

Growth and yield performance of cotton (*Gossypium hirsutum*) expressing *Bacillus thuringiensis* var. *Kurstaki* as influenced by polyethylene mulching and planting techniques

P NALAYINI¹, S PAUL RAJ² and K SANKARANARAYANAN³

Regional station, Central Institute for Cotton Research, Coimbatore, Tamil Nadu 641 003

Received: 4 December 2009; Revised accepted: 5 October 2010

ABSTRACT

Field experiment was conducted during 2006–08 winter (August – February) cropping season to study the growth and yield performance of cotton expressing the *Bacillus thuringiensis* (*Bt*) and non-*Bt* genotypes of 'RCH 20' due to mulching and planting techniques. Three methods of planting, viz single row, triangular and double row (paired row) were compared. Irrespective of the genotypes, double row planting with 22 222 cotton plants/ha yielded significantly higher seed cotton yield (4 181) than other methods of planting. However, in terms of seed cotton equivalent yield, triangular planting with 11 111 plants of cotton and the equal number of intercrop radish (*Raphanus sativus* L.) was at par with double row planting of cotton. Among the genotypes, *Bt* cotton 'RCH 20' yielded significantly higher yield (4 328) than its non-*Bt* counterpart. Polymulching benefited both-*Bt* and non *Bt* cotton, while the benefit was more for *Bt* cotton with 56.4% higher yield as against 34.2% enhanced yield for non-*Bt* cotton. The available soil moisture in 0–45 cm soil depth recorded during periodic soil sampling was higher (24.9%) under polymulching as compared to lower (19.8%) available soil moisture under conventional method. The enhanced soil temperature of 3.9–4.0°C recorded under polymulching in the 0–15 cm soil depth was favourable for faster mineralization and mobilization of nutrients in the soil.

Key words: *Bacillus thuringiensis* cotton, Polyethylene mulching, Planting techniques, Seed cotton yield

Global demand for cotton is projected at 33.3 million tonnes in 2010 and 42.75 million tonnes by 2020. Despite a stiff competition from synthetic fibres, the share of cotton to the global textile pool is 45% (Srinivasan 2009) and this is higher in India (65%). Use of input-responsive cultivars and high-tech production technologies will go a long way to meet the ever-increasing demand for the natural fiber. Polyethylene mulching is a novel technique which has potential for doubling the yield of cotton (Nalayini *et al.* 2009), besides its advantages for conserving moisture and weed control. Fortnum *et al.* (2000) reported the beneficial effects of plastic mulch for enhanced water and fertilizer utilization and weed control. Reflective mulches were more effective than foliar or soil applied insecticides in managing both the leafhopper and the pathogen it transmits (Summer and Stapleton 2002). Considering the immense benefits of polyethylene mulching for enhancing the productivity of cotton, saving

of precious water and controlling of weeds this study was attempted.

MATERIALS AND METHODS

Field experiment was conducted during winter (August – February) 2006–08 cropping season at Regional Station, Central Institute for Cotton Research, Coimbatore. The experimental soil was low in nitrogen (165.8, 180.6 kg/ha), high in phosphorus (25.8, 28.5 kg/ha) and high (580.7, 620.5 kg/ha) in potassium during 2006–08, respectively.

Factorial randomized block design was used with three replications. Cotton cultivar, 'RCH 20 Bt' and 'RCH 20 non-*Bt*' were grown in raised bed under polyethylene mulching (30 micron black bottom and silver colour top layer film) and compared against the bed without mulch (control). Three planting methods such as double row (paired row- two rows/raised bed with 22 222 cotton plants/ha), triangular [zig zag planting – in the double row method, opposite plant hill is planted to an intercrop, radish (*Raphanus sativus* L.)] so that 11 111 plants/ha of cotton and equal number of radish and single row method (one row of cotton/raised bed with 11 111 cotton plants/ha) were studied. The raised bed of the

^{1,3}Senior Scientist (e mail: nalayiniganesh@gmail.com; sankaragro@gmail.com)

