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Effect of cotton-legume intercropping patterns and crop geometry on growth and yield of Bt cotton

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Abstract
Cotton is the most significant and 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. Productivity of cotton in India is lower compared to global average. There are several constraints for low productivity in cotton like use of improper planting techniques, competition from weeds, micronutrient deficiency, boll shedding, leaf reddening, sucking pests, fluctuation in rainfall pattern and inadequate quantities of fertilizer use and poor agronomic practices. The best method of planning is the one which allows crops to take advantage of growth conditions for root development, shoot development, flowering and fructification. Intercropping is best method of cropping for higher crop production and economic benefits. Nowadays farmers are widely adopting intercropping methods. A research trial was conducted at Anand, Gujarat to study the effect of crop geometry in cotton based cropping system. Eight different planting pattern and intercropping system *viz*; Conventional planting of cotton, Paired row planting of cotton, Paired row cotton with two, three and four rows of groundnut and paired row cropping of cotton with two, three and four rows of green gram were studied. After complete evaluation and analysis of the experimental data, it was decided that some changes are required in old intercropping system and that a new approach of intercropping need to be proposed. The production efficiency of paired row cotton with groundnut or green gram intercropping which was higher than that of monocropping. This paired raw planting pattern with intercropping is suitable for demonstration and adoption in the area, as well as in the cotton belt of the Gujarat.

Keywords: Intercropping, legume, cropping, paired planting

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) [18]. 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) [3]. 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) [20]. 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) [1]. 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) [2]. 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) [3].

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) [32-33]. 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) [10]. 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, humiity, temperature etc. and other resources. The various planting patterns have been adopted and developed to exploit these resources for higher crop production. Ghadge (2003) [6] 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. Many experimental results have indicated that ecological environment of farm can be improved by intercropping of legumes. They improve farm condition by interspecific competition and complementary actions (Latati *et al.*, 2014; Singh *et al.*, 2017) [16, 26].

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) [7]. 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) [31] 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

Field experiment site and cultivars

An experiment was conducted at Agronomy Farm of AAU, Anand, Gujarat to evaluate the “Effect of crop geometry in cotton based cropping system” during *kharif* seasons of the years 2020 and 2021. Cotton variety GTHH 49 was tested as main crop while groundnut variety GG 34 and green gram variety GAM 5 was taken as intercrops in *kharif* season.

The topography of research area was even with slightly gentle slope with good drainage availability. The soil of experimental field was loamy sand in texture.

Experiment design and field management

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.

Yield and yield attributes

Three pickings were taken for harvesting of the seed cotton. Weighing of each picking of seed cotton done separately. Total of these three picking per plot used for calculating total seed cotton yield and expressed in kg/ha. A representative ten bolls from five tagged plants from experiment fields were weighted at each plucking. Than divided with total number of plucked bolls in order to get average boll weight and expressed as boll weight in grams. Fully opened bolls were plucked from five observational plants at each plucking from all the treatments. The average value of open balls was recorded as number of plucked bolls/plant.

Dry pods from the plants of each treatments were separated manually. Pod yield of net plot was recorded and converted into hectare basis after adding the pod weight of earlier threshed five plants. The produce of each net plot area was collected separately and allowed to dry under shade. Manual cleaning and threshing was done by skilled labours. Seed yield was recorded in kg per net plot and then computed on hectare basis as per treatment. According to the average local market prices in middle Gujarat in 2020 and 2021.

