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SHORT COMMUNICATION

DRY MATTER PARTITIONING AND PLANT GROWTH RESPONSE OF TRANSGENIC BT AND NON BT COTTON

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Field experiment was conducted at Parbhani during *kharif* season of 2004 and 2005 to study the effects of nutrient and pest management on growth and development of Bt cotton (*Gossypium hirsutum L*) with special reference to dry matter production and its partitioning towards sinks. The Bt cotton recorded significantly less dry matter /plant than non Bt (NBt) cotton hybrids during both years. Green boll was found to be the major sink for photosynthate in Bt cotton at 120 days after sowing and it was to the extent of 37.28 and 51.68 per cent of total dry matter during first and second season crop respectively. It was observed that MECH 184 Bt produced significantly higher seed cotton yield (1658 Kg/ha) over it NBt counterpart (1071 Kg/h).The performance of MECH 184 Bt was exceedingly superior and it produced 54.20 and 52.77 % more seed cotton yield than NBt counterparts MECH 184 and PHH 316, respectively. Moreover, the transgenic MECH 184 Bt cotton hybrid recorded significantly higher harvest index, matured earlier as compared to both MECH 184 and PHH 316 NBt cotton. The MECH 184 Bt cotton hybrid was found quite effective in reducing the insecticidal spray to the extent of 60 % over its NBt counterpart. The insecticidal pest management in cotton was found promising in managing cotton pest complex and finally realized significantly higher seed cotton yield than biopesticidal pest management. The application of graded level of chemical fertilizer, i.e. 80, 40 and 40 kg per ha of N, P and K and 100, 50 and 50 kg per ha of NPK under rainfed condition were equally effective in enhancing growth and yield attributes. Moreover, the improvement in growth and yield attributes was significantly superior over application of FYM (10 t/ha). Thus, it was concluded that due to increased retention of bolls, the crop growth pattern and biomass partitioning has changed substantially in Bt cotton.

***Key words*: Bt cotton, dry matter partitioning, nutrient management, pest management, seed cotton yield**

The introduction of transgenic Bt cotton in India has improved productivity of cotton sustantially from 303 to 561 Kg/ha within a span of seven years. Presently Bt cotton is being cultivated in 6.63M ha which accounts 63.26 % of total cotton area during the year 2007-08 (Anonymous 2008). In Bt cotton, because of increased retention of bolls, the crop growth pattern and biomass partitioning has changed substantially. This aspect needs to be understood thoroughly for designing efficient agronomic management to cater changing plant demand and to get benefit of Bt technology. Therefore, a field study was conducted to determine how dry matter partitioning for the Bt cotton in comparison to NBt cotton hybrids were altered by varying the application rates of fertilizer in combination with pest management.

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A field investigation was conducted to study the effects of nutrient and pest management on biomass partitioning and plant growth response of Bt vs NBt cotton hybrids during the *kharif* season of 2004 and 2005 at Department of Agronomy, Marathwada Agricultural University, Parbhani (409 m mean sea level; 19° 16' N and 76° 47' E). Total rainfall received during the cropping period (June to Feb) was 439.9 and 1275.9 mm distributed over 31 and 43 rainy days for the year 2004-05 and 2005-06 as against the normal precipitation of 885 mm in 57 rainy days (1974 to 2004), respectively. The mean maximum temperature varies from 28.62 to 40.9°C, whereas, the mean minimum temperature varies from 8.7 to 26.60°C. The soils of the experimental plot were Vertisol, low in available N (147.40 and 156.00 kg/ha) P (18.24 and 15.10 kg/ha), fairly rich in K (430.10, 442.25 kg/ha) and slightly alkaline in reaction (pH 8.3 and 8.2) during the year 2004-05 and 2005-06 respectively.

