*J. Cotton Res. Dev.* **32** (1) 97-105 (January, 2018) **ISSN No. 0972-8619**

# Nutrient and irrigation water on leaf reddening in *Bt* hybrid 6 cotton in calcareous substrata soils

A. R. RAJU*, AND RACHANA DESHMUKH

***ICAR-Central Institute for Cotton Research, Nagpur - 440010***

**E-mail: bumaraju@gmail.com*

**ABSTRACT :** Programmable RGB sensor was used for prediction of nutrients need of BG II Hybrid-6 cotton and found $R^2$ value of 0.98 for nitrogen topdressing at the end of September month. Recommended dose of fertilizer nutrients (RDF 90:45:45 kg/ha N:$P_2O_5$:$K_2O$) were sufficient to produce profitable yields with highest water and fertilizer use efficiency in both station and farmer's fields. Validation of it in Calcareous soil farmer's fields (2016) found it had a satisfactory boll size of 5g and competitive with many private commercial hybrids with a lint yield level of 450 kg/ha. Leaf reddening was significantly reduced with supplemental irrigations only in a year of seedling droughts.

**Key words :** *Bt* hybrid, growth retardent, leaf reddening, micronutrients, nutrition, RGB sensor, solubor, supplemental irrigation

*Bt* hybrid cotton was adopted by 7.7 million small cotton farmers in 10.5 million hectares area involving 18 per cent cost of cultivation on seeds (Chaudhary and Gaur, 2015, CAB 2017). Rainfed *Bt* hybrid cotton became unprofitable due to increased cost against sucking pests, appearance of late nutrient deficiencies (N,P,K,Zn,Mn,Fe,B), abrupt increase in labour costs and lower price realization in the absence of imports of raw cotton by china (Raju, 2014). Declining productivity after 2008 was due to continuous cotton cultivation in the absence of profitable rotational crops, seasonal variations in rainfall amount and distribution were clearly visible (Raju *et al.,* 2011; Chaudhary and Gaur, 2015, Gutierrez *et al.,* 2015).

Public funded hybrid 6 cotton was also brought back during this period in the *Bt* form for rainfed condition by Gujarat State Agriculture University, Gujarat State Seeds Corporation and Solar Seed Company, India under public private partnership (PPP) mode with Cry 1 Ac and Cry 2 Ab (GEAC, 2012). Hybrid-6 was also known for yield, quality, 5g boll size and its convenient opening for manual picking, which was comparable to popular Hybrid 4 cotton. *Bt* hybrid 6 was also tested, demonstrated, monitored and reviewed across the country by different public sector agencies during June, 2012-2016 after its formal release. A study was made under rainfed conditions to study the lint yield and quality response to different inputs available at farmer during 2012-2014 years. A low cost electronic prototype device was developed and tested to show the nutrient demand with programmable RGB sensor, which can influence leaf green colour of cotton (Samborski *et al.,* 2008) with a specific algorithms on its linear response based on colorimetric nitrogen analysis. ICAR Central Institute for Cotton Research, Nagpur also demonstrated Hybrid 6 cotton was upscaled and made large scale demonstration during 2014-2016 years Nagpur and Wardha districts in Vidarbha region of Maharashtra state with the help of tribal sub plan (TSP), ICAR funds.