Results and Discussion

Growth attributes

Dry matter accumulation

Dry matter production/plant measured at 30 DAS did not significantly influenced by planting pattern and intercropping. Dry matter production/plant at 60 DAS was significantly influenced by different treatments. During first year paired row planting of cotton recorded significantly higher dry matter accumulation/plant (82.04 g). In year 2021 and in pooled data significantly higher dry matter accumulation/plant (79.09 g and 78.94 g, respectively) was recorded under conventional planting of cotton over all other planting pattern and intercropping treatments, but failed to exert their significant superiority over treatment T_2 and T_3 during 2021, while treatment T_2 found at par with conventional planting in case of pooled results. Significantly the lower dry matter accumulation/plant was observed under paired row cotton + 4 rows of groundnut (T_5) during year 2020 and on pooled basis respectively, while in the year 2021 paired row cotton + 4 rows of green gram noted significantly lower dry matter accumulation/plant. At 90 DAS it was observed from the data that significantly higher dry matter accumulation/plant was recorded under the treatment T_2 in year 2020. While in year 2021 and on pooled basis significantly higher dry matter accumulation per plant was recorded under the treatment T_1 respectively over all other planting pattern and intercropping treatments.

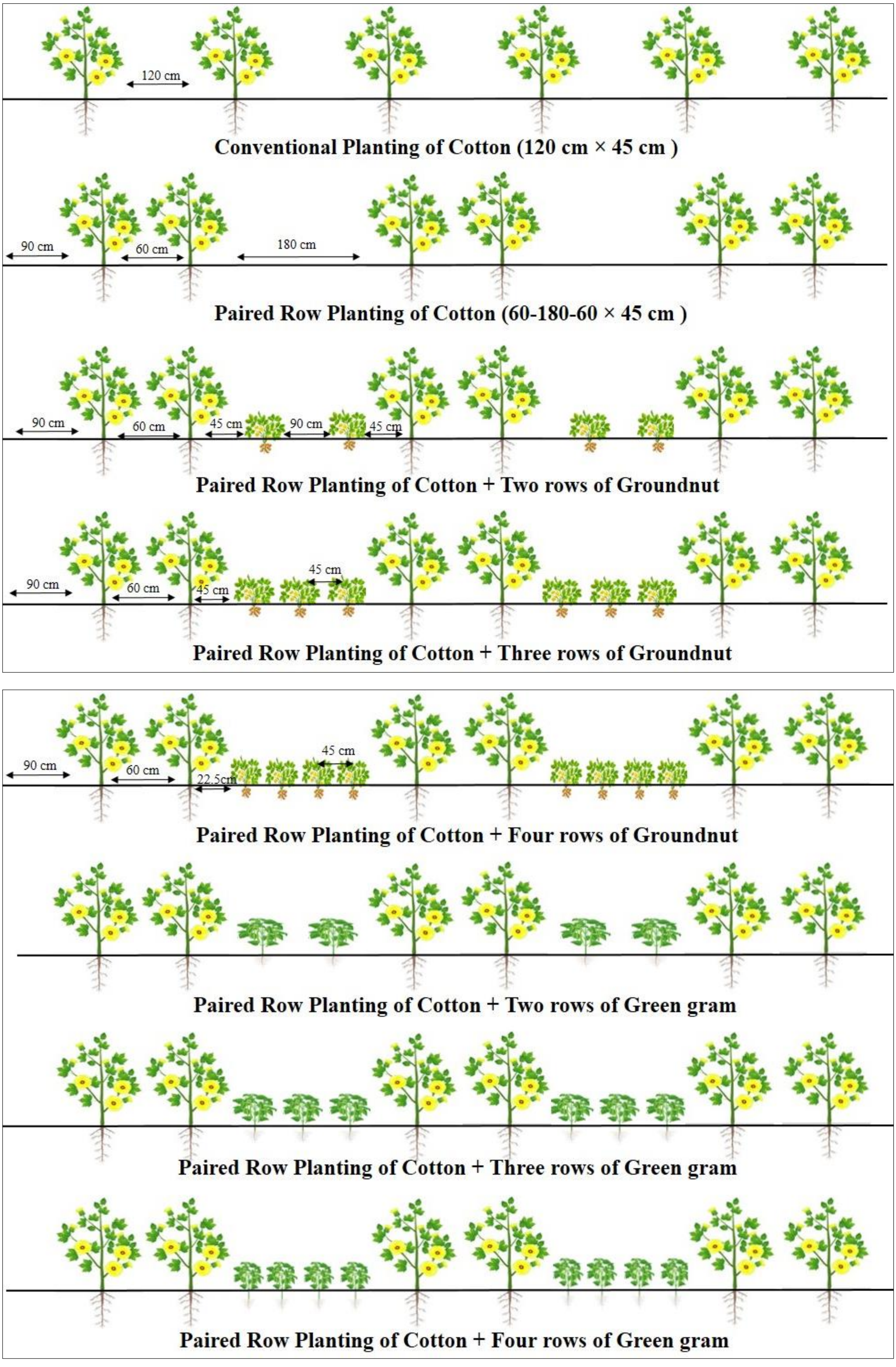

Fig 1: Diagram of cropping pattern with rows of intercrops

Significantly lower dry matter accumulation per plant was observed under paired row cotton + 4 rows of green gram during 2020 as well as in pooled results respectively. In the year 2021 significantly the lowest dry matter accumulation per plant was observed under paired row cotton + 4 rows of groundnut. During the year 2020 and 2021, significantly higher dry matter accumulation/plant 315.74 g and 328.87 g was observed in paired row planting of cotton and conventional planting of cotton, respectively. While in pooled results significantly higher dry matter accumulation/plant 321.92 g was recorded in conventional planting of cotton (over all