²Scientist (e mail: paulraj @gmail.com), Indian Institute of Pulses Research, Kanpur, Uttar Pradesh 208 024

size 9 m×1.2 m were formed leaving 30 cm on all around the bed for irrigation. For double row planting, in each raised bed, two rows of cotton were sown at 60 cm apart in a paired row of 90/60 cm×60 cm so as to maintain the 22 222 plant population/ha. For single row planting in each raised bed only 1 row of cotton was planted so that the population was only 50% of double row planting. In the triangular method, in each paired row, the opposite plant was planted to intercrop, radish so as to maintain the same cotton plant population as that of single row planting and an additional same population of intercrop radish. The recommended dose of fertilizer (25% N, 25% K and 100% P) of 90 kg N, 45 kg P₂O₅ and 45 kg K₂O was given as basal application before spreading the polyfilm. The polymulch film was spread gently on the raised bed and the ends were sealed tightly with soil. The sowing lines were marked on the polyethylene sheets using a sowing rope with markings at required spacing (60 cm plant-to-plant). The holes were made at required spacing using a 2 inch GI pipe (by gently pressing the GI pipe on the polymulch film) and the sowing of cotton was done carefully in the sowing holes and given irrigation immediately. The remaining dose of fertilizers was given as three equal splits at 35, 75 and 115 days after sowing. During the growing season, the cotton crop received 581.9 mm and 511.4 mm rainfall during first and second year of experimentation, respectively. The effective rainfall was computed by the FAO method (Brouwer and heibloem 1986). The two years data were pooled and analyzed for significance using ANOVA.

RESULTS AND DISCUSSION

Growth and yield attributes of *Bt* and non-*Bt* cotton

The *Bt* cotton was shorter in stature and found significantly shorter than non-*Bt* cotton (Table 1). The polymulched plants were significantly taller than the non-mulched control irrespective of the genotypes. The plant height was not altered significantly by methods of planting. The number of nodes/plant was not significantly altered either due to genotypes or methods of planting. However, polymulching produced significantly more nodes/plant. The number of leaves/plant was at par with both *Bt* and non-*Bt* genotypes, while polymulching influenced the production of leaves significantly as evidenced from the enhancement up to 37.3% in-*Bt* cotton and 40.5% in non-*Bt* cotton as compared to the conventional planting of *Bt* and non-*Bt* cotton. This might be due to favourable microclimate under polymulching. Among the planting techniques, triangular and single row planting recorded more number of leaves than double row planting. This might be attributed due to lesser interplant competition under triangular and single row planting than double row planting.

The leaf area varied significantly among treatments. The non-*Bt* genotype produced significantly bigger leaves than

Table 1. Growth characters of *Bt* and non-*Bt* cotton (90 days after sowing) as influenced by polymulching and planting methods

Treatment	Plant height (cm)	Node/plant	Leaves/plant	Leaf area (cm ² /leaf)
<i>Bt</i> cotton (polymulched)				
Single row	119.4	24.1	330.6	169.2
Triangular	116.2	24.4	322.8	172.3
Double row	112.2	23.6	272.7	148.1
Mean	115.9	23.9	308.7	163.2
<i>Bt</i> cotton (without mulch)				
Single row	102.8	22	233.2	158.8
Triangular	107.4	23	242	165.0
Double row	103.8	21.9	199	139.0
Mean	104.7	22.3	224.8	152.1
Non- <i>Bt</i> cotton (polymulched)				
Single row	127.5	24.1	277.5	192.2
Triangular	123.8	24.5	331.4	196.5
Double row	124.8	23.8	252.3	183.1
Mean	129.0	24.1	287	190.6
Non- <i>Bt</i> cotton (without mulch)				
Single row	107.9	21.7	222	181.7
Triangular	110.8	20.6	205.2	161.3
Double row	109.3	21.4	185.8	167.1
Mean	109.3	21.2	204.3	170
CD (P=0.05)				
Genotypes	5.23	NS	NS	15.0
Mulching	5.23	0.91	27.7	15.0
Planting techniques	NS	NS	33.9	18.3

Bt genotype. The polymulching enhanced the leaf size significantly as could be seen from an average leaf area of 163.2 cm²/leaf in *Bt* cotton as against 152.1 cm²/leaf under conventional planting. Similarly, in non-*Bt*, the leaf area under poly mulching was 190.6 cm²/leaf as against 170 cm²/leaf under conventional planting of cotton

