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Dry matter partitioning in *Bt* and non *Bt* cotton (*Gossypium hirsutum*) cultivars under different sowing environments of Punjab

VARINDERJIT KAUR[1]*, SUDHIR KUMAR MISHRA[2] and KULVIR SINGH[2]

Punjab Agricultural University, Ludhiana, Punjab 141 004, India

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ABSTRACT

A field experiment was conducted at Punjab Agricultural University (PAU), Regional Research Station (RRS), Faridkot and Bathinda during rainy (*kharif*) season 2017 to evaluate the performance of *Bt* and non *Bt* cotton (*Gossypium hirsutum* L.) cultivars under different sowing environments. The experiment was laid out in split plot design with 3 sowing dates (April 20, May 10 and May 30) in main plots and 4 American cotton cultivars [2 *Bt* cultivars (NCS 855 BGII and RCH 650 BGII) and 2 non *Bt* cultivars (F 2228 and F 1861)] in sub-plots. Results of the pooled data indicated that early sown (April 20) crop accumulated more dry matter production, higher crop growth rate (CGR) as well as relative growth rate (RGR) followed by crop sown on May 10 and May 30. Maximum CGR (14.35–15.48 $g/m^2/day$) was obtained during 90–120 DAS (days after sowing) while RGR was highest during 60–90 DAS. Among tested cultivars, F 1861 exhibited better CGR and RGR values and hence, accumulated higher dry matter (1303.0 g/m^2) followed by F 2228 (1276.9 g/m^2), NCS 855 BGII (1261.1 g/m^2) and RCH 650 BGII (1206.7 g/m^2). Dry matter accumulation in fruiting bodies has started around 90 DAS and accounted for 30–35% of total above ground biomass. *Bt* cultivar NCS 855 BGII, accumulated higher dry matter in fruiting bodies (458.1 g/m^2), though at par with RCH 650 BGII (432.2 g/m^2) but, significantly higher than F 1861 (403.3 g/m^2) and F 2228 (401.9 g/m^2). Dry matter accumulation towards fruiting bodies in *Bt* cultivars was ~9% higher than non *Bt* cultivars which may be prime reason for better yield performance of *Bt* cotton.

Keywords: Cotton, Cultivars, Dry matter accumulation, Relative growth rate, Sowing dates

Cotton (*Gossypium hirsutum* L.) is one of the most important commercial crops, contributing about 70% of the total raw material to the textile industries and a vital source of generating foreign exchange in many developing and under developed countries, including India. India is a global leader in terms of area under cotton cultivation as well as raw cotton production. Here, cotton is grown on wide range of soil types and climatic conditions under rainfed (65% cotton area) as well as irrigated (remaining 35% cotton area). In Punjab, cotton cultivation is mainly confined to south-western zone of the state with lower productivity (~750 kg/ha) than world (Anonymous 2017). This region is most suitable for cotton cultivation as water table in north-western India is alarmingly depleting, besides the fact that the available ground water of this zone is brackish and thus not suitable for growing high water demanding crops. Hence, irrigation is mainly provided through canals although high closure frequency and staggered canal water supply always hinders productivity potential (Singh *et al.* 2020). Due to these constraints, raising of other high water requiring *kharif* (rainy) crops such as paddy is not possible. Among various mechanisms, understanding of the production and the allocation of the carbohydrates to different parts of the plant is very important for determining total biomass and crop yield.

In case of cotton crop, yield is directly related with sink structures (seed count, abscised bolls, final seed cotton yield and its fibre partitioning) which mainly depend upon prevailing environment and plant source-sink mechanism (Dusserre *et al.* 2002). Difference in the duration of crop maturity among cotton genotypes under varied environments is an important criterion for consideration of plant management practices. *Bt* cotton hybrids, having inbuilt resistance to bollworm complex, also possess the characters like earlier completion of phenological stages (Thakur *et al.* 2017), and higher boll weight (Kaur *et al.* 2019) than non *Bt* genotypes. Therefore, selection of sowing time and suitable genotypes are most important factors affecting final crop yield. Hence, a study was planned with prime objective to understand the dry matter production as well as its partitioning behaviour for each cultivars of *Bt* and non *Bt* cotton grown under 3 sowing environments at

[1]Punjab Agricultural University, Ludhiana, Punjab; [2]Regional Research Station, Faridkot (Punjab Agricultural University), Punjab. *Corresponding author email: varinderjitpau29@gmail.com

2 diverse locations of south-western Punjab.