other treatments. Whereas, significantly the lower dry matter accumulation/plant observed in paired row cotton + 4 rows of groundnut (T_5). At harvest, treatment T_1 recorded significantly higher dry matter accumulation/plant during year 2020. During second year significantly higher dry matter accumulation/plant of 442.14 g was recorded at harvest under the treatment T_1. Significantly higher dry matter accumulation/plant of 435.64 g was recorded under the treatment T_1 [Conventional planting of cotton (120 cm x 45 cm)] in pooled results. 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 T_1 [Conventional planting of cotton (120 cm x 45 cm)] and T_2 [Paired row planting of cotton (60-180-60 cm x 45 cm)] 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) [39], Jayakumar *et al.* (2008) [8], Kumar *et al*. (2017) [13], Manickam and Pillai (2017) [19], Parlawar *et al.* (2017) [23] and Kumar *et al*. (2022) [16].

Monopodial branches

The results revealed that effect of various planting pattern and intercropping on number of monopodial branches/plant before first plucking was found non-significant during both the years and on pooled mean. These results are in confirmity with the results reported by Buttar and Kaur (2010) [4] and Pendharkar *et al.* (2010) [24].

Yield attributes and yield

Sympodial branches

Number of sympodial branches/plant before first plucking in *Bt* cotton indicated that in 2020, 2021 and in pooled mean significantly higher number of sympodial branches/plant (25.35, 25.33, and 25.34) were recorded with the conventional planting of cotton at 120 cm × 45 cm and it was found at par for the year 2020 and 2021 with treatment T_2 [Paired row planting of cotton (60-180-60 cm x 45 cm)], T_3 (Paired row cotton + 2 rows of groundnut), T_4 (Paired row cotton + 3 rows of groundnut), T_6 (Paired row cotton + 2 rows of green gram) and T_7 (Paired row cotton + 2 rows of green gram). Treatment $T_{2,}$ T_3 and T_6 found at par with T_1 in case of pooled results. Significantly minimum number of sympodial branches/plant were registered under paired row cotton + 4 row of groundnut (T_5) before first plucking during both the years and on pooled mean.

