounced with early Bt hybrid cotton genotypes than medium, late duration and stay green hybrids like Vithal, Green Gold, GK 202, Mallika etc vis a vis non-Bt hybrid cotton genotypes. The reduction of chlorophyll content in reddening affected leaf was maximum in Bt hybrid cotton MRC-6301. Anthocyanine content was increased in reddening affected leaves up to 5.0% at square formation stage Pagare & Durge [11]. Long duration BG II Bt hybrid cotton Neeraja produced lowest red leaves and maximum of 25% in short duration Bunny NCS 145 Hosmath et al. [12]. Long duration BG II Sigma Bt hybrid cotton recorded more seed cotton yield ha⁻¹ with high anthocyanin pigment indicating starvation of required nutrients which were forced to translocate to sink Khadangle et al. [13].

Susceptible genotype Bunny NCS 145 BG II. Long duration Bindaas BG II 7213-2 considered as tolerant to leaf reddening Janagouder [14]. Visual observations recorded at 108 DAS indicated BG II hybrids Ankur 216, Ankur 3042, Ankur Jai, Atal, Express, MRC 7301, Paras Krishna, Uttam, VICH 303 and VICH 304 were unaffected by leaf reddening Nagarale [15]. Anthocyanin content in reddening affected leaves of MRC-6301 was maximum compared to reddening affected leaves of NSC-145 BG II hybrid Pagare & Durge [16]. Jackpot, MRC-7347, Marvel and MRC-7351 were found tolerant to sucking pests and reddening symptoms. Bt hybrids such as RCH 2, RCH 530, Brahma, Arya and Bunny were highly sensitive to insect-induced reddening Ghante et al. [17].

Role of hormones and PGR on root activity

Soil moisture conservation practices, super gels, humic acid seed treatment, tank silt and animal manures soil application, foliar application of cyto-kinins, root activating hormones like IBA, humic acid, Annie sheba & Manikandan [18] and other bio-stimulants for enhanced root activity must be evaluated for reducing the leaf reddening Raju et al. [8].

Role of shoot activity

Humic acid extended shoot and leaf growth with its hormonal activity and delayed boll bursting and senescence. Growth retardant CCC foliar application twice reduced plant height and leaf growth further delayed leaf reddening by one month in Hy 6 Bt hybrid cotton Raju et al. [8].

Role of sink / boll load

Early and concentrated boll retention and high fruiting efficiency in Bt hybrid cotton resulted in lower rate and quantity of dry matter plant⁻¹ with shallow roots (30 cm). Higher sink in Bt hybrid cotton leads to lower source to sink ratio, faster senescence and crop maturity Hebbar et al. [4]. Sometimes, the increased assimilate demand of early and higher fruit retention reduces the resources for continued root growth, leading to early maturity and reduced yields.

Role of sucking pests

July and August months' leaf reddening was due to 70% by jassids and 10% by thrips in early maturing Bunny Bt hybrid. BG II Bt hybrids MRC 7301, Atal, Classic, Krish, Ryan, SP 504, Namaskar, Madhura, VICH 312 registered lower population levels of sucking pest, and also lesser leaf reddening and higher yield levels Nagarare et al. [15].

Role of diseases

Foliar leaf spot diseases like *Alternaria*, *Myrothecium*, *Xanthomonas malvacearum*, grey mildew besides *Fusarium* and *Verticillium* wilts also produces yellowing and discoloration, leaf spots, necrosis and bronzing symptoms in 20-30% of the leaf area of green leaf foliage in the absence of any plant protection measures against them Santosh [20]. One or two sprays propiconazole was very effective against foliar diseases in Bt hybrid cotton Janagouder [1], Raju [8].

Role of major nutrients

Mobile elements measured in the index leaves which shown symptoms were often misleading to that of nitrogen content of healthy leaves in Bt hybrid cotton ranged from 1.17 to 1.30% in reddening affected leaves at square formation stage and thereafter progressively reduced upto boll bursting stage as reported by Pagare & Durge [16] needs relook in comparison to those authenticated by Raju & Thakre [9] in Bt hybrid cotton. Carbohydrate percentage 0.99 to 1.05% was maximum in reddening affected leaves as compared to healthy leaves of all the Bt cotton hybrids from square formation stage reddening of leaves were observed in Bt cotton genotypes

Pagare & Durge [11]. Leaf reddening significantly reduced with 25% higher dose of NPK fertilizers but non significant response was observed by Raju & Thakare (2010) in Bunny Bt hybrid cotton. The extent of reduction in leaf reddening was 125 and 150 % RDF was 15 and 30% respectively. Leaf reddening was 2.5% with 100 % RDF Santosh [19]. Redness of leaves was also caused by potassium starvation is a major problem in Bt hybrid cotton. Leaf redness symptoms in cotton, leads to interference and misleading practices from time to time. K uptake in calcareous soils is difficult, therefore, it should be ensured to be within the critical limits prescribed for in the cotton leaf Anonymous [20]; Santosh [19].