The experiment was laid out in split plot design and replicated thrice. There were eighteen treatment combinations comprising three cotton hybrids, viz. MECH 184 Bt, MECH 184 NBt and PHH 316, two pest management practices, viz. insecticidal pest management and biopesticidal pest management and three nutrient management levels, viz. FYM 10 t/ha, 80: 40: 40 kg NPK/ha (RDF), 100:50:50 kg NPK/ha (125 % RDF). Treatment combinations of hybrid and pest management were allotted to main plots and nutrient management was accommodated in subplots. The insecticidal pest management treatment consisted of five sprays of insecticides, viz. methyl demeton, endosulfan, quinolphos and fenvalerate. The insecticides were sprayed when sucking pest and bollworms complex was above economic threshold level. Whereas in biopesticidal pest management release of *Trichogramma chilonis* egg parasitoid of cotton bollworm @ 1.5 lakh/ha and spraying of biorationals such as neem seed kernel extract 5 % and HaNPV @ 250 LE/ha was undertaken as need based plant protection measures in cotton. The cotton was sown on 30 and 22 June in 2004 and 2005, respectively by hand dibbling at 90 cm x 60 cm spacing with one seed per hill and gap filling was done at 10 days after sowing and fertilizers were applied as per treatments. Half dose of N, full dose of P and K was applied as basal dose, while remaining half dose of N was applied one month after sowing. Sucking pests such as aphids, jassids and white flies were invariably common on Bt and NBt cotton. Two sprays of neem seed kernel extract 5 % and methyl demeton were undertaken for the management of sucking pest in biopesticdal and insecticidal pest management, respectively. The bollworm incidence was above ETL (one larva/plant) for two and three instances on NBt cotton hybrids, whereas, it was below ETL on MECH 184 Bt cotton hybrid during first and second season, respectively. Under biopesticidal pest management, egg parasitoid *Trichogramma chilonis* was released @ 5 cards/ha once at 45 days after sowing and then after 15 days in order to kill bollworm eggs which was followed by three sprays of HaNPV @ 250 LE/ha were taken when the bollworms incidence was above ETL in NBt cotton hybrids. On the other hand, bollworms were managed in NBt cotton hybrids with the help of three sprays of insecticides such as endosulfan, quinolphos and fenvalerate in insecticidal pest management. Insecticidal sprays were not required in Bt cotton hybrid for the management of bollworms because incidence was below ETL during both the years. Rests of cultural operation were done in the entire plot uniformly. Dry matter harvests were taken each year on 30, 60, 90,120 and 150 days after sowing. During each harvest, the above ground portion of cotton plants were harvested for dry matter studies and separated in to leaves stem and petiole and bolls. Dry weights were recorded after oven drying these parts to a constant weight for 3 days at 70 ^{0} C. Partitioning or allocation of dry matter to petiole, leaves, stem, boll was calculated as the ratio of dry weight of individual components and total dry matter expressed in percentage. The crop was harvested at boll bursting stage by hand picking of seed cotton. In all three hand pickings were undertaken on 22 October, 6 November and 24 November in 2004, whereas during second year due to continuous rainfall pickings were delayed and it commence on 26 December 2005, 18 January and 15 February 2006.

Dry matter partitioning during the grand growth and boll development phase (31-120 days): The non Bt cotton hybrids produced more total dry matter/plant than Bt cotton hybrid 120 days after sowing (DAS) (Table 1). At end of this phase (at 120 DAS), total dry matter

production under MECH 184 NBt cotton hybrid was 10.71 and 58.54 per cent higher than Bt cotton hybrid during 2004-05 and 2005-06, respectively. Moreover, leaf was the major sink for the photosynthates with the proportion varying from 28.57 to 40.58 per cent in NBt cotton. In case of MECH 184 Bt cotton, the green boll became the major sink for photosynthates at 120 DAS which was to the extent of 37.28 and 51.68 per cent of total dry matter during first and second season of the crop, respectively. During both seasons MECH 184 Bt cotton recorded significantly less dry matter (204.07 and 162.92 g/plant) than other NBt cotton hybrids. This was indicative of the fact that loss of young fruiting forms by the entomological factors was two-three times less in MECH 184 Bt than NBt cotton hybrids. As a consequence, Bt had more early formed bolls on the lower canopy which contributed to higher biomass and seed cotton yield. Heavy boll load altered the growth and partitioning. Thus, boll load changed growth and physiological processes of Bt cotton in comparison to NBt cotton. The results of the present investigation are in close conformity with result reported by Hebbar *et al*.(2007) and Prakash *et al*.(2008). The effect of pest management on dry matter production and its partitioning in sinks was much more convincing during both year of investigation. Cotton crop protected with insecticidal pest