This might be due to conventional planting of cotton (120 cm x 45 cm). In conventional planting all plants were getting even space which led to increase in availability of moisture and nutrients for each plant. It also resulted in maximum sunlight interception which may led to higher stomatal activity and photosynthetic reaction. Ultimately it resulted it enhanced translocation of photosynthetic product into the reproductive organs of cotton i.e. sympodial branches and number of balls per plant. While in intercropping there was more competition for natural resources compared to conventional planting which affected the growth of plant as well as yield defining characters of cotton. The lower number of sympodial branches in intercropped cotton had a direct impact on the productions of seed cotton yield because they are the main square bearing branches and compared to monopodial branches they are more in numbers. These results are in conformity with the results reported by Jayakumar *et al.* (2007) [9], Pendharkar *et al.* (2010) [24], Kumar *et al*. (2017) [14], Parlawar *et al.* (2017) [23], Mukesh *et al.* (2021) [21].

Seed cotton yield

The seed cotton yield (kg/ha) of *Bt* cotton was influenced significantly due to the different planting pattern and intercropping systems during both the years and on pooled mean basis. Conventional planting at 120 cm x 45 cm exhibited significantly higher seed cotton yield of *Bt* cotton (2536 kg/ha) than paired row planting of cotton (60-180-60 cm x 45 cm) and intercropping of groundnut or green gram rows during first year. While treatments T_2 [Paired row planting of cotton (60-180-60 cm x 45 cm)], T_3 (Paired row cotton + 2 rows of groundnut), T_4 (Paired row cotton + 3 rows of groundnut), T_6 (Paired row cotton + 2 rows of green gram), and T_7 (Paired row cotton + 3 rows of green gram) remain at par with conventional planting at 120 cm x 45 during the first year. Significantly lower seed cotton yield 2147 kg/ha was recorded with treatment T_5 (Paired row cotton + 4 rows of groundnut) during 2020. In second year same trend was observed for seed cotton yield (kg/ha) and treatment T_1 [Conventional planting of cotton at 120 cm x 45 cm] recorded significantly higher seed cotton yield of *Bt* cotton (2590 kg/ha), but it was failed to exert significant superiority over treatments T_2 [Paired row planting of cotton (60-180-60 cm x 45 cm)], T_3 (Paired row cotton + 2 rows of groundnut) and T_6 (Paired row cotton + 2 rows of green gram) during the second year. Significantly lower seed cotton yield was recorded with treatment T_8 (Paired row cotton + 4 rows of green gram) during second year. While in pooled data same treatment T_1 [Conventional planting of cotton (120 cm x 45 cm)] recorded significantly higher seed cotton yield of 2563 kg/ha and which remain at par with treatments T_2 and T_6. Significantly lower seed cotton yield observed with T_5 (Paired row cotton + 4 rows of groundnut).

Growth of cotton was not affected by the intercropping of groundnut and green gram because of their short duration compared cotton and compact nature as a crop. They didn't offer much competition to cotton as a result growth condition of cotton was almost identical when two rows and three rows of these crops were intercropped in between paired rows of cotton. Also being the legume crop inclusion of groundnut and green gram had positive impact on growth of cotton owing to their ability to fix atmospheric nitrogen in soil through biological fixation. They also had positive effect by decrease in weed problems in between cotton rows and resulted in better yield parameters of cotton, leading to good cotton yield. Higher number of rows of intercrop increases the competition and had higher impact on growth and development of cotton and ultimately the reduced seed cotton yield. While in sole condition cotton utilized environmental and ground resources in more proficient way without any competition for the growth. These results are in conformity with the results reported by Pendharkar *et al.* (2010) [24], Khargkharate *et al*. (2014) [12], Vekariya *et al.* (2015) [37], Manickam and Pillai (2017) [19], Chand *et al.* (2018) [5], Pujar *et al.* (2018) [25], Pandagale *et al.* (2019) [22], Khan *et al.* (2020) [11], Vaghasia and Dobariya (2021) [36] and Kumar *et al*. (2022) [15].