## MATERIALS AND METHODS

A two years field experiment was conducted at ICAR-Central Institute for Cotton Research, Nagpur, Panjri Farm, during 2012 and 2013 years in sub soil calcareous strata of shallow soil with a depth of 48 cm. The top soil $CaCO_3$ content was 18 per cent. Soil fertility was marginal with 1 per cent bi-directional slope to represent major area (35%) of Maharashtra state (Gajbhiye, 2012) under rainfed condition with or without supplemental irrigations from harvested rain water from 7000 $M^3$ dugout farm pond. Nutrient management treatments (5) *viz*: $T_{1.}$: Control; $T_2$.: 100 per cent recommended dose of fertilizers (RDF 90:45:45 kg/ha $N:P_2O_5:K_2O$); $T_3$ :100 per cent RDF + Mg, S, Zn, B soil application @ 8, 8,10 and 1.0 kg/ha/year, respectively; $T_4$: 150 per cent RDF+ Mg, S, Zn, B; $T_5$: 200 per cent RDF + Mg, S, Zn, B as per $T_3$ and sub plots were three supplemental irrigation and rainfed cotton. Closer (90x45cm) and wider spacings (90 x 60 cm) were evaluated in sub sub plots in split plot design with 4 replications. Foliar application chloromequat chloride was applied at 250 ppm (over dose) at early boll formation stage to $T_4$ and $T_5$ treatments to reduce excess growth anticipated due to higher fertilization combined with irrigation and to estimate losses due to excess chlormeqat chloride (CCC) concentration during 2012 only to estimate losses incase of accidental overdosing. Foliar application of Solubor @ 0.2 per cent was also applied twice at squaring to flowering stage to $T_3$ and $T_5$ during 2013 to supplement the residual value of micronutrients application in 2nd year. Inorder to reduce cost of cultivation pre plant foliage (PPF) application of pendimethalin + glyphosate each 0.75 kg a.i./ ha was applied to kill present and emerging weeds and cotton was planted directly without disturbing the soil. Post emergence application of pyrithiobac sodium + propaquizafop ethyl herbicides each 0.035 kg *a. i.* /ha were applied at 45, 65 DAS and directed application of glyphosate to nut sedge spots alongwith three times intercultures at 20, 40, 60 DAS. Tap/ lateral root penetration, plant height, number of nodes and their canopy spread within and in between rows were also measured. Red leaf number/plant was also measured in early September, which were classified due to insect, disease and nutrient deficiency at top, middle and bottom portion of the plant. Basal fertilizers were applied 12 DAS, micronutrients 22 DAS and top dressings 45, 60 DAS for rainfed and supplemental irrigations. Three supplemental irrigations were provided by flood irrigation in both years depend on soil moisture demand in October month. N, P, K was analysed from plants as per standard procedures. Leaf colour

**Table 1.** Rainfall distribution during experimentation

| | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 |
|---|---|---|---|---|---|---|---|---|
| June | 210 | 115 | 104 | | 148 | 52 | 426 | 19 |
| July | 181 | 221 | 267 | 413 | 120 | 467 | 513 | 226 |
| August | 181 | 132 | 213 | 266 | 287 | 184 | 247 | 247 |
| September | 272 | 113 | 78 | | 184 | 184 | | 245 |
| **Season Total** | **852** | **591** | **702** | **679** | **739** | **883** | **1186** | **737** |
| Percentage of 2007 | | 69 | 82 | 80 | 87 | 101 | 139 | 87 |

photographs was recorded with a digital camera and measured the colour with programmable RGB sensor and regression was established for sensor value *vs* colorometrically analysed nutrient content at 35, 55 DAS to predict nutrients sufficiency for application of topdressing for rainfed and irrigated cotton. Algorithm was written with the calibrated regression and incorporated to a low cost proto type instrument, having sensor, measuring block for leaf insertion, results

Can be read on programmable LCD display supported by a dry cell battery. This instruments was built at a cost of US $ 50, which directly predicts the nutrient demand for topdressing by taking soil fertility status into consideration where leaf colour is consider as indicator with +2 nm sensitivity compared to visual leaf colour charts. This is expandable to all other colour calibrated variables in crop production including pest damage, deficiency of nutrients/soil moisture etc.

## RESULTS AND DISCUSSION

**Response for fertilizer dose**: A higher amount of 39 per cent rainfall was received during June, July, 2013 (Table1), which caused leaching of mobile nutrients, severe soil erosion and unfavourable environment reduced the seed cotton yield/plant by 44 per cent, boll number by 72 per cent, harvest index by 44 per cent, fertilizer use efficiency by 39 per cent and lint yield by 40 per cent. However, significant response for recommended dose of fertilizer for non *Bt* hybrid cotton application *viz., i.e.* 90:45:45 N: $P_2O_5$: $K_2O$ kg/ha was observed in both the years regardless of amount and distribution of rainfall. This was also confirmed in farmer's fields and in agreement with those observed by Raju, 2014. It was made clear that higher amount of fertilizers with or without micro and secondary nutrients soil/foliar application is only luxurious consumption, which did not improve the fertilizer use efficiency as 40 per cent of lint