Table 1. Effect of nutrient and pest management on partitioning of dry matter in Bt and NBt cotton hybrids at 120 days after sowing

Treatment	Partitioning of dry matter in different plant parts								Total dry matter	
	Petiole		Leaves		Stem		Green boll		(g/plant)	
	2004-05	2005-06	2004-05	2005-06	2004-05	2005-06	2004-05	2005-06	2004-05	2005-06
Hybrids										
MECH 184 Bt	5.71 (2.79)	2.08 (1.27)	38.80 (19.01)	20.25 (12.42)	83.87 (41.09)	45.80 (28.11)	76.28 (37.28)	84.20 (51.68)	204.07	162.92
MECH 184 NBt	7.80 (3.45)	16.10 (6.23)	69.78 (30.88)	104.83 (40.58)	131.55 (58.22)	90.74 (35.12)	0.00 (0.00)	23.95 (9.27)	225.93	258.30
PHH 316	10.44 (4.05)	12.22 (4.97)	73.63 (28.57)	81.93 (33.35)	161.50 (62.67)	103.45 (42.09)	0.00 (0.00)	22.41 (9.12)	257.66	245.46
SEm ±	0.24	0.42	1.08	4.21	3.08	1.88	1.50	3.44	4.31	2.73
CD (P=0.05)	0.76	1.34	3.40	13.25	9.71	5.92	4.72	10.85	13.57	8.59
Pest management										
Insecticidal	9.94 (3.81)	10.67 (4.15)	67.21 (25.81)	73.06 (28.42)	143.41 (55.09)	82.99 (32.29)	27.05 (10.39)	49.38 (19.21)	260.31	257.00
Biopesticidal	6.42 (3.22)	9.60 (5.12)	54.26 (27.38)	64.95 (34.64)	107.87 (54.44)	77.00 (41.07)	23.80 (12.01)	41.00 (21.87)	198.14	187.45
SEm ±	0.19	0.35	0.88	3.43	2.52	1.53	1.22	2.81	3.52	2.23
CD (P=0.05)	0.62	NS	2.77	NS	7.93	4.84	3.60	NS	11.08	7.02
Nutrient management										
FYM 10 t/ha	6.53 (3.38)	7.85 (4.67)	48.03 (24.92)	62.83 (37.41)	94.51 (49.04)	74.60 (44.42)	17.18 (8.91)	38.30 (22.80)	192.72	167.94
80:40:40 kg NPK/ha	8.40 (3.45)	11.07 (4.53)	61.78 (25.37)	70.48 (28.84)	125.60 (51.59)	80.30 (32.86)	23.10 (9.48)	45.99 (18.82)	243.43	244.34
100:50:50 kg NPK/ha	9.62 (3.82)	11.47 (4.50)	72.40 (28.78)	73.69 (28.96)	156.81 (62.34)	85.08 (33.43)	36.00 (14.31)	51.30 (20.16)	251.52	254.44
SEm ±	0.20	0.34	1.56	1.54	4.46	1.35	0.80	1.05	3.51	3.85
CD (P=0.05)	0.58	1.00	4.57	4.49	13.00	3.95	2.34	3.07	10.24	11.24

Per cent dry matter partitioned in different plant part are given in parenthesis

management recorded significantly higher dry matter than biopesticidal management. Moreover, in cotton protected with insecticides stem was the major sink for the photosynthates with the proportion varying from 32.29 to 55.09 per cent. Similarly Ghodki (2004) and Math *et al.* (2004) observed optimum plant growth and significant improvement in plant height, numbers of sympodial and monopodial branches/plant, and number of functional leaves/plant, due to better management of sucking pest complex in early growth stages of cotton through insecticidal pest management compared to biopesticidal pest management. In this context, Mathews (1989) reported that sucking pest reduced the growth and vigour of cotton plant in early stages that ultimately affected the yield. The application of chemical fertilizers, i.e. 80:40:40 and 100:50:50 kg N, P and K/ha was found beneficial in enhancing the dry matter production and its partitioning to boll than FYM 10 t/ha. At the end of this phase (at 120 DAS) application of 100:50:50 and 80:40:40 kg/ha N, P and K were equally effective in increasing the total dry matter/plant substantially and it was significantly higher (251.52 and 254.44) than FYM (10 t/ha) during 2004-05 and 2005-06, respectively. Moreover, partitioning of photosynthates towards sinks was also increased significantly due to application of chemical fertilizer compared to FYM 10 t/ha during both the years. This might be associated with increased availability of nutrient and its subsequent removal by crop under fertilizer application.

