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RESEARCH ARTICLE

Physiological basis of variations in yield of commercial Bt cotton hybrids

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SUMMARY

A field experiment was conducted during 2010-11 under irrigated conditions at Main Agricultural Research Station, Raichur. Twenty two Bt cotton hybrids released by various private firms were evaluated for seed cotton yield and yield parameter along with the quality, physiological and biophysical parameters. Results revealed that Bt cotton hybrids differed significantly with respect to yield, yield components and quality parameters (*viz.*, seed cotton yield, lint yield, no. of bolls per plant, ginning out percentage, fibre strength, 2.5% span length). Physiological parameters (radiation attenuation, SPAD chlorophyll values, SLW and nitrate reductase activity) also recorded the significant differences among the hybrids. Leaf area index (LAI), chlorophyll content and nitrate reductase (NR) enzyme activity was more in the Bt cotton hybrids recorded with the more seed cotton yield. The correlation studies indicated a significant correlations between number of bolls per plant and seed cotton yield (r=0.23*). However, positive correlation (r=0.567) was displayed by sympodial branches with seed cotton yield, which showed that seed cotton yield was greatly influenced by sympodial branches. Whereas bolls per plant exhibited strong positive association with seed cotton yield (r=0.96**). However, tmonopodial branches per plant showed non significant association with the seed cotton yield.

Key Words : Chlorophyll, Cotton, LAI, NR, Radiation attenuation, Seed cotton yield

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Cotton (*Gossypium hirsutum* L.) "King of fibre"and the leading fibre crop of the world. In Karnataka, it is grown over an area of 3.56 lakh hectares with a production of 7.0 lakh bales and a productivity of 334.0 kg lint per hectare (Afiah and Ghoneim, 2000). Cotton is a long duration crop, which is greatly influenced by seasonal and environmental fluctuations over different locations. High yielding varieties/ hybrids with stable performance over different agro climatic conditions had great significance towards sustainable production and productivity. A genotype is known to show differential phenotypic response in developments when introduced in different environments.

The chlorophyll virtually essential pigments for the conversion of light energy to stored chemical energy. The amount of solar radiation absorbed by a leaf is a function of the photosynthetic pigment content; thus, chlorophyll content can directly determine photosynthetic potential and primary production (Curran *et al.*,1990, Filella *et al.*,1995). In addition, Chl gives an indirect estimation of the nutrient status because much of leaf nitrogen is incorporated in chlorophyll. Canopy light interception, which determines plant biomass production, depends on leaf area index (LAI) and canopy architecture. LAI is the ratio of total leaf area per unit ground area, and it indicates canopy volume also. Usually, larger canopy volume or greater LAI values indicate greater light interception. Canopy architecture modifies light penetration

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and also affects total canopy light interception. Canopy photosynthesis and productivity is a function of canopy volume and longevity of leaves. Leaf longevity can be modified by plant canopy architecture by modifying the amount of light reaching lower leaves. Light attenuation affects the development of bolls at lower sympodia. Light is an important factor controlling the induced synthesis of nitrate reductase in green plants (Hagemani and Flesher, 1960).

Several Bt cotton hybrids have been evolved and recommended for commercial cultivation. Stable performance in yielding ability is a valuable attribute in a crop, particularly long duration crop like cotton which is grown as rainfed as well as irrigated under diverse agro climatic situations. But till date the performance of Bt cotton hybrids is not known for stability under varying agro climatic conditions. The Bt cotton hybrids developed so far differ in their morphology, phenology and physiological characters including yield .

Keeping all these in view, it is desirable for plant breeder to know the extent of relationship between yield and its various components which will facilitate in selecting plants of desirable traits considering with the physiological parameters. Considerable emphasis has been given on the inter relationship between yield and yield components in cotton. Fonseca and Paterson (1968) found that correlation co-efficient analysis measures the magnitude of relationship between various plant characters and determines the component character on which selection can be based for improvement in seed cotton yield. The understanding of the correlation of factors influencing yield is a pre-requisite for designing an effective plant breeding programme.The aim of this study was to understand interrelationships of seed cotton yield, yield components and morpho-physiological and biophysical characters in Bt cotton hybrids.