MATERIALS AND METHODS

Field experiments were conducted in 2 different agro climatic zones of south-western Punjab, i.e. at Punjab Agricultural University (PAU), Regional Research Station (RRS), Faridkot (latitude 30°40’ N, longitude 74°44’ E, altitude 200 m amsl) and also at PAU, RRS, Bathinda (latitude 30°58’N, 74°18’E longitude, altitude 211m amsl) during rainy (*kharif*) season 2017. The experiment comprised of 3 sowing dates (April 20, May 10 and May 30) in main plots and 4 American cotton cultivars, viz. 2 non *Bt* cultivars (F 2228 and F 1861) and 2 *Bt* hybrids (NCS 855 BGII and RCH 650 BGII) in sub plots of split plot design with 3 replications. Both the experimental locations are characterized by semi-arid climate, deficit rainfall and brackish underground water. The average annual rainfall is 419 mm at Faridkot and 440 mm at Bathinda. The soil of the experimental fields at both locations was slightly alkaline with normal EC (<0.80 ds/m), medium in P (<22.5 kg/ha), high in K (>138 kg/ha) and medium in organic carbon (0.40–0.75%). The sowing was done by dibbling two seeds/hill in a planting geometry of 67.5 cm × 75 cm for *Bt* cultivars and 67.5 cm × 60 cm for non *Bt* cultivars. Subsequently after thinning only one seedling/hill was maintained. A basal dose @30 kg/ha phosphorous was applied to all treatments and nitrogen @150 kg/ha for *Bt* and @75 kg/ha for non *Bt* cultivars was given in two splits i.e. first half dose at thinning and remaining at flowering stage. For pre-emergence weed control, pendimethalin (stomp 30 EC) @2.5 l/ha was uniformly applied and intercultural operations were carried out using tractor drawn cultivator as per requirement. All the standard cultural and plant protection measures recommended for cotton crop cultivation in Punjab given in “Package of practices for *Kharif* crops of Punjab” (Anonymous 2017) have been followed. Three plant samples from each plot were taken at 30 days interval starting from 30 days after sowing (DAS). Total above ground biomass was recorded and partitioned into leaves, stem and fruiting bodies (squares, green and mature bolls, etc.). All samples were dried in an oven at 70°C for 72 h and weighed. The significance of the experimental data was analyzed using CPCS-I statistical software. Since trends in results were almost similar at both locations, therefore data were pooled to increase the precision for better interpretation. The results of dry matter accumulation were further evaluated by calculating the crop growth rate (CGR) and relative growth rate (RGR) as (Pandey and Bhambri 2017, Gosh *et al.* 2018).

$$\text{CGR (g/m}^2\text{/day)} = (W_2 - W_1) / (t_2 - t_1)$$

$$\text{RGR (g/g/day)} = (\ln W_2 - \ln W_1) / (t_2 - t_1)$$

where W_1 and W_2, plant dry weights (g/m^2) at time t_1 and t_2; ln, indicates the natural log.

RESULTS AND DISCUSSION

Effect of sowing dates on dry matter production and partitioning: Dry matter accumulation followed a typical sigmoid curve over crop growth period. It was slow up to 60 DAS and thereafter, substantially increased until 150 DAS. However, towards maturity increase was again nominal in line with the findings of Singh *et al.* (2013). The pooled data revealed that at maturity, crop sown on April 20 accumulated significantly higher (1424.1 g/m^2) dry matter as compared to the crop sown on May 10 (1282.8 g/m^2) and May 30 (1078.9 g/m^2) with a similar trend throughout the crop growth period (Fig 1). The biomass partitioning into stem, leaves and fruiting bodies, also followed the same trend i.e. higher in April 20 sown crop followed by May 10 and May 30 (Table 1, 2 and 3). Analysis of dry matter partitioning indicated that relative proportion of stem component varied between 30–50% with the progress of season, whereas proportion of leaves ranged between 25% (near maturity) and 65% (early growth stages). Similarly, accumulation of dry matter in fruiting bodies (young buds, squares, flowers and bolls) started from 90 DAS and continued until crop maturity. Near maturation stage, the dry matter allocation in fruiting bodies accounted for 30–35% of the total above ground dry weight of the plant (Table 1). Early sowing was associated with more dry matter production owing to better mobilization of photosynthates towards reproductive parts in accordance with Ali *et al.* (2009) and Dai *et al.* (2015), which in turn resulted into higher CGR and RGR indices (Fig 2 and Fig 3). More biomass production is the foundation of higher seed cotton yield (Khan *et al.* 2020). However, Bange and Milroy (2004) found that size of the plant during beginning of reproductive stage was important for higher biomass production. Higher seed cotton yield due to significant improvement in various yield attributes such as more bolls per plant and higher boll weight was found to be reason behind significantly better yield under early sown of cotton as compared to delayed sowing (Singh *et al.* 2011). The present findings also elucidate that better dry matter production under crop sown on April 20 over the delayed sowing might be advantageous to achieve higher cotton productivity.

