Biological Forum – An International Journal **15(11): 275-279(2023)**

ISSN No. (Print): 0975-1130
ISSN No. (Online): 2249-3239

Growth Behaviour of *Bt*-cotton under Legume Intercropping with Paired Planting of Cotton

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(Received: 11 September 2023; Revised: 10 October 2023; Accepted: 20 October 2023; Published: 15 November 2023)
(Published by Research Trend)

ABSTRACT: India is one of the major cotton producing country in the world. Production of cotton increased after the introduction of transgenic *Bt* cotton. The area under cotton is increasing in India. Indian textile industry rapidly moving upward. Therefore, experiment is conducted to study the growth pattern of cotton. A field experiment was conducted at Anand Agricultural University, Anand, Gujarat to study the effect of crop geometry in cotton based cropping system during *kharif* seasons of the years 2020 and 2021. Eight different planting pattern and intercropping system were studied under randomized block design (RBD) with four replications. Periodical examination of data shows that conventional planting of cotton recorded significantly higher dry matter accumulation due to better availability of the resources and less competition compared to the treatments with intercrops and paired planting. Dry matter accumulation directly responsible for growth rate but has no or slight significant effect on crop growth rate, absolute growth rate and relative growth rate.

Keywords: Cotton, Crop growth rate, Absolute growth rate, Relative growth rate.

INTRODUCTION

Cotton is the most important agricultural crop and has great impact of country as well as worlds economics. There for cotton is known as the king of the fibre (Madavi *et al.,* 2017). Cotton is far superior than other fibre crops there for it cannot be compared. Because of the quality and superiority cotton is called as "White Gold" (Anon., 2021b). Textiles industries in India and in world depends on production of cotton. Livelihood of millions of people especially farmers, workers and people associated with industries like trade, manufacturing, transportation, processing and other allied industries are dependent on it. Cotton is widely cultivated crops throughout the world for its great importance as multipurpose crop. It provides lint, oil, hulls, seed meal and linters. Bt cotton introduced in Northern area during 2005-2006 which resulted in increase in cotton area and greater productivity (Mayee *et al.,* 2009). Globally India is one of the largest yarn producer and exporter. In India, only textile industry contribute nearly about 14 % in manufacturing sector and 11 percent in industrial production. Textile industry contributes 4 % to the GDP and 12 % in country's total export earnings (Anon., 2014) As per Cotton Advisory Board estimate, cotton production in India during 2021-22 is expected to be 340.62 lakh bales of 170 kg from 123 lakh hectares with a productivity of 469 kg lint/ha. During the year 2019-20, Gujarat, Maharashtra and Telangana were the major cotton growing states covering around 71% (86.4 lakh hectare) in area under cotton cultivation and 64% (230 lakh bales) of cotton production in India (Anon., 2021a). Cotton is the most important fibre among the Indian textile mills, as a major raw material. In textile industry raw material consumption of cotton is around 60 % (Anon., 2021b). Productivity of cotton in India is lower against world's average. There are several constraints for low productivity in cotton like use of improper planting techniques, competition from weeds, micronutrient deficiency (Boron and Zinc), boll shedding, leaf reddening, sucking pests, fluctuation in rainfall pattern and inadequate quantities of fertilizer use and poor agronomic practices. There are different scientific approaches for increasing the agricultural productivity. One of the best non-economic or less costly approach is intercropping. It is one of the highly promising approach in most countries of Asia, tropical Africa, and central and south America. These countries are characterized by small land holding, limited resource, and low crop productivity (Singh and Ahlawat 2011, 2012). The paired row planting and skip row planting method increased the yield when compared with conventional planting. It made best use of land resources by providing space for growing intercrops without reducing the plant population of main crop (Khan *et al.,* 2001). Different planting methods are adopted for better utilization of available resources like moisture for better growth and

development. It also maximizes the utilization of climatic elements *viz*., sunlight, precipitation, humidity, temperature etc. and other resources. The various planting patterns have been adopted and developed to exploit these resources for higher crop production. Ghadge (2003) reported that the rows of cotton can also be paired or skipped without affecting the plant population and adjusting spacing for cotton seeding did not show any effect on yield and fiber qualities. Thus for increasing productivity per plant, the suitable planting pattern needs to be investigated.