The production of sympodial branches/plant did not vary between *Bt* and non-*Bt* cotton (Table 2). While polymulching influenced the sympodial numbers significantly. *Bt* genotype recorded significantly higher number of squares/plant than non *Bt*. Poly mulching influenced the plants to partition efficiently to reproductive structures as could be seen from significant enhancement in the squares and bolls/plant. *Bt* cotton produced on an average 86.7 squares and 33.4 bolls on 90 days after sowing under conventional system which was enhanced to 103.5 squares and 57 bolls under poly mulching. Similarly, the non-*Bt* genotype recorded significant enhancement in the production of squares and bolls under poly mulching. The *Bt* and non-*Bt* cotton were at par with in terms of dry matter accumulation. Though *Bt* cotton was shorter in stature than its non-*Bt* counterpart, enhanced dry matter was due to efficient partitioning to reproductive structures as could be seen from significantly higher squares

Table 2. Dry matter accumulation and reproductive attributes of *Bt* and non *Bt* cotton (90 DAS) as influenced by polymulching and planting methods

Treatments	DMP (g/plant)	Sympodia/ plant	Squares/ plant	Bolls/ plant
<i>Bt</i> cotton (polymulched)				
Single row	407.2	19.7	116.2	63.5
Triangular	376.1	19.6	115.9	57.7
Double row	332.3	18.1	78.4	49.8
Mean	371.8	19.1	103.5	57.0
<i>Bt</i> cotton (without mulch)				
Single row	210.1	17.8	86.2	34.8
Triangular	278.0	18.6	97.7	36.0
Double row	157.2	17.7	76.2	29.3
Mean	215.1	18.0	86.7	33.4
<i>Non-Bt</i> cotton (polymulched)				
Single row	350.8	19.3	86.3	40.8
Triangular	418.7	20.1	96.2	47.3
Double	345.5	19.7	68.6	26.3
Mean	388.3	19.6	83.6	38.2
<i>Non-Bt</i> cotton (without mulch)				
Single row	180.3	17.6	73.9	28.2
Triangular	210.5	17.2	62.8	25.1
Double row	214.5	17.0	54.7	19.2
Mean	201.8	17.3	63.8	24.2
CD ($P=0.05$)				
Genotypes	NS	NS	16.3	7.23
Mulching	35.39	1.01	17.11	7.24
Planting techniques	43.26	1.03	20.96	9.22

DMP, Drymatter production

and bolls which might have contributed to enhanced dry matter accumulation which was at par with non-*Bt* genotype. Polymulching resulted in significant enhancement in dry matter accumulation due to highly conducive growth environment under poly mulching. The dry matter accumulation was 72.9 and 92.5% higher, respectively in *Bt* and non-*Bt* cotton under polymulching as compared to control (without mulch). Single and triangular planting were at par with and found significantly superior to double row planting

Seed cotton yield and seed cotton equivalent yield

Bt cotton recorded significantly more number of harvestable bolls ranging from 78 to 101.2 bolls/plant under polymulching and 59.7 to 79.9 bolls/plant under conventional method (Table 3). The polymulching significantly enhanced the production of harvestable bolls with an average of 93 bolls/plant in *Bt* cotton and 66.5 bolls/plant in non-*Bt* cotton. Double row planting recorded significantly higher number of bolls/plant on per unit area basis (bolls/m²). The enhanced boll load on per plant basis under single or triangular methods of planting could not compensate the population loss as compared to double row planting. The boll weight for *Bt* cotton was 6.2 under conventional method as compared to

Table 3 Yield attributes, seed cotton yield and seed cotton equivalent yield as influenced by polymulching and planting methods

Treatment	Harvestable bolls/ plant	Harvestable bolls/m ²	Boll weight/ g/boll	SCY (kg/ha)	SCEY (kg/ha)*
<i>Bt</i> cotton (polymulched)					
Single row	101.2	112.2	7.3	4875	5476
Triangular	100.0	110.8	7.3	4809	6098
Double row	78.1	173.5	7.2	6157	6758
Mean	93.1	132.1	7.3	5280	6111
<i>Bt</i> cotton (without mulch)					
Single row	78.9	87.4	6.5	3104	3705
Triangular	79.9	88.5	6.2	3129	4418
Double row	59.7	132.8	5.9	3897	4498
Mean	72.8	103	6.2	3376	4207
<i>Non-Bt</i> cotton (polymulched)					
Single row	76.4	84.9	7.0	3054	3655
Triangular	67.3	74.8	6.9	2782	4071
Double row	53.0	117.7	6.8	3688	4281
Mean	65.6	92.4	6.9	3175	4002
<i>Non-Bt</i> cotton (without mulch)					
Single row	63.3	73.1	6.4	2294	2895
Triangular	68.5	76	6.2	2283	3572
Double row	49.7	110.4	6.1	2980	3581
Mean	60.5	86.5	6.3	2519	3349
CD ($P=0.05$)					
Genotypes	3.65	4.63	0.19	301.1	199
Mulching	3.65	4.63	0.25	301.1	199
Planting techniques	4.47	5.67	Ns	367.9	242.8