**Table 2.** Economics of nutrients and supplemental irrigations

| Treatments | Lint yield (kg/ha) | | Bolls picked/ plant | | Yield (g/ plant) | | Water use efficiency (kg/$M^3$) | | CB (Ratio) | | Net returns (US $ /ha) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2012 | 2013 | 2012 | 2013 | 2012 | 2013 | 2012 | 2013 | 2012 | 2013 | 2012 | 2013 |
| No fertilizers | 700 | 219 | 30.2 | 21.0 | 159 | 47 | 15.9 | 5.4 | 4.8 | 3.2 | 952 | 279 |
| RDF 100 per cent | **927** | **375** | **37.7** | **27.5** | **162** | **72** | 21.1 | 9.3 | **3.6** | **4.5** | **1175** | **529** |
| RDF 100 per cent + Mg S Zn B | 785 | 370 | 39.1 | 25.4 | 177 | 60 | 17.8 | 9.1 | 2.8 | 4.4 | 898 | 506 |
| RDF 100 per cent | 773 | 388 | 36.7 | 26.2 | 177 | 70 | 17.6 | 9.6 | 2.8 | 4.6 | 884 | 525 |
| RDF 100 per cent + Mg S Zn B | 900 | 402 | 35.9 | 27.5 | 162 | 80 | 20.5 | 9.9 | 2.8 | 4.7 | 1018 | 542 |
| SE+(5%) | | | | 2.5 | | | | | | | | |
| CD(p=0.05) | 134 | 70 | 5.4 | | 6 | 27 | 3.0 | 1.7 | 0.4 | 0.83 | 208 | 248 |
| Three supplemental irrigations | 842 | 365 | 37.1 | 28.4 | 167 | 76 | 19.1 | 9.0 | 3.0 | 4.2 | 980 | 496 |
| Rainfed cotton | 792 | 337 | 34.7 | 22.6 | 166 | 55 | 18.0 | 0.4 | 3.7 | 4.4 | 991 | 457 |
| SE+(5%) | | 19 | 1.4 | | 1.23 | | | 0.5 | | | 26 | 38 |
| CD(p=0.05) | 43 | | | 3.3 | | 21 | 1.0 | 0.0 | 0.3 | 0.40 | | |
| Spacing 90 x45 cm | 753 | 370 | 33.9 | 22.90 | 167 | 60 | 17.1 | 9.1 | 3.2 | 4.4 | 882 | 506 |
| Spacing 90 x 60 cm | 881 | 332 | 38.0 | 28.10 | 166 | 72 | 20.0 | 8.2 | 3.6 | 4.2 | 1090 | 447 |
| SE+(5%) | | | | | 1.14 | | | | | | | |
| CD(p=0.05) | 68 | 21.9 | 3.2 | 1.35 | | 4 | 1.6 | 0.4 | 0.2 | 0.09 | 104 | 28.7 |

yields were depend upon rainfall amount and distribution. Therefore, it can be concluded to apply fertilizers @ 45:45:45 N:$P_2O_5$:$K_2O$ kg/ha in basal and @ 45 N kg/ha in two split top dressings alongwith 1st and 2nd interculture operations *i.e.* 25-30 and 45-50 DAS only followed by hand weeding/ post emergence application of herbicides, which can further reduce the cost of production and improves profitability. These results were in agreement with those observed by Raju and Thakare, 2012.

**Response for supplemental irrigations :** Three supplemental irrigations were provided at 20 days interval from the end of September to November in both the years from the harvested runoff from the dugout farm pond, improved seed cotton yield only in 2012 when the total rainfall received was 883 mm with three additional irrigation the water requirement was more than sufficient, therefore significantly responded but in 2013 already 1186 mm rain was received in a saturated condition did not responded but yields

**Table 3.** Profitability of nutrients x population interaction

| Treatments | Lint yield (kg /ha) 2013 | | Net returns (US $/ha ) 2013 | | BC ratio 2013 | | BC ratio 2012 | |
|---|---|---|---|---|---|---|---|---|
| Plant to plant spacing cm | 45 | 60 | 45 | 60 | 45 | 60 | Irrigations | Rainfed |
| No fertilizers | 256 | 182 | 344 | 215 | 3.6 | 2.9 | 3.82 | 5.79 |
| RDF 100 per cent | 415 | 335 | 600 | 458 | 4.7 | 4.2 | 3.25 | 3.94 |
| RDF 100 per cent+Mg S Zn B | 414 | 327 | 584 | 428 | 4.7 | 4.2 | 2.72 | 2.91 |
| RDF 100 per cent | 389 | 387 | 519 | 531 | 4.6 | 4.6 | 2.57 | 3.03 |
| RDF 100 per cent + Mg S Zn B | 375 | 429 | 481 | 604 | 4.5 | 4.9 | 2.62 | 2.90 |
| **Mean** | **370** | **332** | **506** | **447** | **4.4** | **4.2** | **2.99** | **3.72** |
| CD (p=0.05) | 57 | | 182 | | 0.5 | | 0.46 | |