The cropping intensity in Gujarat is low which is (124 per cent) as against 145 per cent in India. Intercropping involves growing of two or more crops simultaneously on same piece of land. The crops does not need to be sown at exactly the same time, their harvest times may also differ, but they are usually 'simultaneous' for a most part of their growing periods (Willey *et al.* 1979). Cultivation of Bt cotton is started by More than 60 lakhs Indian farmers in nearly 9.4mha upto 2010, Which is almost 90% of the India's total cotton area (James, 2010). Bt cotton mostly sown at wider spacing of 90-120 cm and therefore it provides an opportunity for cultivation of short- duration intercrops (Singh *et al.*,2009) for better utilization of land, solar energy, available soil moisture and nutrients. The current are under cultivation of *Bt.* cotton is 93 per cent of the total cultivated area of cotton. Although, the average production is lower than that of other countries indicating an opportunity to increase production further.

MATERIALS AND METHOD

A field experiment was conducted at Agronomy Farm, B. A. College of Agriculture, Anand Agricultural University, Anand, Gujarat during *kharif* seasons of the years 2020 and 2021. Eight different planting pattern and intercropping system *viz*; Conventional planting of cotton (120 cm × 45 cm) (T_1), Paired row planting of cotton (60-180-60 cm × 45 cm) (T_2), Paired row cotton + 2 row of groundnut (T_3), Paired row cotton + 3 row of groundnut (T_4), Paired row cotton + 4 row of groundnut (T_5), Paired row cotton + 2 row of green gram (T_6), Paired row cotton + 3 row of green gram (T_7), Paired row cotton + 4 row of green gram (T_8) were studied under randomized block design (RBD) with four replications. Cotton variety GTHH 49 was tested as main crop while groundnut variety GG 34 and greengram variety GAM 5 was taken as intercrops in *kharif* season. The experimental field had an even topography with a gentle slope having good drainage and loamy sand in texture. Three successive plants from crop line were cut close to the ground at 30 DAS, 60 DAS, 90 DAS, 120 DAS and at harvest by destructive sampling. The plants were initially dried under sun for 48 hrs. followed by hot air oven dried at 65°C till a constant weight was obtained. Then the dry weights were recorded and dry matter accumulation was expressed as g/plant. The different growth rates are were calculated with help of given formulas.

Crop Growth Rate (CGR): The values for CGR g/m^2/day were calculated with the help of the following formula (Watson, 1952).

$$CGR(g/m^2/day) = \frac{1}{A} \times \frac{W_2 - W_1}{t_2 - t_1}$$

Where; W_1 and W_2 = Weight of dry matter of plant (g/plant) at first and second stages

t_1 and t_2 = Time in days of first and second stages

A = Area (m^2)

Note: Here area for all the treatment considered according to 120 cm × 45 cm spacing for obtaining the effect of different number of rows.

Absolute Growth Rate (AGR): The values for AGR were calculated using the formula of Radford (1967) given below and expressed in 'g' per plant per day

$$AGR\ (g/plant/day) = \frac{W_2 - W_1}{t_2 - t_1}$$

Where; W_1 and W_2 = Weight of dry matter of plant (g/plant) at first and second stages

t_1 and t_2 = Time in days of first and second stages

Relative Growth Rate (RGR). The values of RGR were calculated with the help of the following formula (Redford, 1967).