Maturity phase (121 days onwards): The partitioning of dry matter to sinks in MECH 184 NBt cotton hybrid was improved substantially wherein 44.08 and 25.29 per cent of dry matter was diverted towards sinks during first and second seasons of the crop (Table 2). Due to indeterminate characteristics of cotton it grows vegetatively and produces fruiting sites (sinks).Thus increased total dry matter as well as its partitioning towards sinks might have reflected in both NBt cotton hybrids during this phase. In Bt cotton early maturity and leaf senescence with reduction in total dry matter was observed. The nutritional hypothesis states that the timing of crop maturity is determined when the fruit that are already growing monopolies resources and prevent the crop from producing new fruiting sites. In insecticidal pest management total dry matter production/plant was increased significantly by 18.50 and 38.60 per cent over biopesticidal pest management during 2004-05 and 2005-06, respectively. Such improvements in dry matter indicated optimized growth due effective control of sucking pest in insecticidal pest management compared to biopesticidal pest management.

Seed cotton yield: Cotton hybrid MECH 184 Bt produced significantly more seed cotton yield as compared to non-Bt cotton hybrids (Table 3). The seed cotton yield was increased by 98.1, 29.12 and 54.7 % in MECH 184 Bt cotton over its NBt counterpart during 2004-05, 2005-06 and in pooled result, respectively. The increased seed cotton yield in MECH 184 Bt cotton hybrid might be attributed to better fruiting efficiency, efficient source-sink relationship, balanced vegetative growth, early maturity, inbuilt resistance to bollworms, more number of picked bolls/plant and bigger boll size which ultimately reflected in higher seed cotton yield/ plant and finally seed cotton yield. Such higher yield advantage in majority of Bt cotton hybrids over non-Bt cotton hybrids were also observed by Halemani *et al.* (2004), Hallikeri *et al*. (2004) and Srinivasulu *et al.* (2006).

Season's effects especially higher rainfall influenced the pest incidence wherein bollworm incidence was above ETL (one larva/plant) for three and two instances on NBt cotton hybrids, whereas, it was below ETL on 'MECH 184 Bt' cotton hybrid during first and second season respectively. Moreover, there was reduction of 3 insecticidal sprays in Bt cotton for the management of bollworms during 2004-05 and 2005-06, respectively. The response of insecticidal pest management on cotton hybrids was much more convincing in terms of better crop growth and seed cotton yield. Average seed cotton yield of cotton obtained with insecticidal pest management was 15.5, 20.5 and 18.3 % more than biopesticidal pest management during 2004-05, 2005-06 and in pooled result, respectively. Similar improvement in yield attributes and seed cotton yield due to insecticidal pest management was reported earlier by Bhosale *et al.* (2004).

Similarly, effect of fertilizer levels on growth and yield attributes was significant (Table 3). The application of higher level of fertilizer, i.e. 80: 40: 40 kg N, P and K/ha and 100:50:50 kg N, P and K/ha were equally

Table 2. Effect of nutrient and pest management on partitioning of dry matter in Bt and NBt cotton Hybrids at 150 days after sowing