**Table 4.** Profitability of irrigations x population interaction in 2013

| Interaction | Lint yield (kg/ha) | | Net returns (US $/ha) | | BC ratio | |
|---|---|---|---|---|---|---|
| | IRRI | RAIN | IRRI | RAIN | IRRI | RAIN |
| 90 x45 cm | 561 | 450 | 402 | 337 | 4.4 | 4.4 |
| 90 x 60 cm | 430 | 464 | 328 | 336 | 3.9 | 4.4 |
| CD (p=0.05) | 115 | | 36 | | 0.3 | |

were reduced by 60 per cent. This confirms two things present genotype is suitable only for rainfed cotton; secondly determinate *Bt* hybrids respond to deficit irrigations only in *vertic inceptisols*. Supplemental irrigations may be needed in semi arid rainfed cotton, whenever the effective rainfall is always less than the water requirement of cotton 650 mm.

Three supplemental irrigations in the winter months, which improved 3rd picked bolls and cotton in the month of December. Farm ponds were filled 3-4 times (2012; 2013) after month of December. Farm ponds were filled 3-4 times (2012; 2013) after receiving a initial rainfall of 60 mm which saturated the soil Raju *et al.,* 2011. Significantly higher profitability was observed under rainfed condition; therefore, unless in a drought year farmers should plan for double cropping.

A reasonable profitability of more than US $ 1000/ha were achieved when the rainfall was +35 per cent of water requirement. Runoff

**Table 5. Input use efficiency in Biomass and economic yield**

| Treatments | Biomass (t /ha) | | Harvest Index | | FUE | |
|---|---|---|---|---|---|---|
| | 2012 | 2013 | 2012 | 2013 | 2012 | 2013 |
| No fertilizers | 3.25 | 2.35 | 62.2 | 29.0 | | |
| RDF 100 per cent | 3.52 | 4.13 | 59.6 | 26.3 | 2.28 | 0.89 |
| RDF 100 per cent + Mg S Zn B | 3.64 | 3.95 | 57.6 | 28.7 | 1.06 | 0.61 |
| RDF 100 per cent | 3.82 | 4.03 | 58.1 | 30.3 | 0.80 | 1.74 |
| RDF 100 per cent + Mg S Zn B | 3.54 | 4.53 | 58.9 | 26.3 | 1.33 | 1.56 |
| SE+5per cent | 0.21 | | 4.2 | 2.2 | 1.05 | 1.95 |
| CD(p=0.05) | | 0.72 | | | | |
| Three supplemental irrigations | 3.46 | 4.26 | 58.1 | 25.0 | 1.26 | 1.15 |
| Rainfed | 3.64 | 3.33 | 60.4 | 31.0 | 1.47 | 1.25 |
| SE+5per cent | 0.16 | | 2.1 | | 0.21 | 0.61 |
| CD(p=0.05) | | 0.38 | | 2.9 | | |
| Spacing 90 x45 cm | 3.86 | 4.00 | 57.6 | 28.0 | 0.87 | 1.23 |
| Spacing 90 x 60 cm | 3.25 | 3.60 | 61.0 | 28.0 | 1.87 | 1.17 |
| SE+5per cent | | | | 1.9 | | 0.28 |
| CD (p=0.05) | 0.27 | 0.18 | 2.2 | | 0.55 | |

was storable upto November month end with 50 per cent losses as seepage and evaporation, which could be used for soybean-gram cropping system instead of rainfed *Bt* hybrid cotton in shallow soils Raju *et al.,* 2011.

**Water use efficiency (WUE)**: Water use efficiency kg lint $M^3$ of water was highest in a year of deficient rainfall and most optimum with recommended spacing (0.6m) and fertilizer nutrients *i.e.* 90:45:45 N: $P_2O_5$: $K_2O$ kg/ha, subsequently law of diminishing returns operates. Supplemental irrigations improved WUE 4-5 times for Hybrid 6 BG II cotton when planted with adequate drainage during excess rains (Table 2).

**Higher plant density:**There is significantly higher seed cotton yield under wider spacing in less rainfall year and for closer spacing in higher rainfall year which could be easily explained by the plant growth in respective years and inter plant competition within the row. However, adoption of higher plant density was not economical interms of net returns, FUE, CB ratio and HI compared to normal spaced rainfed cotton. There is no positive response for higher plant density, although which increased the unproductive biomass and nutrient uptake. Nutrient applications did not significantly improve the uptake and use efficiency of the NPK (Table 2).

**Interaction :** A closer spacing of 90x45 cm produced 80 kg lint /ha142 US $ /ha net returns with a matching B:C ratio during 2012 which was not same for supplemental irrigations (Table 3). Similarly during 2013 under three supplemental irrigations 111 kg /ha lint with 69 US $/ha net returns were observed with significantly higher B:C ratio for a closer spacing 90x45 cm over wider spacing 90x60cm (Table 4).