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

Where; W_1 and W_2 = Weight of dry matter of plant (g) at first and second stages

t_1 and t_2 = Time in days of first and second stages

Log_e = Natural logarithm

RESULTS AND DISCUSSION

A. Dry matter accumulation (DMA) in cotton

Dry matter accumulation by plant is directly related to the crop environment. If the all the need of the crop are satisfied crop growth reaches its peak. DMA plant is one of the growth indicator of plant which ultimately results in better yield. On the basis of the DMA we can understand the growth behaviour of plant and growth rate.

Dry matter production/plant measured at 30 DAS did not significantly influenced by planting pattern and intercropping. At 60 DAS paired row planting of cotton recorded significantly higher DMA/plant during year 2020. In year 2021 and in pooled data significantly higher DMA/plant was recorded under conventional planting of cotton over all other treatments. At 90 DAS it was observed from the data that significantly higher DMA/plant was recorded under the treatment T_2 in year 2020.While in year 2021 and on pooled basis significantly higher DMA per plant was recorded under the treatment T_1 respectively over all other intercropping treatments. At 120 DAS significantly higher DMA/plant was observed in paired row planting in the year 2020, while conventional planting of cotton recorded significantly higher DMA/plant in the year 2021 and in pooled mean. At harvest, treatment conventional Planting recorded significantly higher DMA/plant during both the years and in pooled mean. The accumulation of dry matter per plant is probably the best index of growth put forth by crop. It is observed that dry matter/plant increase progressively over the time. The higher increase in dry matter accumulation observed after 60 DAS and 90 DAS while the rate declined after

120 DAS up to the harvest this might be due to leaf senescence.

Significantly higher dry matter accumulation/plant observed in treatments without intercrops might be due to the difference in availability of space and intercrop competition for nutrients, water and sunlight. There is slight decrease in dry matter when two or three rows of intercrop are added in between the space availed due to paired planting. Although there is increase in cotton plant height observed but it didn't increases the dry matter accumulation due to unidirectional growth. The decrease in dry matter accumulation under intercropping was due to the early, vigorous growth of the intercrop and resulted smothering effect on the cotton crop. Groundnut and green gram are legume crops and have beneficial effect by soil nitrogen fixation but having four rows of any of them increases the planting density and ultimately resulted in decline of growth of plant which affected dry matter accumulation of plant. Secondly availability of wider space for the growth in conventional planting of cotton and paired row planting of cotton resulted in maximum growth of photosynthetic structure due to better availability of light, nutrients and water i.e. leaf area having improved rate of biomass synthesis and consequently dry matter accumulation per plant. Thus under wider spacing and two and three rows of groundnut or green gram resulted in better photosynthetic activity and higher dry matter accumulation. These results are in confirmity with the results reported by Wankhade *et al.* (2000); Jayakumar *et al.* (2008); Kumar *et al*. (2017); Manickam and Pillai (2017); Parlawar *et al.* (2017).

B. Crop growth rate (CGR)

Crop growth rate represent the dry weight gained by a crop in a unit area in a given time. Significantly higher crop growth ratewas calculated during first year under paired row planting of cotton. Although, there was no significant difference between conventional planting of cotton and Paired row cotton + 2 rows of groundnut. Meanwhile, conventional recorded significantly higher crop growth rate during second year and on pooled results. It was apparent from the data that the crop growth rate of cotton between 60-90 DAS, 90-120 DAS and 120-Harvest found to be non-significant during both the years and in pooled mean. It was also obvious from the numeric comparison of the data that numerically maximum growth rate was observed under the conventional planting of cotton due to maximum dry matter accumulation. These findings are in conformity with those reported by Singh and Ahlawat (2014).

C. Absolute growth rate (AGR)

Absolute growth rate represent the dry weight increase per unit time. At 30-60 DAS during first year significantly higher AGR was recorded under the paired row planting of cotton. Although, there was at par relation reported with conventional planting of cotton and paired row cotton + 2 rows of groundnut. Whereas, conventional planting of cotton recorded significantly higher absolute growth rate during second year and on pooled mean respectively but it remain at par with treatment T_2 and T_3 during second year while only treatment T_2 was found at par with T_1on pooled results. Absolute growth rate between 60-90 DAS, 90-120 DAS and 120-Harvest was not significantly influenced by different treatments during both the years and in pooled result.