Cotton seed yield

After separation of lint from seed cotton, cotton seed yield was obtained. Different treatments did not show any significant influence on cotton seed yield during both years. Numerically higher cotton seed yield (1602 kg/ha) observed with treatment T_2 [Paired row planting of cotton (60-180-60 cm × 45 cm)] in first year, while in second year conventional planting at 120 cm x 45 cm recorded maximum cotton seed yield (1623 kg/ha). Although it was influenced significantly due to the different planting pattern and intercropping systems on pooled mean and treatment T_1 (Conventional planting at 120 cm x 45 cm) exhibited significantly higher cotton seed yield of *Bt* cotton (1610 kg/ha) than other treatments. However, it was remained at par with treatments T_2 [Paired row planting of cotton (60-180-60 cm x 45 cm), T_3 (Paired row cotton + 2 rows of groundnut) and T_6 (Paired row cotton + 2 rows of green gram) in case of pooled results. Intercropping of paired row cotton with 4 rows of groundnut (T_5) observed significantly lower cotton seed yield (1390 kg/ha) on pooled mean basis.

The reason behind higher cotton seed yield noticed under conventional planting might be due to the higher seed cotton yield plus maximum number of plucked ball/plant was obtained in conventional planting. These results are in conformity with the results reported by Singh *et al.* (2015a) [27].

Lint yield

Cotton fibre obtained after ginning is called lint. The lint yield (kg/ha) of *Bt* cotton was influenced significantly due to the different planting pattern and intercropping systems during both the years and on pooled mean basis. Treatment T_1 (Conventional planting at 120 cm x 45 cm) produce significantly higher lint yield of 939, 967 and 953 kg/ha than paired row planting of cotton (60-180-60 cm x 45 cm) and intercropping of groundnut or green gram rows between paired row cotton during the year 2020, 2021 as well as in pooled results, respectively. Meanwhile, there was at par relation of treatment T_1 reported for both the year with treatment T_2 [Paired row planting of cotton (60-180-60 cm x 45 cm)], T_3 (Paired row cotton + 2 rows of groundnut), T_4 (Paired row cotton + 3 rows of groundnut) and T_6 (Paired row cotton + 2 rows of green gram). However, treatments T_2, T_3, and T_6 were remain at par with conventional planting at 120 cm × 45 cm in case of pooled mean basis. Treatment T_8 (Paired row cotton + 4 rows of greengram) recorded significantly lower lint yield of 768, 808, 788 kg/ha during 2020, 2021 and on pooled mean basis respectively.

Significantly higher seed cotton yield obtained in conventional planting might be the reason behind significantly higher lint yield achieved in conventional planting of cotton (120 cm × 45 cm). These results are in conformity with the results reported by Singh *et al.* (2015a) [27].

Stalk yield

There was significant influence of different treatment on stalk yield of cotton during both the years and on pooled mean basis. Maximum stalk yield of *Bt* cotton (7496 kg/ha) was obtain in treatment T_2 [Paired row planting of cotton (60-180-60 cm x 45 cm)] during first year and it was found at par with treatments T_1 [Conventional planting (120 cm x 45 cm)], T_3 (Paired row cotton + 2 rows of groundnut), T_4 (Paired row cotton + 3 rows of groundnut) and T_6 (Paired row cotton + 2 rows of green gram) during the first year. During the year 2021 treatment T_1, conventional planting at 120 cm x 45 cm recorded significantly higher stalk yield of *Bt* cotton 7383 kg/ha and it was comparable with treatment $T_{2,}$ $T_{3,}$ $T_{4,}$ T_6 and T_7. In pooled results same trend was observed as the year 2021 and treatment T_1 [Conventional planting of cotton (120 cm x 45 cm)] obtained maximum stalk yield of 7435 kg/ha but it was found statistically at par with treatments $T_{2,}$ T_3 and T_6. The intercropping system paired row cotton + 4 row of groundnut observed significantly lower stalk yield (6138 and 6224 kg/ha) during first years and on pooled mean basis, respectively. In second year the intercropping system paired row cotton + 4 row of greengram observed significantly lower stalk yield (6237 kg/ha). The decrease in stalk yield might be due to intercropping of different rows of groundnut or green gram between the paired row cotton affected the crop growth at initial stages and resulted in reduced dry matter accumulation in cotton. In case of 120 cm x 45 cm (conventional planting) and paired row planting each plant was getting more space for growth, maximum solar radiation for photosynthesis and higher amount nutrients from soil which resulted in higher stalk yield. Incorporation of two three and four rows of green gram or groundnut in between paired cotton increases the competition and had higher impact on growth and development of cotton and ultimately resulted in the reduced stalk yield. These results are in conformity with the results reported by Chand *et al.* (2018) [5], Pujar *et al.* (2018) [25], Vaghasia and Dobariya (2021) [36].