MATERIAL AND METHODS

The experimental material consisted of 22 released Bt cotton hybrids developed by different private seed companies. The complete set of 22 hybrids was tested at Main Agricultural Research Station, Raichur. The material was sown in Randomized Block Design using three replications with spacing of 90 x 60 cm. Each entry had five rows of 6 m length. The whole experiment was conducted under irrigated condition.Plant protection measures were taken as per the recommended package of practices. Physiological and biophysical parameters were recorded on five randomly selected plants. The radiation attenuation was measured by using PAR/LAI Ceptometer (AccuPAR PAR/LAI ceptometer model LP-80 Decagon Devices,Inc. USA) at above the canopy and in the middle of the canopy at 60 and 120 DAS (Days after sowing) in randomly selected five plants and expressed in percentage. The leaf area index was also recorded by PAR/LAI Ceptometer (LP-80 Decan Divice Technology USA Model) at 60 and 120 DAS. Specific leaf weight was measured by disc method as suggested by Vivekanandan *et al.* (1972). Ten leaf discs of known size 5x3 cm were taken from five plants. Both disc and remaining leaf blades were oven dried at 75-80^0C for 48 hours and the specific leaf weight was calculated and expressed in mg/dm^2. Leaf chlorophyll content was measured by a Minolta SPAD-502 chlorophyll meter at 60 and 120 days after sowing. Leaf chlorophyll readings were taken on the fifth fully expanded leaf below the terminal shoot of the plant.Nitrate reductase activity was determined by the procedure of Murthy (1999).

RESULTS AND DISCUSSION

The Bt cotton hybrids exhibited wide variability for seed cotton yield, lint yield, ginning out percentage (GOT), no. of monopodia, no. of sympodial branches, no. of bolls, 2.5 per cent span length and fibre strength parameters (Table 1).Yield is the manifestation of various morphological, physiological, biophysical, biochemical and growth parameters in any crop. The difference in yield and yield attributes of cottons hybrids were due to both genetic and environmental factors. There was a considerable variation in seed cotton yield ranging from 1150 kg per ha. to 1819 kg per ha. was recorded. The Bt cotton hybrids differed significantly with respect to seed cotton yield. The higher seed cotton yield could be due to relatively higher biomass,better partitioning of assimilates towards reproductive structures, higher values of yield components,chlorophyll content, specific leaf weight and better retention of bolls. Among the hybrids the maximum seed cotton yield was recorded in ACH-177-2 BG-II (1819kg/ha) followed by MRC-7347 BG-II (1763 kg/ha) and Mallika BG-II (1751kg/ha) as compared with mean (1492 kg/ha). For lint yield the Bt hybrid ACH-177-2 BG-II (633 kg/ha) recorded maximum followed by Mallika BG-II (627 kg/ha) and MRC-7347 BG-II (609 kg/ha as compared with mean (524 kg/ha) of all the hybrids. Tulsai-188 BG-II (38.2%) recorded the maximum ginning outturn followed by Pratik-9632 BG-II (37.8 %) and Rasi-530 BG-II (37.6 %). This indicated that increase in seed cotton yield was due to increase in number of sympodial branches per plant, number of bolls per plant and also indicated positive significant correlation with seed cotton yield (Table 3). But there was negative correlation with 2.5 per cent span length ($r = -0.10$) and fibre strength ($r = -0.52$). The similar findings were noticed by Bennet *et al.* (2001), Butter *et al.* (2007) and Wier *et al.*, (1998). With respect to fibre quality characters such as 2.5 per cent span length and fibre strength Bt cotton hybrids Tulasi-118 BG-II (33.1 mm) and hybrid Bunny Bt (32.7 mm) recorded greater 2.5 per cent span length than population mean (31.28). While for the fibre strength MRC-7351 BG-II (24.2 g/tex) followed by Rakhi-621 BG-II (23.7 g/tex) recorded higher fibre strength than population mean (22.68), (Table 3). These Bt cotton hybrids also indicated negative correlation with seed cotton yield.

There was non-significant correlation (r=0.34) between number of monopodial branches per plant and seed cotton yield(Table 3). This may be due to different genetic makeup of the experimental material. Surriya (1996) and Murthy (1999) recorded similar observations in regard to the relationship of monopodial branches and seed cotton yield.