*The intercrop green gram grown in the irrigation channel yielded 426 kg/ha of dried grains and radish yielded up to 5.5 t/ha which were converted to cotton equivalent yield after deducting the harvesting charges

6.3 g/boll under non-*Bt* cotton. Polymulching enhanced the boll weight of *Bt* genotype to 7.3 g/boll as compared to non-*Bt* cotton (6.9 g/boll). This might be due to the efficient partitioning to sink (bolls) which were accelerated by favourable growth environment (stress free) under poly mulching. The boll weight was not significantly altered due to methods of planting.

Fibre quality

Bt cotton recorded significantly higher yield than non-*Bt* cotton. Polymulching benefited both *Bt* and non-*Bt* cotton but the response was found to be more for *Bt* cotton. The *Bt* cotton recorded 56.5% higher yield under polymulching while non-*Bt* recorded 34.2% yield increase under poly mulching as compared to conventional method. Elias and Gold hammer (1991) reported an yield improvement of 39% due to polyethylene mulching in cotton. Similarly, Ramakrishna *et al.* (2006) reported 94.5% higher yield in groundnut due to polyethylene mulching. Among the planting

Table 4 Fiber quality parameters as influenced by genotypes, polymulching and Planting methods

Treatments	2.5% span length (mm)	Micronaire (μ g/inch)	Fibre strength (g/tex)
<i>Bt</i> cotton (polymulched)	31.1	3.95	23.45
Single row	30.7	3.95	23.85
Triangular	31.9	4.00	24.25
Double row	31.23	3.97	23.85
Mean			
<i>Bt</i> cotton (without mulch)	31.45	4.30	22.15
Single row	31.35	3.90	22.16
Triangular	32.15	3.90	24.30
Double row	31.65	4.03	22.87
Mean			
<i>Non-Bt</i> cotton (polymulched)	33.5	3.95	23.75
Single row	31.7	4.00	22.70
Triangular	32.35	3.98	23.80
Double row	32.52	3.98	23.42
Mean			
<i>Non-Bt</i> cotton (without mulch)	31.95	4.25	22.65
Single row	31.75	4.00	23.55
Triangular	31.55	4.20	23.05
Double row	31.75	4.15	23.08
Mean			
CD ($P=0.05$)			
Genotypes	NS	NS	NS
Mulching	NS	NS	NS
Planting techniques	NS	NS	NS

techniques, double row planting gave significantly higher seed cotton yield than triangular or single row planting. The seed cotton equivalent yield calculated after taking into account the yield from intercrops (greengram and radish) has shown that double row planting was on par with triangular planting and significantly superior to single row planting. This suggests that it is advantages to go for double row planting and however if the growers want to realize some income during the growing season, triangular planting with fast growing intercrops like radish (which can be harvested in 45–50 days after sowing) may be adopted which also gave on par yield with double row planting with the advantages of getting some income from the intercrops within the first two months of sowing cotton.

The fibre quality parameters were tested using high volume instrument and none of the parameters were found to be influenced by genotypes, mulching and planting techniques (Table 4).