Role of secondary nutrients

Excess of exchangeable Ca in calcareous soils leads to Mg and K deficiency resulting in leaf reddening. Leaf Magnesium was reduced by 0.44 to 0.46%, in reddening affected leaves Pagare & Durge [21]. Nutrient supply through foliar spray showed that if 2% Urea + 0.2% MgSO₄ + 0.1% ZnSO₄ sprayed twice enhance high level of chlorophylls which kept under check the accumulation of anthocyanin content of Sigma Bt hybrid cotton leaf Khadangle et al. [13]. Reddening affected leaves magnesium content level was slightly lowered than that of healthy leaves Pagare & Durge [16]. Leaf reddening significantly reduced with foliar sprays of MgSO₄ + KNO₃, MgSO₄ + 19:19:19 and MgSO₄ thrice @1% combined with initial soil application of MgSO₄ @ 25 kg ha⁻¹. Leaf reddening 18.7 and 16.2 per cent with three foliar sprays of MgSO₄ + KNO₃ and MgSO₄ + 19:19:19 respectively, along with soil application of MgSO₄ @ 25 kg ha⁻¹ Santosh et al. [19]. Minimum intensity of reddening in Bt hybrid cotton was observed in 100 % RDF + foliar sprays with 1% KNO₃, which suggest that at boll development stage the application of nitrogen and potassium were helpful for controlling the reddening in Bt hybrid cotton. However, the application of 100 % RDF + 1 % MgSO₄ spray was found to be the best for highest content of chlorophyll as well as yield of Bt hybrid cotton Masram et al. [22]. Foliar spray of MgSO₄ (1%) is often recommended as a corrective measure. Field experiments were conducted at Faridkot and Bathinda indicated highest seed cotton yield (3064 kg ha⁻¹) with application of MgSO₄@1.5%thrice due to reduction in leaf reddening (8%) when leaf Mg content was below critical limits Singh et al. [23]. In *mera gaon mera gaurav* programme both calcareous and non calcareous soils 850 demonstrations in the farmers fields were conducted with non significant improvement in seed cotton yield and leaf reddening by any of the soil and foliar application of N, P, K, Zn, Mg, B and humic acid except change in leaf color quality for one month probably due to fresh growth of new leaves Raju et al. [8].

Role of micronutrients

Maximum reduction of red leaves were with the soil application of @ 120-70-40 NPK in combination with Zn and B @ 4 and 1.5 kg ha⁻¹, respectively Gandhi et al. [24]. However, the direct effect on leaf reddening major from and micronutrients could not be verified in farmers fields but helped only in putting up more fresh growth, thereby reduces percent red leaves in Bt hybrid cotton Raju et al. [8].

Role of Growth Regulators

Plant growth regulators application to modify early and mid season growth is very essential in the management of leaf reddening through reduction in the shoot biomass and increase in root growth for continued uptake throughout the boll development. There is potential to influence present seed cotton yield levels of 560 kg ha⁻¹ lint with optimum adoption. Plant growth regulators have the potential to promote square and boll retention, higher nutrient uptake, and keeping vegetative and reproductive growth in harmony to improve lint yield and quality. Gibberellins are associated with increase in fruit retention in cotton.

Role of cytokinins

Cytokinins can also delay aging of leaves, allowing longer photosynthetic activity with reduction in fruit abscission and also can promote cell division and enlargement of stems, leaves and fruit. PGR IV may be options for growers who want to pursue high yields through a more intensive management approach. It would be advisable to apply the materials early in the growing season to promote early growth, such as in-furrow (PGR IV) or match head square treatments, then use Pix or Mepichlor after bloom to slow vegetative growth and force a timely cut out. Over an 8-year period, PGR IV on cotton if applied 2 to 4 ounces per acre beginning at match head square and applying weekly for a total of four applications has produced 115 pound lint yield from foliar applications.

Cytokinin may be most beneficial under stressed conditions to maintain proper boll set and retention, promote earliness and develop a better root system Albers & Schnakenberg [25]. Growth chamber studies revealed that the in-furrow applications of PGR-IV @ 1.13 µL/plant dramatically increased root length (+47%), root dry weight (+29%), number of lateral roots per plant (+75%), and nutrient uptake one week after planting. These differences were still apparent five weeks later at pinhead square but to a lesser degree. Positive effect of PGR-IV on root growth and accelerated early-season growth could have very substantial benefits in reducing the leaf reddening in Bt hybrid cotton production Oosterhuis & Zhao [26,27].

Conclusion

Integrated module comprised use of sucking pest-tolerant cotton hybrid (Ankur 216, Ankur 3042, Ankur Jai, Atal, Classic, Express, GK 202, Green Gold, Jackpot, Krish, Mallika, Marvel, MRC 7301, MRC-7347, MRC-7351 Namaskar, Madhura, Paras Krishna, Ryan, SP 504, Uttam, VICH 303 VICH 304, VICH 312 and Vithal) avoiding cultivation of Sucking pests sensitive hybrids such as Arya, Brahma, Bunny, RCH 2 and RCH 530. Balanced and timely soil application of macro- and micro-fertilizers as per recommendation based on site-specific soil test results; threshold-based management of sucking pests, especially leafhoppers, using systemic insecticides; foliar applications of Mancozeb 75WP at 2 g/L against leaf spot disease; three foliar applications of water-soluble multi nutrient mixtures at 4 ml/L during 60, 75 and 90 DAS and weeding during first 40 DAS proved best for the management of Bt cotton reddening Ghante et al. [17].

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