Sympodial branches form the principal segment of cotton plant on which the fruiting bodies develop. Among Bt hybrids MRC-7160 BG-II (23.4) and hybrid MRC-7347 BG-II (23.3) recorded higher sympodial branches which also had higher number of bolls and seed cotton yield. This indicates that the number of sympodial branches have a great role in the yield determination. The number of sympodial branches per plant was positively correlated with seed cotton yield (r=0.16). Higher number of sympoidal branches indicate formation of more fruiting points (Khorgade and Ekbote, 1980; Giri and Upadhyay, 1980). Study on number of bolls per plant revealed that there had been positive and highly significant association between number of bolls per plant and seed cotton yield. The similar findings were noticed by Surriya (1996), Larik *et al.*,1999, Murthy (1999), Soomro (1999), Sultan *et al.* (1999), Satange *et al.* (2000), Afiah and Ghoneim (2000) and Hussain *et al.* (2000).

Leaf area index and the rate of photosynthsis decide the production of plant biomass.Specific leaf weight which indicate the thickness of the leaves and is known to have a positive correlation with photosynthetic rate (Rasulov and Assrrorov, 1982). The Bt cotton hybrids indicated considerable variation in LAI. Among the hybrids , the maximum LAI was recoded (8.41) in VICH-303 BG-II followed by hybrid

Table 1: Kapas yield, lint yield and yield components of commercially cultivated Bt cotton hybrids

Sr. No.	Cotton hybrids	Kapas yield (kg/ha)	Lint yield (kg/ha)	GOT (%)	No. monopodia/plant	No. sympodia/plant	No. bolls/ plant	2.5% span length (mm)	Fibre strength (g/tex)
1.	Tulasi-9 BG-II	1686	580	34.4	2	20.7	37.80	31.7	22.1
2.	Tulasi-4 BG-II	1557	552	35.5	1.5	20.1	44.46	31.1	21.8
3.	Tulasi-118 BG-II	1376	530	38.2	1.4	21.8	43.50	33.1	22.7
4.	Tulasi-117 BG-II	1150	384	33.4	1.2	16.7	38.93	31.9	23
5.	MRC-7347 BG-II	1763	609	34.5	1.6	23.3	47.43	31.4	22.3
6.	MRC-7160 BG-II	1306	463	35.4	1.4	23.4	35.86	31.7	22.8
7.	MRC-7351 BG-II	1424	514	36.1	1.5	18.5	31.76	32.4	24.2
8.	MRC-7383 BG-II	1638	539	32.9	1.5	18.9	38.53	31.4	21.7
9.	Bunny-Bt	1732	581	33.5	1.8	19.6	40.73	32.7	23
10	Bunny-Bt 2	1482	494	33.3	1.9	18.9	44.00	30.3	22.6
11.	Chirutha BG-II	1319	494	37.4	1.9	22.7	42.33	32.5	22.7
12.	Mallika BG-II	1751	627	35.8	1.4	17.3	46.70	30.6	21.4
13.	ACH-33-2 BG-II	1415	501	35.4	1.6	22.9	48.26	31.6	22
14.	ACH-177-2 BG-II	1819	633	34.8	1.9	19.9	37.36	31.1	22.5
15.	ACH-155-2 BG-II	1485	501	33.7	1.8	20.4	40.60	31.3	23
16.	Pratik-9632 BG-II	1642	621	37.8	2	22.2	39.63	28.9	21.3
17.	Maruti-9632BG-II	1569	503	32.0	1.6	19.5	36.43	30.8	23.3
18.	Rakhi-621 BG-II	1324	487	36.8	1.8	18.5	36.70	31.6	23.7
19.	Rasi-530 BG-II	1325	498	37.6	1.7	16.7	38.13	27.9	23
20.	RCH-2 BG-II	1404	488	34.8	1.7	18.3	36.40	30.8	22.4
21.	VICH-5 BG-II	1356	471	34.7	1.7	17.9	38.93	31.1	23.4
22.	VICH-303BG-II	1299	453	34.9	1.6	19.9	40.60	31.6	23.3
	Mean	1492	524.05	35.17	1.69	19.92	40.23	31.28	22.68
	C.V. %	14.5	15.12	5.3	7.94	7.88	16.10	4.41	8.23
	S.E. ±	54.86	30.47	1.52	0.11	1.28	1.67	2.15	1.34
	C.D. (0.05)	110.71	61.48	3.07	0.22	2.59	3.38	5.59	3.61

VICH-5 BG-II (7.75) and ACH-177-2 BG-II (7.06). VICH-303 BG-II also recorded more SLW as compared to other hybrids. The assimilate partitioning might helped in development of bolls and fruiting bodies and resulted in maximum seed cotton yield. A similar results were reported by Landiver *et al*.(1983).