Effect of polymulching on soil temperature and soil moisture

The hourly soil temperature recorded in the 0–15 cm soil depth during November has shown that on an average an enhanced soil temperature of 4.0°C in the forenoon and 3.9°C in the afternoon due to polymulching (Fig 1) and this increased temperature under polymulching is advantages for faster mineralization and mobilization of soil nutrients for

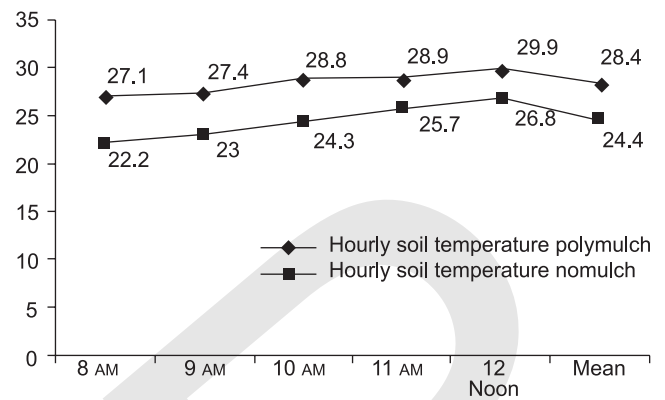


Fig 1 Hourly soil temperature as influenced by polyethylene mulching.

plant absorption. Hu *et al.* (1995) reported that the increase in soil temperature under mulching was due to sun's energy passes through the mulch and heats the air and soil beneath the mulch directly and then the air is trapped by the 'greenhouse effect'.

The available soil moisture recorded at fortnightly interval in the polymulched and without mulch soil revealed that the soil moisture is always higher (24.9%) under polymulched soil as against lower (19.8%) recorded under without mulching. Mulches greatly retard the loss of moisture from the soil and as a result higher and uniform soil moisture regime is maintained reducing the irrigation frequencies (Ramakrishna *et al.* 2006). Improved soil moisture and temperature with polythene mulching was earlier reported by Niu *et al.* (1998). The soil moisture recorded under conventional planting revealed that the plant is subjected to two types of stress due to high moisture immediately following irrigation and nearer to wilting point after one week of irrigation pushing the plant to suffer due to excess as well as deficit moisture stress. However, under polymulching, the soil moisture was consistently higher and was nearer to field capacity moisture which is highly conducive for plant growth.

It can be concluded that the polymulching technique can be used to increase the yield of both *Bt* and *non-Bt* cotton. *Bt* cotton gave significantly higher seed cotton yield than *non-Bt* cotton and the double row (paired row) planting with 22 222 cotton plants/ha significantly improved the yield of both *Bt* and *non Bt* cotton. while triangular planting with 11 111 plants/ha of cotton and equal number of intercrop radish was at par with double row planting in terms of seed cotton equivalent yield.

REFERENCES

- Brouwer C and Heibloem M. 1986. Irrigation water needs, *Irrigation Water Management Training Manual* No.3, FAO, Rome, Italy.
- Elias Fereres, David A Goldhamer. 1991. Plastic mulch increases Cotton Yield, reduces need for pre-season irrigation. *California Agriculture* 45 (1): 25–8.
- Fortnum Kasparauer MJ and Decoteau D R. 2000. Effect of Mulch

- Surface colour on root – knot nematode of tomato grown in simulated planting beds. *Journal of Nematology* **32**(1): 101–9.
- Hu W, Duan S, Sui Q, 1995. High yielding technology for groundnut. *International Arachis Newsletter* **15** (suppl.), 1–22.
- Nalayini P, Anandham R, Sankaranarayanan K and Rajendran T P. 2009. Polyethylene mulching for enhancing crop productivity and water use efficiency in cotton (*Gossypium hirsutum*) and maize (*Zea mays*) cropping system. *Indian Journal of Agronomy* **54**(4): 409–14.
- Niu J Y, Gan Y T, Zhang J W, and yang Q F. 1998. Post anthesis dry matter accumulation and distribution in spring wheat mulched with plastic film. *Crop Science* **38**: 1562–8.
- Ramakrishna A, Hoang Minh Tam, Suhas P Wani, Tranh dinh Long. 2006. Effect of mulch on soil temperature, moisture, weeds infestation and yield of groundnut in northern Vietnam. *Field Crops Research* **95**: 115–25.
- Sreenivasan S. 2009. Technology Interventions in cotton for enhancing its diversified use. (in) *International Conference on Emerging Trends in Production, Processing and Utilization of Natural Fibres. Book of Papers*, pp 208–15.
- Summers C G and Stapleton J J. 2002. Management of corn leafhopper (Homoptera: Cicadellidae) and corn stunt disease in sweet corn using reflective mulches. *Journal of Economic Entomology* **95** (2): 325–30.