Three supplemental irrigations under closer planting had significantly improved NK and NPK uptake, respectively without increasing yield brought down the nutrient use efficiency. Therefore, present recommendations for non *Bt* hybrid cotton are sufficient for both rainfed and supplemental irrigated *Bt* hybrid cotton also.

**Growth retardents and leaf reddening: :** Significant reduction in plant height and inter

**Table 6.** Nutrient Uptake and their use efficiency

| Treatments | Uptake kg /hain above ground parts | | | | | | Nutrient use efficiencykg cotton kgnutrient uptake | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | N | | P | | K | | N | | P | | K | |
| | 2012 | 2013 | 2012 | 2013 | 2012 | 2013 | 2012 | 2013 | 2012 | 2013 | 2012 | 2013 |
| No fertilizers | 87.4 | 54 | 3.9 | 4.43 | 52.5 | 63 | 26.3 | 12.8 | 632 | 148 | 50.8 | 12.0 |
| RDF 100 per cent | 91.5 | 101 | 3.9 | 6.54 | 60.3 | 104 | 23.5 | 10.8 | 602 | 171 | 41.9 | 10.8 |
| RDF 100 per cent + Mg S Zn B | 98.8 | 100 | 4.3 | 6.1 | 73.3 | 101 | 21.7 | 11.2 | 511 | 178 | 30.7 | 11.3 |
| RDF 100 per cent | 105.9 | 109 | 4.2 | 6.56 | 74.8 | 100 | 22.4 | 11.3 | 565 | 180 | 37.0 | 13.0 |
| RDF 100 per cent + Mg S Zn B | 94.1 | 110 | 3.9 | 6.44 | 65.3 | 121 | 23.8 | 11.1 | 591 | 183 | 39.3 | 10.0 |
| SE+5per cent | 10.8 | | 0.5 | | 9.2 | | 2.8 | 0.72 | 95 | | 6.3 | 1.13 |
| Three supplemental irrigations | 108.1 | 15.4 | 4.2 | 1.25 | 80.9 | 20.6 | 22.0 | | 593 | 18.2 | 33.0 | |
| Rainfed | 83.0 | 108 | 3.9 | 6.8 | 49.4 | 113 | 25.1 | 10.2 | 567 | 157 | 46.9 | 10 |
| SE+5per cent | | 81 | 0.2 | 5.2 | | 83 | | 12.6 | 69 | 186 | | 13 |
| CD (p=0.05) | 13.8 | | | | 11.7 | | 2.5 | | | | 9.2 | |
| Spacing 90 x45 cm | 104.6 | 11.9 | 4.4 | 0.75 | 76.1 | 10.1 | 22.4 | 1.3 | 554 | 16.2 | 37.0 | 1.3 |
| Spacing 90 x 60 cm | 86.6 | 98 | 3.7 | 6.4 | 54.2 | 102 | 24.7 | 11.5 | 606 | 171 | 42.8 | 11.3 |
| SE+5per cent | | 91 | | 5.7 | | 93 | | 11.3 | 41 | 173 | 4.8 | 11.5 |
| CD (p=0.05) | 5.2 | 5.3 | 0.37 | | 5.3 | 6.3 | 1.4 | 0.71 | | 8.5 | | 1.09 |

**Table 7.** Nutrient Uptake and their use efficiency interactions in 2013

| Treatments | Biomass tonnes/ha | | | | N uptake kg/ha | | | | P uptake kg ha | | | | K uptake kg/ha | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | IRRI | RF | 45 | 60 | IRRI | RF | 45 | 60 | IRRI | RF | 45 | 60 | IRRI | RF | 45 | 60 |
| No fertilizers | 3.0 | 1.8 | 2.6 | 2.1 | 69 | 39 | 58 | 50 | 6 | 3 | 5 | 4 | 85 | 42 | 73 | 54 |
| RDF 100 per cent | 4.2 | 4.0 | 4.4 | 3.8 | 110 | 92 | 111 | 91 | 7 | 6 | 8 | 6 | 108 | 100 | 109 | 98 |
| RDF 100 per cent + Mg S Zn B +(0.2%)solubor | 4.4 | 3.5 | 4.2 | 3.7 | 109 | 90 | 101 | 98 | 6 | 6 | 6 | 6 | 110 | 91 | 102 | 99 |
| RDF 100 per cent | 5.1 | 3.0 | 4.0 | 4.1 | 137 | 81 | 102 | 117 | 8 | 5 | 6 | 7 | 132 | 68 | 98 | 102 |
| RDF 100 per cent + Mg S Zn B +(0.2%)solubor | 4.7 | 4.4 | 4.8 | 4.2 | 116 | 104 | 118 | 102 | 7 | 6 | 7 | 6 | 129 | 114 | 128 | 114 |
| **Mean** | **4.3** | **3.3** | **4.0** | **3.6** | **108** | **81** | **98** | **91** | **7** | **5** | **6** | **6** | **113** | **83** | **102** | **93** |
| CD (p=0.05) | 0.8 | | | | 26.6 | | | | 2 | | 1 | | 14.2 | | 22.6 | |