Canopy light interception determines plant biomass production, which depends on leaf area index (LAI) and canopy architecture. Light penetration to the lower layers of canopy keep the leaves photosynthetically active and contribute for the development of bolls at lower levels. Radiation attenuation plays important role in Bt cotton, since Bt cotton retains more fruiting structures and there will be heavy demand for the photo assimilates for the development of bolls. Among Bt cotton hybrids studied Rasi-530 BG-II recorded highest attenuation followed by Tulasi-9 BG-II and MRC-7351 BG-II as compared with mean(Table 2). Higher per cent of radiation attenuation indicated that hybrids have thicker leaf canopy and more leaf area so that light penetration is less.

The total chlorophyll content determine the photosynthetic capacity of the genotypes and influences the rate of photosynthesis, dry matter production and the yield (Krasichkova *et al.*,1989). Among the Bt hybrids VICH-303 BG-II recorded highest chlorophyll content followed by MRCH-7160 BG-II at 60 DAS and 120 DAS. Hybrid having the higher chlorophyll content also recorded higher seed cotton yield indicated a positive association between chlorophyll content and seed cotton yield. The physiological function of NR is to catalyze pyridine nucleotide-dependent nitrate reduction as a component of the nitrogen-acquisition mechanism in higher plants, fungi and algae. The degree of the plant response to nitrate depends on other environmental and genetic factors such as light and plant genotype (Campbell, 1999). Bt cotton hybrids differed significantly for enzyme NR activity. Among the hybrid MRC-7383 BG-II recorded highest NR activity at 60 and 120 DAS. There was

Table 2 : Physiological and biochemical parameters of commercially cultivated Bt cotton hybrids

Bt cotton hybrids	Radiation attenuation (%)		Leaf area index		SPAD chlorophyll values		Specific leaf weight (mg/dm^2)		Nitrate reductase activity (µmoles gm^{-1}hr^{-1})	
	60 DAS	120 DAS	60 DAS	120 DAS	60 DAS	120 DAS	60 DAS	120 DAS	60 DAS	120 DAS
Tulasi-9 BG-II	32.34	25.75	4.51	3.85	38.01	42.81	5.80	9.00	0.474	0.321
Tulasi-4 BG-II	21.32	12.88	4.91	4.18	38.17	47.28	6.67	7.33	0.466	0.280
Tulasi-118 BG-II	30.78	13.85	5.51	4.28	39.23	46.23	5.93	7.40	0.385	0.351
Tulasi-117 BG-II	21.85	15.31	5.00	4.52	37.23	42.85	7.00	8.00	0.511	0.340
MRC-7347 BG-II	25.30	16.15	5.31	4.56	39.07	45.84	5.53	7.40	0.408	0.355
MRC-7160 BG-II	23.09	15.92	5.69	5.92	39.24	42.37	6.40	8.60	0.377	0.346
MRC-7351 BG-II	31.70	25.33	5.66	6.21	36.26	47.09	5.93	9.20	0.376	0.328
MRC-7383 BG-II	25.28	20.58	6.38	5.68	36.59	43.05	6.00	8.27	0.996	0.351
Bunny-Bt	27.04	19.65	6.73	6.10	36.83	41.51	6.20	9.27	0.702	0.357
Bunny-Bt 2	30.80	23.71	5.09	3.3	36.57	44.19	6.27	7.53	0.238	0.325
Chirutha BG-II	28.83	22.11	4.41	4.07	37.18	42.03	5.80	8.20	0.510	0.331
Mallika BG-II	23.70	15.90	4.14	3.83	36.40	47.57	6.80	8.33	0.400	0.350
ACH-33-2 BG-II	23.88	6.64	4.12	3.19	35.63	42.49	6.33	8.07	0.269	0.355
ACH-177-2 BG-II	18.45	9.34	7.06	6.32	35.98	46.49	5.67	8.00	0.387	0.350
ACH-155-2 BG-II	22.82	14.45	7.01	6.58	36.79	42.54	6.33	7.80	0.651	0.349
Pratik-9632 BG-II	27.40	19.55	5.25	5	35.63	43.09	6.20	8.00	0.496	0.348
Maruti-9632 BG-II	23.96	22.09	5.18	4.32	37.37	46.39	6.07	8.20	0.470	0.357
Rakhi-621 BG-II	19.33	10.32	5.11	4.16	36.83	46.71	7.00	7.67	0.388	0.349
Rasi-530 BG-II	34.47	26.15	5.25	4.81	36.37	43.92	6.60	8.73	0.448	0.332
RCH-2 BG-II	23.82	17.91	5.17	4.17	36.29	43.47	6.67	7.53	0.434	0.309
VICH-5 BG-II	24.58	18.00	7.75	6.1	38.15	47.53	6.87	8.73	0.548	0.359
VICH-303BG-II	23.10	14.43	8.41	5.94	39.61	44.91	7.20	9.27	0.412	0.348
Mean	25.63	17.55	5.62	4.89	37.25	44.56	5.98	8.13	0.460	0.338
C. V.%	15.46	13.35	11.5	13.4	4.42	3.58	4.18	3.36	7.547	6.276
S.E.±	3.23	4.62	0.51	4.33	1.35	1.30	0.20	0.22	0.028	0.017
C.D. (0.05)	6.53	8.12	1.02		2.72	2.63	0.41	0.45	0.057	0.035