Table 1: Dry matter accumulation in cotton as influenced by different treatments

Treatments		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: Growth and yield of cotton as influenced by different treatments

Treatment		Number of Monopodial branches/plant			Number of Sympodial branches/plant			Seed cotton yield (kg/ha)			Cotton seed yield (kg/ha)			Lint yield (kg/ha)			Stalk yield (kg/ha)		
		2020	2021	Pooled	2020	2021	Pooled	2020	2021	Pooled	2020	2021	Pooled	2020	2021	Pooled	2020	2021	Pooled
T_1		3.65	3.50	3.58	25.35	25.33	25.34	2536	2590	2563	1597	1623	1610	939	967	953	7487	7383	7435
T_2		3.63	3.65	3.64	25.05	25.20	25.13	2524	2526	2525	1602	1596	1599	922	930	926	7496	7335	7416
T_3		3.40	3.40	3.40	24.55	24.05	24.30	2344	2456	2400	1474	1556	1515	870	900	885	7369	7268	7318
T_4		3.30	3.35	3.33	23.70	23.15	23.43	2309	2337	2323	1437	1461	1449	872	876	874	6674	6679	6676
T_5		3.30	3.20	3.25	21.75	22.05	21.90	2147	2289	2218	1358	1422	1390	789	867	828	6304	6237	6270
T_6		3.45	3.40	3.43	24.85	24.40	24.63	2425	2367	2396	1494	1476	1485	930	892	911	7219	7321	7270
T_7		3.35	3.25	3.30	22.90	23.15	23.03	2298	2242	2270	1510	1422	1466	788	820	804	6509	6678	6593
T_8		3.30	3.20	3.25	22.30	22.15	22.23	2259	2211	2235	1491	1401	1446	768	808	788	6138	6309	6224
SEm ±	Y			0.06			0.29			29.99			25.36			12.67			106.84
	T	0.20	0.16	0.12	0.86	0.80	0.59	84.25	85.43	57.43	75.59	67.63	48.74	39.42	31.85	24.29	331.58	269.64	199.37
	Y×T			0.18			0.83			84.84			71.72			35.84			302.20
CD (P=0.05)	Y			NS			NS			NS			NS			NS			NS
	T	NS	NS	NS	2.53	2.36	1.56	248	251	164	NS	NS	138	115.94	93.66	69.06	975.17	792.02	609.86
	Y×T			NS			NS			NS			NS			NS			NS
CV%		11.73	9.24	10.58	7.23	6.76	7.00	7.15	7.19	7.17	10.11	9.05	9.59	9.17	7.22	8.23	9.61	7.81	8.76

Conclusion

The result of this experiment provide information about productivity of cotton when inter cropped with legumes like groundnut and green gram. It clearly shows that legume intercropping in cotton is needed for sustainable crop production in India where land is fragmented. The Experimental results clearly showed that intercropping of legume in cotton is not affecting growth of cotton. Also had significant positive impact on seed cotton yield. No negative effect on cotton growth was observed by growing groundnut and green gram in between paired rows of cotton. Considering crop intensification and diversification as a need of the hour it reduces the risk associated with long duration crop and also provide yield assurance which ultimately reduces import load of cooking oil and provide better equivalent yield with legumes.