**Table 8.** NP Uptake during 2012

| 2012 | Nutrient uptake (kg/ha) | | | |
|---|---|---|---|---|
| | Nitrogen | | Potassium | |
| Interaction | RAIN | IRRI | RAIN | IRRI |
| 90 x45 | 88 | 121 | 53 | 100 |
| 90 x 60 | 78 | 95 | 46 | 62 |
| CD+5per cent | 14 | | 12.1 | |

nodal length was reduced by application of growth retardant (CCC) @ 250ppm without reducing seed cotton yield (Table 9). Three supplemental irrigations significantly reduced leaf reddening in both the years (Table 9,10). Insect induced reddening was more in top and bottom leaves only. Growth retardants could not significantly improve root activity (Table 10).

**Table 9.** Growth retardant on leaf reddening in 2012

| Treatments | *Bt* hybrid plant's | | | Red leaves/plant | | **Total** |
|---|---|---|---|---|---|---|
| | Height (cm) | Fruiting nodes | Nutrient deficiency | Insect damaged | Disease damaded | |
| No fertilizers | 87 | 24.5 | 8.3 | 4.6 | 4.1 | **16.8** |
| RDF 100 per cent | 96 | 26.3 | 7.0 | 3.9 | 4.6 | **15.5** |
| RDF 100 per cent+ Mg S Zn B+CCC 250ppm | 79 | 25.2 | 5.5 | 4.6 | 4.3 | **14.5** |
| RDF 100 per cent | 80 | 26.5 | 6.4 | 4.5 | 5.5 | **16.3** |
| RDF 100 per cent+ Mg S Zn +CCC 250ppm | 98 | 27.2 | 7.0 | 4.1 | 4.0 | **15.0** |
| SE+5% | | 0.9 | 1.9 | 0.6 | 0.8 | **2.2** |
| CD (p=0.05) | **8.1** | | | | | |
| Three supplemental irrigations | 92 | 25.9 | 6.0 | 3.8 | 4.7 | **14.5** |
| Rainfed | 85 | 25.9 | 7.7 | 4.8 | 4.3 | **16.8** |
| SE+5% | | 0.5 | | | | |
| CD (p=0.05) | **4.3** | | **1.3** | **0.7** | **0.8** | **1.8** |
| Spacing 90 x45 cm | 92 | 27.6 | 6.0 | 4.3 | 4.7 | **15.0** |
| Spacing 90 x 60 cm | 85 | 24.3 | 7.7 | 4.3 | 4.3 | **16.3** |
| SE+5% | | | 0.9 | 0.4 | 0.4 | **1.0** |
| CD (p=0.05) | **2.8** | **1.0** | | | | |

**Fibre properties :** Major, secondary and micronutrient fertilizers @ recommended or higher level of soil and foliar applications did not significantly influenced any fibre property in both the years in *Bt* Hybrid 6 cotton. Three supplemental irrigations at squaring and early flowering stage significantly reduced 2.5 per cent staple length and elongation per cent (2012), but positively influenced on length of uniformity, micronaire in both the years and bundle strength only in 2012 over rainfed cotton. Introduction of Cry 1Ac *Bt* gene reduced cotton duration and solved the reduction in micronaire over pickings from penalty to fairly good range. However, 3rd picking in 2012 significantly reduced uniformity and bundle strength over 1st picking. Staple length 2.5 per cent, UR per cent 2012, 2013 micronaire, and SFI were significantly reduced in rainfed condition in last picking which significantly improved by two supplementary irrigations.

## REFERENCES

**Choudhary, B. and Gaur, K. 2015**. Biotech Cotton in India, 2002 to 2014. ISAAA Series of Biotech Crop Profiles. ISAAA: Ithaca, NY.