Effect of cultivars on dry matter production and partitioning: Among the tested cultivars there were non-significant differences for dry matter accumulation, except for stem component at 150 DAS and for leaves at 120 and 150 DAS where cultivars F 1861 accumulated significantly higher dry matter (Table 1 and Table 2). Besides the production and partitioning characteristics, it was the timing of the commencement of reproductive phase that differed distinctly among the studied genotypes (Bange and Milroy 2004). As far as dry matter accumulation into fruiting bodies at maturity was concerned, the cultivar NCS 855 BGII (458.1 g/m^2) recorded maximum followed by RCH 650 BGII (432.2 g/m^2). The data elucidated that both *Bt* cultivars performed significantly better than the non *Bt* cultivars i.e. F 1861 (403.3 g/m^2) and F 2228 (401.9 g/m^2) and trend remained similar throughout crop growth period except at 90 DAS (Table 3). *Bt* cultivars accumulated significantly higher dry matter (~9%) in fruiting bodies than the non *Bt*

Table 1 Dry matter accumulation (g/m^2) in cotton stem under different sowing environments

Treatment	30 DAS			60 DAS			90 DAS			120 DAS			150 DAS			At harvest (180 DAS)		
	Faridkot	Bathinda	Pooled	Faridkot	Bathinda	Pooled	Faridkot	Bathinda	Pooled	Faridkot	Bathinda	Pooled	Faridkot	Bathinda	Pooled	Faridkot	Bathinda	Pooled
Sowing date																		
April 20	13.2	12.5	12.8	37.3	37.4	37.4	164.2	163.3	163.8	318.3	320.6	319.4	528.1	517.0	522.5	604.8	610.4	607.6
May 10	11.7	10.7	11.2	33.9	35.0	34.4	146.6	153.0	149.8	298.3	298.6	298.5	474.5	473.8	474.1	511.1	564.4	537.7
May 30	8.4	8.3	8.33	26.6	26.6	26.6	111.5	110.5	111.0	268.8	267.0	267.9	389.5	394.3	391.9	420.4	445.9	433.2
CD (5%)	1.2	1.3	0.74	3.4	3.0	1.9	8.8	11.8	6.1	20.1	15.5	10.6	40.6	55.9	28.7	60.0	67.0	37.8
Cultivar																		
F 2228	11.4	10.7	11.0	33.9	33.9	33.9	147.0	148.8	147.9	301.3	305.3	303.3	485.6	495.6	490.6	525.0	573.3	549.1
F 1861	11.8	10.8	11.3	34.2	35.3	34.7	149.3	151.5	149.3	314.7	310.7	312.7	489.7	505.0	497.4	530.5	589.7	560.1
NCS 855 BGII	10.8	10.4	10.6	31.8	31.9	31.8	138.3	137.8	138.1	282.9	283.9	283.4	441.6	437.9	439.8	502.4	507.6	505.0
RCH 650 BGII	10.4	10.1	10.2	30.5	30.9	30.7	130.7	130.9	130.8	281.7	281.7	281.7	439.2	408.2	423.7	490.4	490.3	490.3
CD (5%)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	45.64	NS	NS	NS

Table 2 Leaf dry matter accumulation (g/m^2) of cotton under different sowing environments