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References

1. Anonymous. Cotton Industry in India; c2014. http://www.indiantradeportal.in. Accessed January 1, 2023.
2. Anonymous. Cotton Corporation of India. National Cotton Scenario. https://cotcorp.org.in. 2021a. Accessed January 1, 2023.
3. Anonymous. India Brand Equity Foundation. Cotton Industry and Export; 2021. Available: https://www.ibef.org/exports/cotton-industry-india.aspx. 2021b. Accessed January 1, 2023.
4. Buttar GS, Singh P. Performance of Bt cotton hybrids of different plant populations in South-Western region of Punjab. Journal of Cotton Research and Development. 2010;20:97-98.
5. Chand P, Thakare R, Chaudhari RD, Patil TD. Influence of cotton based pulse intercropping on nutrient availability and yield on vertisol. International Journal of Chemical Studies. 2018;6(6):161-164.
6. Ghadge HL. Effect of planting patterns, irrigation techniques and mulching on growth, yield and quality of irrigated cotton (cv, NHH-44) Ph.D. thesis submitted to M.P.K.V., Rahuri; c2003.
7. James C. Global status of commercialized biotech/GM crops: (2010) (ISAAA Briefs No. 42); c2010.
8. Jayakumar M, Ponnuswamy K, Amanullah MM. Effect