**Cotton Advisory Board, 2017.** Cotton Statistics 2016-17.

**GEAC, 2012.** Yearwise list of commercially released varieties of *Bt* cotton hybrids by GEAC (Year

**Table 10.** Growth retardant on leaf reddening in 2013

| Treatments | Root studies at harvest | | | | Red leaves/plant | | | | | | | | | | | | **Total GT** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Top | | | | Middle | | | | Bottom | | | | |
| | He-ight (cm) | Pri-mary root length (cm) | Secon-dary root length (cm) | wt (g) | Di | In | Su | T | Di | In | Su | T | Di | In | Su | T | |
| No fertilizers | 71 | 41 | 17 | 1.82 | 0.5 | 1.9 | 1.5 | 3.9 | 5.2 | 2.5 | 2.5 | 10.1 | 6.3 | 1.6 | 3.5 | 11.4 | **25.4** |
| RDF 100 per cent | 91 | 44 | 24 | 2.09 | 0.1 | 4.1 | 2.5 | 6.7 | 5.9 | 3.5 | 3.0 | 12.5 | 7.5 | 4.9 | 4.5 | 16.9 | **36.2** |
| RDF 100 per cent + Mg S Zn B +(0.2%) Solubor | 86 | 46 | 22 | 1.91 | 0.1 | 3.7 | 2.9 | 6.7 | 4.4 | 3.5 | 3.2 | 11.0 | 4.8 | 4.2 | 4.9 | 13.9 | **31.6** |
| RDF 100 per cent | 88 | 41 | 21 | 2.19 | 0.1 | 2.4 | 2.7 | 5.2 | 4.8 | 2.5 | 3.5 | 10.7 | 5.1 | 3.0 | 4.2 | 12.3 | **28.3** |
| RDF 100 per cent + Mg S Zn+(0.2%) Solubor | 97 | 49 | 24 | 1.99 | 0.1 | 2.1 | 2.4 | 4.6 | 3.3 | 3.6 | 3.0 | 9.9 | 3.3 | 3.7 | 3.3 | 10.3 | **24.8** |
| SE+(5%) | | 3 | 3 | 0.16 | 0.3 | | 0.6 | | 0.9 | 0.7 | 0.5 | | 1.5 | | 0.8 | | |
| CD (p=0.05) | **18** | | | | | **2.3** | | | | | | | | **3.2** | | | **7.5** |
| Three supplemental irrigations | 86 | 46 | 21 | 1.89 | 0.3 | 0.8 | 1.0 | 2.1 | 1.6 | 1.0 | 1.0 | 3.5 | 1.9 | 1.0 | 1.2 | 13.4 | **18.9** |
| Rainfed | 87 | 42 | 22 | 2.11 | 0.1 | 4.9 | 3.8 | 8.7 | 7.9 | 5.3 | 5.0 | 18.2 | 8.9 | 6.0 | 6.9 | 12.2 | **39.1** |
| SE+(5%) | 2.7 | 2 | 1 | 0.1 | 0.2 | | | | | | | | | | | | |
| CD (p=0.05) | | | | | | **2.2** | **1.7** | | **3.6** | **2.7** | **1.8** | | **2.8** | **2.5** | **2.7** | | **15.0** |
| Spacing 90 x45 cm | 88 | 44 | 21 | 2.07 | 0.3 | 2.8 | 2.5 | 5.6 | 5.4 | 3.1 | 3.1 | 11.7 | 5.5 | 3.7 | 4.2 | 12.8 | **30.0** |
| Spacing 90 x 60 cm | 85 | 44 | 22 | 1.93 | 0.1 | 2.9 | 2.3 | 5.2 | 4.0 | 3.1 | 3.0 | 10.0 | 3.2 | 3.3 | 4.0 | 12.8 | **28.0** |
| SE+(5%) | 3.9 | 2 | 1 | 0.09 | 0.2 | 0.6 | | | 0.9 | 0.5 | 0.5 | | 1.0 | 0.7 | 0.8 | | **4.3** |
| CD (p=0.05) | | | | | | | **1.6** | | | | | | | | | | |