Treatment	30 DAS			60 DAS			90 DAS			120 DAS			150 DAS			At harvest (180 DAS)		
	Faridkot	Bathinda	Pooled	Faridkot	Bathinda	Pooled	Faridkot	Bathinda	Pooled	Faridkot	Bathinda	Pooled	Faridkot	Bathinda	Pooled	Faridkot	Bathinda	Pooled
Sowing date																		
April 20	29.1	27.4	28.2	44.9	45.1	45.0	154.9	154.1	154.5	383.5	384.6	384.0	371.9	372.6	372.2	346.9	344.1	345.5
May 10	26.4	24.1	25.3	41.7	43.0	42.4	138.3	144.2	141.3	358.7	358.1	358.4	348.7	346.1	347.4	313.7	321.0	317.4
May 30	19.9	19.8	19.8	34.4	34.4	34.4	105.1	104.1	104.6	324.6	320.1	322.4	314.6	308.1	311.4	277.9	267.6	272.8
CD (5%)	2.1	2.6	1.38	2.6	6.1	2.7	8.1	11.4	5.8	42.8	18.9	19.4	23.7	18.8	12.6	27.1	28.0	16.2
Cultivar																		
F 2228	25.7	24.2	24.9	41.9	42.1	42.0	132.3	133.9	133.1	371.2	364.8	368.0	362.0	352.8	357.4	332.3	319.4	325.8
F 1861	26.5	24.3	25.4	42.0	43.3	42.7	137.7	141.8	139.7	393.4	375.5	384.4	381.4	363.5	372.5	346.2	332.9	339.5
NCS 855 BGII	24.6	23.6	24.1	39.4	39.4	39.4	131.6	131.1	131.4	339.2	340.2	339.7	327.2	328.2	327.7	290.9	305.0	298.0
RCH 650 BGII	23.7	22.9	23.3	38.1	38.5	38.3	129.5	129.7	129.6	318.6	336.6	327.6	309.6	324.5	317.1	282.0	286.4	284.2
CD (5%)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	40.42	NS	NS	39.23	NS	NS	29.98

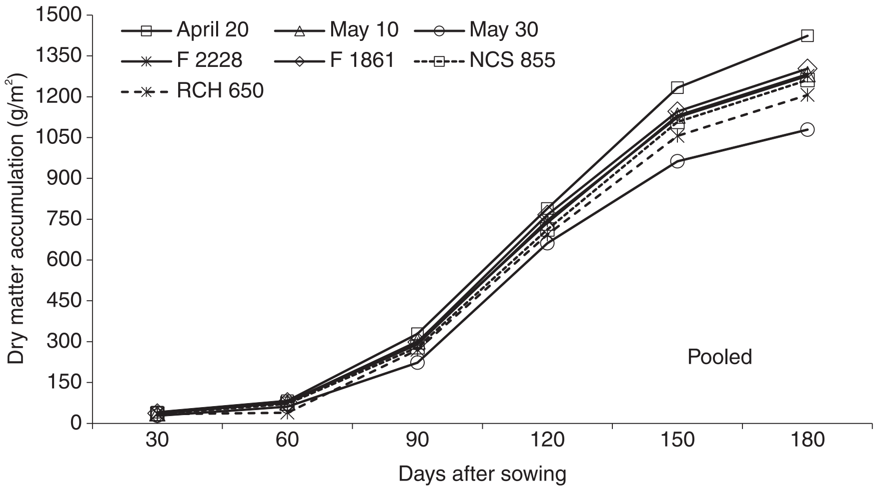

Fig 1 Effect of different treatments on total above ground dry matter accumulation (g/m^2) of cotton (Pooled over locations).