D. Relative growth rate (RGR)

Relative growth rate of crops at time instant (t) is defined as the increase of plant material per unit weight per unit time. At 30-60 DAS the relative growth rate of cotton between 30-60 DAS was not significantly influenced by different treatments during the years 2020 and 2021 but in case of pooled results significant difference was observed due to different treatments. Significantly higher relative growth rate 0.1078 g/g/day was recorded under paired row cotton + 3 rows of green gram in pooled results. Although, there was at par relation reported with conventional planting, paired row planting, paired row cotton + 2 rows of groundnut, paired row cotton + 2 rows of green gram and paired row cotton + 3 rows of green gram. Relative growth rate between 60-90 DAS, 90-120 DAS and 120-Harvest found to be non-significant during both the years and in pooled results.

Here Absolute growth rate and crop growth rate reached maximum between 90 and 120 DAS and thereafter it declined owing to leaf senescence. Relative growth rate of cotton was maximum between 30 and 60 DAS. The growth of cotton was slow up to 30 DAS and attained its peak between 90 and 120 DAS might be due to intercropping and paired row planting, four rows of intercrop induce competition for natural resources like solar radiation, water, nutrient and space. Significant result between 30-60 DAS may be due to peak stage of vegetative growth of groundnut and green gram and dense plant population which resulted in more resource utilization by intercrops and affecting the growth rate of cotton in early stages. Groundnut and greengram are short duration crop with short stature and have non-competitive nature but due to paired row cropping and multiple rows of groundnut or greengram resulted in dense planting and affected the growth rate of cotton. Although two rows and three rows of intercrops didn't affect the growth rate as much as four rows. Planting pattern also affect the growth of cotton as cotton doesn't get as much space as conventional planting further in paired row planting the additional intercrops in between rows increase the pressure on the cotton in early stages which affected its growth, specially dry matter accumulation and yield. These findings are in conformity with those reported by Singh and Ahlawat (2014).

Table 1: Dry matter accumulation at 30 DAS, 60 DAS and 90 DAS in cotton as influenced by different treatments.

T		DMA/plant at 30 DAS (g)			DMA/plant at 60 DAS (g)			DMA/plant at 90 DAS (g)			DMA/plant at 120 DAS (g)			DMA/plant at Harvest (g)		
		2020	2021	Pooled	2020	2021	Pooled	2020	2021	Pooled	2020	2021	Pooled	2020	2021	Pooled
T_1		3.23	3.08	3.15	78.82	79.07	78.94	191.97	195.07	193.52	314.97	328.87	321.92	430.93	442.14	436.53
T_2		3.50	3.70	3.60	82.04	75.35	78.70	196.59	187.50	192.05	315.74	324.12	319.93	416.42	431.98	424.20
T_3		3.63	3.29	3.46	69.82	70.25	70.03	171.71	184.65	178.18	307.37	311.60	309.49	407.65	412.43	410.04
T_4		3.81	3.61	3.71	66.43	68.92	67.67	162.25	170.37	166.31	282.45	291.27	286.86	382.21	391.24	386.73
T_5		3.48	3.67	3.58	60.08	60.81	60.44	152.47	152.28	152.37	257.09	270.48	263.79	348.68	369.63	359.16
T_6		3.75	3.58	3.66	68.24	68.65	68.44	173.32	174.92	174.12	306.63	299.31	302.97	405.96	394.31	400.13
T_7		2.48	2.86	2.67	66.49	65.63	66.06	167.00	173.63	170.32	289.33	291.17	290.25	379.70	377.08	378.39
T_8		3.00	3.13	3.06	60.36	60.58	60.47	151.65	153.01	152.33	271.02	277.01	274.02	364.16	358.82	361.49
SEm ±	Y			0.13			1.46			3.44			4.2			5.23
	T	0.43	0.29	0.26	4.73	3.41	2.75	10.23	9.19	6.48	13.53	13.16	8.83	15.75	13.46	10.46
	Y × T			0.38			4.12			9.72			13.35			14.80
CD (P = 0.05)	Y			NS			NS			NS			NS			NS
	T	NS	NS	NS	13.91	10.03	7.81	30.07	27.03	18.43	39.80	38.72	25.11	52.55	60.19	36.47
	Y × T			NS			NS			NS			NS			NS
CV %		25.59	17.45	21.89	13.07	9.94	11.98	11.97	10.57	11.28	9.23	8.80	9.02	8.17	6.78	7.50