**Table 11.** Fibre properties of Boll guard II Hy-6 cotton during 2012, 2013

| Treatments | 2.5per cent SL length (mm) | | UR (%) | | Micro-naireig/ in | | Bundle strength (g/tex) | | El (%) | | SFI | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2012 | 2013 | 2012 | 2013 | 2012 | 2013 | 2012 | 2013 | 2012 | 2013 | 2012 | 2013 |
| No fertilizers | 29.1 | 27.3 | 49.9 | 51.1 | 4.25 | 3.84 | 23.1 | 22.3 | 5.52 | 5.16 | 7.93 | 8.96 |
| RDF 100 per cent | 29.1 | 27.6 | 50.8 | 51.4 | 4.30 | 3.87 | 23.5 | 22.5 | 5.48 | 5.18 | 7.82 | 8.65 |
| RDF 100 per cent+ Mg S Zn B | 29.1 | 27.4 | 50.1 | 51.7 | 4.28 | 3.92 | 23.4 | 22.4 | 5.57 | 5.23 | 7.94 | 8.97 |
| RDF 100 per cent | 28.5 | 27.4 | 50.6 | 51.7 | 4.26 | 3.79 | 22.7 | 22.6 | 5.57 | 5.19 | 8.48 | 8.83 |
| RDF 100 per cent+ Mg S Zn B | 29.0 | 27.2 | 50.3 | 51.4 | 4.21 | 3.81 | 23.4 | 22.5 | 5.73 | 5.23 | 8.05 | 9.10 |
| **SE+(5%)** | 0.3 | 0.3 | 0.6 | 0.5 | 0.08 | 0.15 | 0.5 | 0.4 | 0.12 | 0.09 | 0.43 | 0.60 |
| Three supplemental irrigations | 28.8 | 27.4 | 51.0 | 52.5 | 4.40 | 3.94 | 23.8 | 22.6 | 5.30 | 5.18 | 7.95 | 8.60 |
| Rainfed | 29.2 | 27.4 | 49.7 | 50.4 | 4.12 | 3.76 | 22.6 | 22.4 | 5.84 | 5.22 | 8.13 | 9.20 |
| **SE+(5%)** | | 0.3 | | | | | | 0.3 | | 0.05 | 0.24 | 0.36 |
| CD (p=0.05) | 0.4 | | 0.5 | 0.83 | 0.09 | 0.13 | 0.4 | | 0.17 | | | |
| 1st Pick | 29.1 | 27.5 | 51.1 | 51.5 | 4.31 | 3.83 | 23.9 | 22.6 | 5.52 | 5.19 | 7.81 | 9.10 |

**Table 12.** Fibre properties interaction with supplemental irrigations at different pickings

| Pickings | 2.5 per cent SLlength (mm) | | UR 2012 (%) | | UR 2013 (%) | | Micro-naire (ig / in) | | Bundle strength tenacity (g/tex)at 3.2 mm gauge | | SFI | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | I | R | I | R | I | R | I | R | I | R | I | R |
| 1st | 28.6 | 29.6 | 51.2 | 50.9 | 53.0 | 50.0 | 4.39 | 4.23 | 23.8 | 23.9 | 8.2 | 7.4 |
| 2nd | 28.4 | 29.0 | 51.1 | 48.8 | 52.0 | 50.7 | 4.47 | 4.06 | 23.7 | 22.0 | 8.1 | 8.3 |
| 3rd | 29.4 | 28.9 | 50.8 | 49.2 | | | 4.33 | 4.06 | 23.8 | 22.0 | 7.6 | 8.6 |
| CD (p=0.05) | 0.5 | | 0.9 | | 1.0 | | 0.14 | | 0.7 | | 0.70 | |

2002-Upto May, 2012). http:// d*Bt*biosafety.nic.in/Standing_Committee/ YearWise_List2002_ May2012.pdf pp.60

**Gutierrez, A.P., Ponti, L., Herren, H. R., Baumgärtner, J. and Kenmore, P. E. 2015.** Deconstructing Indian cotton: weather, yields, and suicides. Environmental Sciences Europe (2015) 27:12 DOI 10.1186/ s12302-015-0043-8

**Raju, A.R., Thakare, S.K. 2012.** Nutrient management on FUE, red leaf, fibre properties of *Bt* hybrid cotton(*Gossypium hirsutum*). *Ind. Jour. Agro.* **57 :** 13-19.

**Raju, A.R., 2014.** Improving hybrid cotton profitability and micronaire with stripcropping of soybean+pigeon pea with conservation furrows, Mn and B application. *African J. Agri.Res.* **9 :**183-95.

**Raju, A.R., Majumdar, G., Reddy, A. R. 2011.** Validation of farm pond size for irrigation during drought. *Ind. Jour. Agro.* **56 :** 356-64.

**Samborski, S., Tremblay, M. N. and Fallon, E. 2008.** Strategies to make use of plant sensors-based diagnostic information for nitrogen recommendations.Agron J. 101 ( 4):800-816. doi: 10.2134/ agronj2008. 0162Rx.

**Received for publication : January 16, 2017**
**Accepted for publication : July 17, 2017**