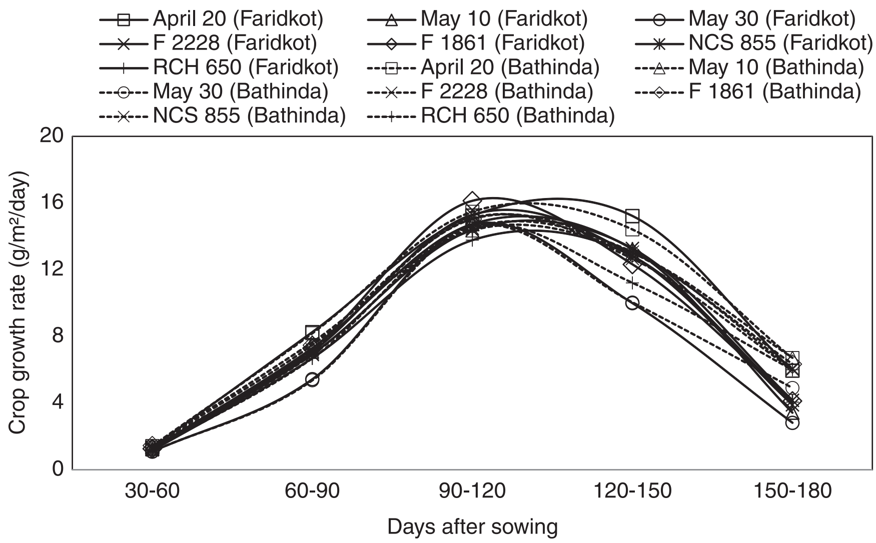

Fig 2 Effect of sowing dates and cultivars on crop growth rate of cotton.

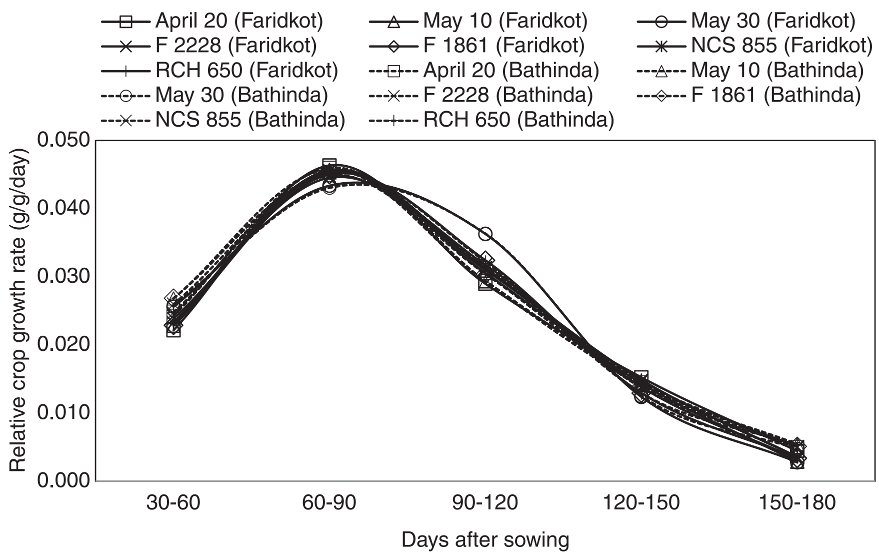

Fig 3 Effect of sowing dates and cultivar on relative growth rate of cotton.

cultivars which might be due to their inherent genetic characters (Kaur *et al.* 2019). Besides better fruiting structures, *Bt* cultivars also possessed the quality of producing higher total dry matter over non *Bt* cultivars (Joshi *et al.* 2011). Higher seed cotton yield for *Bt* cotton hybrids has been evident in accordance with findings of Mishra *et al.* (2021) who reported better yield contributing parameters such as more bolls per plant and bigger boll size to be primary reason for superiority of transgenic cultivars over conventional varieties.

Effect of sowing dates and cultivars on crop growth rate (CGR): Among different sowing dates, maximum crop growth rate (CGR) was observed around 90–120 DAS with values being maximum (15.24 g/m^2/day) for April 20 sown crop followed by May 10 (14.74 g/m^2/day) and May 30 (14.71 g/m^2/day) at Faridkot. Whereas, the corresponding values at Bathinda were 15.48, 14.69 and 14.61 g/m^2/day, respectively (Fig 2). Late sowing (May 30) resulted about 30% reduction in CGR than April 20 sown crop. Initially, CGR was low but it followed a phenomenal increase from 90 to 120 DAS and after that it again decreased slowly near maturity in conformity with findings of Ali *et al.* (2014). Among, tested cultivars higher CGR was observed in cultivar F 1861, followed by F 2228, NCS 855 BGII and RCH 650 BGII, at both locations (Fig 2). Distinct difference in the CGR values among studied cultivars and sowing dates, may be due to the differential response of endogenous plant growth regulators like, cytokinins (Rauf and Sadaqat 2007). Moreover, cultivar-dependent differential responses would be helpful in the identification of cultivars best suited to a particular environment to alleviate the impact of various abiotic stresses during vegetative and reproductive stages in accordance with Singh *et al.* (2018).