Treatment	Partitioning of dry matter in different plant parts								Total dry matter	
	Petiole		Leaves		Stem		Green boll		(g/plant)	
	2004-05	2005-06	2004-05	2005-06	2004-05	2005-06	2004-05	2005-06	2004-05	2005-06
Hybrids										
MECH 184 Bt	3.23 (2.55)	2.50 (2.31)	14.20 (11.23)	23.35 (21.59)	51.08 (40.41)	50.34 (46.54)	64.86 (51.31)	28.78 (26.61)	126.39	108.15
MECH 184 NBt	5.01 (2.37)	8.86 (2.95)	29.96 (14.19)	73.83 (24.66)	82.91 (39.29)	125.01 (41.75)	93.01 (44.08)	75.73 (25.29)	210.99	299.39
PHH 316	3.55 (2.12)	6.72 (1.92)	25.76 (15.44)	69.41 (19.86)	75.65 (45.35)	172.07 (49.24)	67.42 (40.41)	84.11 (24.06)	166.81	349.45
SEm ±	0.03	0.21	0.80	1.04	1.78	2.63	1.76	1.90	6.21	2.52
CD (P=0.05)	0.11	0.68	2.52	3.28	5.60	8.29	5.56	5.97	19.53	7.93
Pest management										
Insecticidal	4.26 (2.33)	6.16 (2.10)	26.76 (14.67)	58.29 (19.88)	77.23 (42.36)	119.21 (40.66)	82.36 (45.17)	64.92 (22.14)	182.30	293.16
Biopesticidal	3.60 (2.34)	5.89 (2.78)	19.85 (12.90)	52.76 (24.94)	62.53 (40.64)	112.40 (53.14)	67.81 (44.08)	60.83 (28.76)	153.83	211.50
SEm ±	0.02	0.17	0.65	0.85	1.45	2.15	1.44	1.55	5.07	2.05
CD (P=0.05)	0.09	NS	2.06	2.68	4.57	6.77	4.54	NS	15.95	6.47
Nutrient management										
FYM 10 t/ha	2.48 (1.89)	5.83 (3.01)	14.95 (11.42)	51.91 (26.80)	50.77 (38.78)	110.32 (56.96)	54.60 (41.71)	59.23 (30.58)	130.89	193.65
80:40:40 kg NPK/ha	4.45 (2.43)	6.03 (2.17)	22.56 (12.36)	56.12 (20.19)	70.40 (38.59)	116.52 (41.93)	68.17 (37.37)	63.24 (22.75)	182.41	277.87
100:50:50 kg NPK/ha	4.86 (2.54)	6.22 (2.17)	32.41 (16.97)	58.55 (20.51)	88.48 (46.35)	120.57 (42.23)	102.50 (53.69)	66.15 (23.17)	190.88	285.47
SEm ±	0.06	0.16	0.77	1.30	1.60	2.32	2.17	1.07	5.67	3.17
CD (P=0.05)	0.17	NS	2.25	NS	4.66	6.77	6.33	3.12	16.54	9.24

Per cent dry matter partitioned in different plant part are given in parenthesis

effective in enhancing the seed cotton yield and they were significantly superior over application of FYM 10 t/ha. The increase in seed cotton yield with application of chemical fertilizers, i.e. 80: 40: 40 kg N, P and K/ha and 100:50:50 kg N, P and K/ha was 12.92 and 18.81, 15.57 and 16.47, 14.41 and 17.48 % over FYM 10 t/ha during 2004-05, 2005-06 and in pooled result, respectively. The cumulative effect of fertilizer application finally reflected in improvement of number of picked bolls/plant and seed cotton yield. The results of present investigation corroborate the findings of Halemani *et al*. (2004) and Hallikeri *et al*. (2004).

Seed cotton yield differed significantly due to pest management and nutrient management interaction effects in pooled analysis results. The treatment combination of insecticidal pest management with application of 100: 50:50 kg N, P and K/ha and insecticidal pest management with application of 80: 40: 40 kg N, P and K/ha were equally effective in producing higher seed cotton yield and both were found significantly superior over rest of the treatment combinations. The results revealed that seed cotton yield (kg/ha) was optimized at recommended dose of nutrients (80: 40: 40 kg N, P and K/ha) with recommended plant protection measures

(insecticidal pest management) resulting in balance crop growth with effective bollworm management. By considering the favourable effects of application of 80: 40: 40 kg N, P and K/ha and combination with insecticidal plant protection measures on seed cotton yield of Bt cotton hybrid it could be recommended for cultivation of Bt cotton hybrid, under rainfed situation in Marathwada region of Maharashtra during *kharif* season on clay soil.