Table 2: Crop growth rate in cotton as influenced by different treatments.

Treatment		CGR (g/m^2/day)											
		(30-60 DAS)			(60-90 DAS)			(90-120 DAS)			(120 DAS to Harvest)		
		2020	2021	Pooled	2020	2021	Pooled	2020	2021	Pooled	2020	2021	Pooled
T_1		4.67	4.68	4.67	6.99	7.18	7.08	7.59	8.26	7.93	3.36	3.28	3.32
T_2		4.85	4.42	4.64	7.07	6.92	7.00	7.35	8.43	7.89	2.91	3.12	3.02
T_3		4.09	4.13	4.11	6.29	7.06	6.68	8.37	7.84	8.11	2.90	2.92	2.91
T_4		3.87	4.03	3.95	5.91	6.26	6.09	7.42	7.46	7.44	2.89	2.89	2.89
T_5		3.49	3.53	3.51	5.70	5.65	5.67	6.46	7.30	6.88	2.65	2.87	2.76
T_6		3.98	4.02	4.00	6.49	6.56	6.52	8.23	7.68	7.95	2.87	2.75	2.81
T_7		3.95	3.87	3.91	6.20	6.67	6.44	7.55	7.26	7.40	2.61	2.49	2.55
T_8		3.54	3.55	3.54	5.64	5.71	5.67	7.37	7.65	7.51	2.69	2.37	2.53
SEm ±	Y			0.09			0.22			0.34			0.10
	T	0.28	0.21	0.18	0.68	0.59	0.42	0.98	0.97	0.65	0.32	0.24	0.20
	Y × T			0.25			0.64			0.97			0.28
CD (P=0.05)	Y			NS			NS			NS			NS
	T	0.83	0.62	0.47	NS	NS	NS	NS	NS	NS	NS	NS	NS
	Y × T			NS			NS			NS			NS
CV %		13.90	10.41	12.29	21.70	18.04	19.91	25.93	25.03	25.48	21.97	17.02	19.68

Table 3: Absolute growth rate in cotton as influenced by different treatments.

Treatment		AGR (g/plant/day)											
		(30-60 DAS)			(60-90 DAS)			(90-120 DAS)			(120 DAS to Harvest)		
		2020	2021	Pooled	2020	2021	Pooled	2020	2021	Pooled	2020	2021	Pooled
T_1		2.52	2.52	2.52	3.77	3.87	3.82	4.10	4.46	4.28	1.81	1.77	1.79
T_2		2.62	2.39	2.50	3.82	3.74	3.78	3.97	4.55	4.26	1.57	1.69	1.63
T_3		2.21	2.23	2.22	3.40	3.81	3.60	4.52	4.23	4.38	1.57	1.58	1.57
T_4		2.09	2.18	2.13	3.19	3.38	3.29	4.01	4.03	4.02	1.56	1.56	1.56
T_5		1.89	1.90	1.90	3.08	3.05	3.06	3.49	3.94	3.71	1.43	1.55	1.49
T_6		2.15	2.17	2.16	3.50	3.54	3.52	4.44	4.15	4.30	1.55	1.48	1.52
T_7		2.13	2.09	2.11	3.35	3.60	3.48	4.08	3.92	4.00	1.41	1.34	1.38
T_8		1.91	1.92	1.91	3.04	3.08	3.06	3.98	4.13	4.06	1.46	1.28	1.37
SEm ±	Y			0.05			0.12			0.18			0.05
	T	0.15	0.11	0.09	0.37	0.32	0.23	0.53	0.52	0.35	0.17	0.13	0.11
	Y × T			0.13			0.34			0.53			0.15
CD (P=0.05)	Y			NS			NS			NS			NS
	T	0.45	0.33	0.25	NS	NS	NS	NS	NS	NS	NS	NS	NS
	Y × T			NS			NS			NS			NS
CV %		13.90	10.41	12.27	21.70	18.04	19.90	25.94	25.03	25.46	21.97	17.02	19.68