Table 3: Correlation co-efficient (r) of seed cotton yield, yield component, qulity characters, physiological and biochemical parameters of commercially cultivated Bt cotton hybrids

		SCY	Lint yield	GOT	No. monopodial	No. sympodial	No. bolls	2.5 % span length	Fibre strength	Radiation attenuation		LAI		SPAD chlorophyll		SLW-		NR	NR
										60	120	60	120	60	120	60	120	60	120
Seed cotton yield		----	0.92**	-0.25	0.34**	0.16	0.23*	-0.10	-0.52	-0.05	0.12	-0.02	0.20	-0.22	0.15	-0.56	-0.04	0.15	0.11
Lint yield			---	0.14	0.37**	0.25*	0.27*	-0.16	-0.57	0.06	0.09	-0.12	0.09	-0.23	0.21	-0.55	-0.08	0.09	0.06
GOT				---	0.09	0.22	0.07	-0.14	-0.07	0.30**	0.46**	-0.26	-0.05	-0.01	0.13	0.02	-0.08	-0.16	-0.12
No. monopodial					---	0.19	-0.08	-0.28	-0.08	0.21	0.13	0.08	0.12	-0.34	-0.24	-0.32	0.05	0.01	-0.04
No. sympodial						---	0.34**	0.29*	-0.28	0.00	0.08	-0.13	0.18	0.32**	-0.31	-0.54	-0.19	-0.14	0.14
No. bolls							---	0.02	-0.56	-0.05	0.16	-0.29		0.11	0.00	-0.04	-0.42	-0.10	0.06
2.5 % span length								---	0.30**	-0.15	-0.19	0.11	0.06	0.39**	-0.04	-0.21	0.08	0.12	0.12
Fibre strength									---	0.05	0.11	0.39**	0.42**	0.19	0.19	0.18	0.35**	-0.20	0.16
Radiation attenuation	60									---	0.09	-0.24	0.11	-0.03	-0.21	-0.36	0.31**	-0.01	-0.15
	120										--	0.14	0.17	0.09	0.11	-0.09	0.34**	-0.06	0.14
LAI	60											----	0.09	0.29	0.09	0.18	0.37**	0.36**	0.35**
	120												---	0.11	0.14	0.22	0.41**	0.34**	0.25
SPAD chlorophyll	60													---	0.17	0.07	0.05	-0.07	0.02
	120														---	0.14	-0.17	-0.37	-0.05
SLW	60															---	0.10	-0.03	-0.10
	120																---	0.19	0.23
NR	60																	---	0.08
	120																		---

* and ** Indicate significance of value at P=0.05 and 0.01, respectively

positive correlation with seed cotton yield at 60 and 120 DAS (r= 0.15 and r= 0.11), respectively. This indicates the enzyme reductase activities are reduced in later stages of crop growth.

Conclusion :

Data recorded in the investigation revealed that there was a lot of variability in commercially released Bt cotton hybrids in northern Karnataka with respect to yield and yield components along with the physiological and biophysical parameters. The leaf area index, chlorophyll content and light attenuation were the important parameters to be considered for plant geometry so that nutrient and light may utilize efficiently for the development of bolls. Number of sympodial and monopodial branches also contributes much for the development of flowers and squares. Among the hybrids Tulsi-9BGII and Bunny-Bt 2 yielded maximum kapas yield.

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