Harvest index and earliness index: The cotton hybrid 'MECH 184 Bt' recorded significantly higher harvest index of 45.17 and 38.75 per cent during 2004-05 and 2005-06, respectively, than non-Bt cotton hybrids (Table 3). The higher harvest index in Bt cotton was associated with efficient translocation of photosynthates towards sink (bolls) and conversion of biomass into economic yield. Whereas, on the contrary absence of sink (bolls) due to bollworm damage in non-Bt cotton hybrid might have resulted in more vegetative growth in terms of number of functional leaves, leaf area expansion and reflected in poor harvest index. The observations are in conformity with the observation of Singh *et al*. (2006) who had reported higher harvest index in MECH 184 Bt of 46.5 % on shallow soil and 51.5 % on deep soil than MECH 184 non-Bt (28.9 % on shallow soil and 28.4 % on deep soil). It was observed that harvest index was not improved due to application of nutrients as well as pest management in cotton during both the years which was the indicative of the fact these parameters were primarily governed by the genetic makeup of cotton hybrids

In general, crop matured earlier during 2004-05 and recorded lower earliness index values due abiotic stress of deficit rainfall (47.55 % less than normal rainfall) than 2005-06. Earliness index values were significantly higher in MECH 184 Bt (0.72 and 0.67) compared to MECH 184 non-Bt cotton hybrid (0.6 and 0.54) during 2004-05 and 2005-06, respectively. It was good indicator of the fact that Bt cotton matured earlier than non-Bt cotton hybrids. The higher earliness index values in Bt cotton hybrid were basically because of better protection of early formed boll from bollworm damage and balanced

Table 3. Effect of different treatment on earliness index, harvest index and seed cotton yield

Treatment	Earliness index		Harvest index(%)		Seed cotton yield (kg/ha)		
	2004-05	2005-06	2004-05	2005-06	2004-05	2005-06	Pooled analysis
Hybrids							
MECH 184 Bt	0.72	0.67	45.17	38.75	1575.10	1740.80	1658.00
MECH 184 NBt	0.60	0.54	19.96	25.21	794.71	1348.10	1071.40
PHH 316	0.64	0.62	23.49	21.16	945.11	1218.10	1081.60
SEm ±	0.008	0.009	1.11	0.85	50.01	42.43	66.87
CD (P=0.05)	0.02	0.03	3.50	2.70	157.34	133.49	242.79
Pest management							
Insecticidal	0.64	0.60	29.62	29.23	1184.80	1569.20	1377.00
Biopesticidal	0.66	0.62	29.46	27.51	1025.20	1302.10	1163.60
SEm ±	0.006	0.007	0.90	0.70	40.83	34.64	54.60
CD (P=0.05)	NS	NS	NS	NS	128.47	108.99	198.23
Nutrient management							
FYM 10 t/ha	0.67	0.62	29.34	28.85	999.28	1297.10	1148.20
80:40:40 kg NPK/ha	0.65	0.61	29.97	28.08	1128.40	1499.10	1313.70
100:50:50 kg NPK/ha	0.64	0.59	29.32	28.19	1187.30	1510.80	1349.00
SEm ±	0.10	0.012	0.88	0.68	26.26	30.63	14.23
CD (P=0.05)	NS	NS	NS	NS	76.33	89.26	42.40

NS = Non significant

plant growth might have enhanced the maturity in MECH 184 Bt cotton hybrid. Cotton being an indeterminate crop, produces fruiting bodies (sink) as well as leaves (source) simultaneously and fulfills demand of photosynthates of bolls, however, ever-increasing demand for photosynthates due to higher retention of early formed bolls on MECH 184 Bt cotton might have influenced source sink relationship and eventually higher dry matter was partitioned towards sink than source. As a result of which production of newly formed leaves in later stage of Bt cotton was reduced and crop matured earlier than NBt cotton. Such observations were also reported by Mayee and Rao (2002) who concluded that retention of early formed fruiting parts due to inbuilt resistance leads to pronounced earliness in Bt cotton. Mean data of two crop seasons revealed that biopesticidal pest management increased the earlyness index, although both the pest management remained statistically on par with each other (Table 3). This was primarily because of the fact that earliness index is largely based on genetic variability observed amongst hybrids and secondly the cotton bollworms have developed resistance to the most of the insecticides that is being used for bollworm management. Purohit (1989) also did not observe any significant differences in earliness index due to pest management. Similarly, it was observed that earliness index was not improved due to application of nutrients in cotton during both the years.

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