Table 4: Relative growth rate in cotton as influenced by different treatments.

Treatment		RGR (g/g/day)											
		(30-60 DAS)			(60-90 DAS)			(90-120 DAS)			120 DAS to Harvest		
		2020	2021	Pooled	2020	2021	Pooled	2020	2021	Pooled	2020	2021	Pooled
T_1		0.1064	0.1084	0.1074	0.0298	0.0301	0.0299	0.0167	0.0175	0.0171	0.0049	0.0046	0.0048
T_2		0.1052	0.1005	0.1028	0.0294	0.0304	0.0299	0.0159	0.0181	0.0170	0.0043	0.0045	0.0044
T_3		0.0989	0.1022	0.1006	0.0298	0.0323	0.0310	0.0197	0.0174	0.0185	0.0044	0.0044	0.0044
T_4		0.0959	0.0988	0.0974	0.0299	0.0302	0.0300	0.0185	0.0179	0.0182	0.0048	0.0046	0.0047
T_5		0.0958	0.0937	0.0947	0.0309	0.0301	0.0305	0.0173	0.0196	0.0185	0.0048	0.0049	0.0048
T_6		0.0982	0.0987	0.0984	0.0313	0.0315	0.0314	0.0190	0.0179	0.0185	0.0044	0.0043	0.0044
T_7		0.1107	0.1048	0.1078	0.0309	0.0324	0.0317	0.0183	0.0173	0.0178	0.0043	0.0041	0.0042
T_8		0.1013	0.0996	0.1004	0.0306	0.0308	0.0307	0.0194	0.0198	0.0196	0.0047	0.0040	0.0043
SEm ±	Y			0.0013			0.0009			0.0008			0.0002
	T	0.0043	0.0033	0.0027	0.0029	0.0023	0.0018	0.0025	0.0023	0.0017	0.0005	0.0004	0.0003
	Y × T			0.0039			0.0027			0.0024			0.0006
CD (P=0.05)	Y			NS			NS			NS			NS
	T	NS	NS	0.01	NS	NS	NS	NS	NS	NS	NS	NS	NS
	Y × T			NS			NS			NS			NS
CV %		8.54	6.57	7.62	19.52	15.05	17.38	28.09	25.12	26.64	21.42	19.28	20.41

CONCLUSIONS

The results of this investigation shows that growth behaviour of cotton under *Bt* cotton+legume intercropping system with green gram and groundnut as intercrops played important role in the growth of plant. Involvement of legumes in cotton is not affecting growth of cotton. These unaffected growth rates had significant positive impact on seed cotton yield. This is relevant considering the need for crop diversification in the *Bt* cotton to minimize the risk associated with sole transgenic cotton.

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How to cite this article: P.M. Parmar, J.C. Shroff, N.N. Chaudhary and S.N. Shah (2023). Growth Behavior of *Bt*-cotton under Legume Intercropping with Paired Planting of Cotton. *Biological Forum – An International Journal*, *15*(11): 275-279.