Effect of sowing dates and cultivars on relative growth rate (RGR): RGR also called as efficiency index, is more equitable comparison to respond the environmental and

Table 3 Dry matter accumulation (g/m^2) in fruiting bodies (buds, flowers and bolls) and yield of cotton under different sowing environments

Treatment	90 DAS			120 DAS			150 DAS			At harvest (180 DAS)			Seed cotton yield (kg/ha)		
	Faridkot	Bathinda	Pooled	Faridkot	Bathinda	Pooled	Faridkot	Bathinda	Pooled	Faridkot	Bathinda	Pooled	Faridkot	Bathinda	Pooled
Sowing date															
April 20	10.8	10.8	10.8	85.4	86.1	85.7	341.0	335.4	338.2	470.6	471.4	471.0	3006.4	2887.2	2946.8
May 10	9.7	10.1	9.87	79.7	80.0	79.8	308.9	308.2	308.5	411.3	444.2	427.7	2783.1	2671.0	2727.0
May 30	7.3	7.3	7.3	71.8	71.6	71.7	259.5	258.7	259.1	351.1	394.7	372.9	2129.5	2052.3	2090.9
CD (5%)	0.6	0.8	0.4	5.2	4.7	2.9	23.6	19.7	12.8	46.3	20.2	21.0	425.7	319.0	220.9
Cultivar															
F 2228	8.9	9.1	8.9	74.7	74.5	74.6	277.4	276.0	276.7	391.8	412.0	401.9	2376.3	2214.2	2295.3
F 1861	9.4	9.7	9.5	70.0	67.9	69.0	276.6	275.8	276.2	394.9	411.8	403.3	2225.8	2127.4	2176.6
NCS 855 BGII	9.5	9.4	9.4	88.9	89.2	89.0	340.5	339.0	339.8	441.1	475.8	458.1	3026.6	2968.2	2997.4
RCH 650 BGII	9.2	9.3	9.3	82.2	85.3	83.7	318.1	312.2	315.2	416.3	448.2	432.2	2930.0	2837.4	2883.7
CD (5%)	NS	NS	NS	7.0	12.8	7.04	49.6	48.7	33.54	35.5	28.3	21.91	182.9	223.9	139.5

management limitations. Among sowing dates, higher RGR was observed in early sowing (April 20) except at 30–60 and 90–120 DAS where late sown crop (May 30) was leading (Fig 3) at both the locations. For early (April 20), mid (May 10) and late (May 30) sowings, the RGR during 30–60 DAS was 0.022, 0.023 and 0.026 g/g/day at Faridkot and 0.024, 0.027 and 0.026 g/g/day, respectively at Bathinda. With respect to periodical RGR values among evaluated genotypes, *Bt* cultivars were leading during 60–90, 120–150 and 150–180 DAS (Fig 3) over non *Bt* cultivars. Benefits of higher CGR as well as RGR in early sown crop have been also documented by Ali *et al.* (2009). RGR was higher during vegetative stage (before squaring i.e. 60–90 DAS) and then gradually decreased towards reproductive stage and maturity under all the sowing environments in line with Afzal *et al.* (2018). *Bt* cultivars has better morphological, phenological and physiological characters, higher retention of sink structures and more efficient partitioning towards sink structures (Prakash *et al.* 2008, Kaur *et al.* 2019). On the other hand, non *Bt* cotton cultivars accumulated more biological yield which may be due to the loss of fruiting structures that impose indeterminate characters in cotton plants (Thakur *et al.* 2017).

Variation in the weather conditions profoundly influenced the rate of dry matter accumulation of cotton, at both locations. It can be concluded that early sown cotton crop was efficient to accumulate higher dry matter as compared to delayed sowing. Consequently, early sown cotton in April month was able to attain higher CGR and RGR than delayed and late sowing dates. Among cultivars, there was not much difference in dry matter accumulation and partitioning except for reproductive parts. *Bt* cotton cultivars accumulated significantly higher dry matter towards fruiting bodies, which might be a prime reason for their better performance in terms of higher yield over non *Bt* genotypes.

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