of sources of nitrogen and intercropping on weed control, growth and yield of cotton. Research Journal of Agriculture and Biological Sciences. 2008;4(2):154-158.
9. Jayakumar M, Ponnuswamy K, Amanullah MM, Yassin MM, Balasubramanian V. Effect of intercropping and sources of nitrogen on growth, yield and "N" use efficiency in cotton. Research Journal of Agriculture and Biological Sciences. 2007;3(5):398-402.
10. Khan MB, Akhtar M, Khaliq A. Effect of planting patterns and different intercropping systems on the productivity of cotton (*Gossypium hirsutum* L.) under irrigated conditions of Faisalabad. International Journal Agriculture Biology. 2001;3:432-435.
11. Khan MN, Shoaib M, Ashraf MS, Qamar R, Mahboob A, Ijaz S. Mungbean (*Vigna radiata*) intercropping enhances productivity of late season irrigated cotton in Punjab. Asian Journal of Agriculture and Biology. 2020;8(4):472-479.
12. Khargkharate VK, Kadam GL, Pandagale AD, Awasarmal VB, Rathod SS. Studies on Kharif legume intercropping with Bt. cotton under rainfed conditions. Journal of Cotton Research and Development. 2014;28(2):243-246.
13. Kumar P, Karle AS, Singh D, Verma L. Effect of High Density Planting System (HDPS) and Varieties on Yield, Economics and Quality of Desi Cotton. International Journal of Current Microbiology and Applied Sciences. 2017;6(3):233-238.
DOI: https://doi.org/10.20546/ijcmas.2017.603.025
14. Kumar R, Turkhede AB, Nagar RK, Nath A. Effect of different intercrops on growth and yield attributes of American cotton under dryland condition. International Journal of Current Microbiology and Applied Sciences. 2017;6(4):754-761.
15. Kumar S, Turkhede AB, Wankhede R, Meena AK. Growth, yield and quality of cotton in cotton based intercropping system under organic and rainfed condition. The Pharma Innovation Journal. 2022;11(2):154-157.
16. Latati M, Blavet D, Alkama N, Laoufi H, Drevon JJ, Gerard F. The intercropping cowpea-maize improves soil phosphorus availability and maize yields in an alkaline soil. Plant Soil. 2014;385:181-191.
DOI: 10.1007/s11104-014-2214-6.
17. Lupwayi NZ, Kennedy AC. Grain legumes in northern plains: Impacts on selected biological processes. Agronomy Journal. 2007;99:1700-1709.
18. Madavi B, Leela Rani PS, Sreenivas G, Surekha K. Effect of High Density Planting and Weed Management Practices on Productivity and Economic Analysis of Bt Cotton. International Journal of Current Microbiology and Applied Sciences. 2017;6(7):2225-2230.
19. Manickam J, Pillai SU. Intercropping and balanced nutrient management for sustainable cotton production. Journal of Plant Nutrition. 2017;40(5):632-644.
20. Mayee CD, Monga D, Dhillon SS, Nehra PL, Pundhir P. Cotton–wheat production system in South Asia: A success story. Bangkok, Thailand: Asia Pacific Association of Agricultural Research Institutions; c2008.
21. Mukesh, Singh KD, Devi P, Meena S, Malik S. Performance of cotton genotypes intercropped with pearl millet and greengram. Journal of Cotton Research and Development. 2021;35(1):97-100.
22. Pandagale AD, Khargkharate VK, Kadam GL. Studies on various intercropping system under different plant geometry in Bt cotton. International Journal of Research in Agronomy. 2019;2(1):07-09.
23. Parlawar ND, Jiotode DJ, Khavle VS, Kubde KJ, Puri PD. Effect of planting geometry and varieties on morpho-physiological parameters and yield of cotton. International Journal of Researches in Bioscience, Agriculture and Technology. 2017;5(2):429-436.
24. Pendharkar AB, Solunke SS, Sawargaonkar GL, Kote GM. Response of Bt cotton hybrids to different plant spacing under rainfed condition. Advance Research Journal of Crop Improvement. 2010;1(2):180-182.
25. Pujar AM, Angadi VV, Hosmath JA. Response of cotton and soybean intercropping system to integrated nutrient management. International Journal of Environment and Climate Change. 2018;8(1):18-26.
26. Singh A, Weisser WW, Hanna R, Houmgny R, Zytynska SE. Reduce pests, enhance production: benefits of intercropping at high densities for okra farmers in Cameroon. Pest Management Science. 2017;73:2017-2027. DOI: 10.1002/ps.4636
27. Singh K, Rathore P, Gumber RK. Studies on the nutrient management of Bt cotton based legume intercropping system. Journal of Cotton Research and Development. 2015a;29(2):237-241.
28. Singh K, Singh H, Rathore P, Gumber RK. Productivity parameters of Bt cotton (*Gossypium hirsutum*) hybrids as influenced by mungbean intercropping under semiarid conditions. Journal of Cotton Research and Development. 2014b;28(2):247-250.
29. Singh RJ, Ahlawat IPS. Growth behaviour of transgenic cotton with peanut intercropping system using modified fertilization technique. Proceedings of the National Academy of Sciences, India, Section B: Biological Sciences (Springer). 2014;84(1):19-30.
30. Singh RJ, Ahlawat IPS, Singh S. Effects of transgenic Bt cotton on soil fertility and biology under field conditions in subtropical Inceptisol. Environment Monitoring and Assessment. 2013;185(1):485-495.
31. Singh RJ, Ahlawat IPS, Gangaiah B. Direct and residual effects of nitrogen requirement in Bt cotton–wheat cropping system. Indian Journal of Agronomy. 2009;54(4):401-408.
32. Singh RJ, Ahlawat IPS. Dry matter, nitrogen, phosphorous, and potassium partitioning, accumulation, and use efficiency in transgenic cotton-based cropping systems. Communications in Soil Science and Plant Analysis. 2012;43(20):2633-2650.
33. Singh RJ, Ahlawat IPS. Productivity, competition indices, and soil fertility changes of Bt cotton-groundnut intercropping system using different fertility levels. Indian Journal of Agricultural Sciences. 2011;81(7):606-611.
34. Subba Rao GV, Kumar Rao JVDK, Kumar J, Johansen C, Deb UK, Ahmed I. Spatial distribution and quantification of rice fallow in South Asia - Potential for legumes. Hyderabad, India: ICRISAT. 2001.
35. Thavaprakash N, Velayudham K, Muthukumar VB. Effect of crop geometry, intercropping systems and nutrient management on cob yield and nutrient uptake of baby corn (*Zea mays* L.). Madras Agricultural Journal. 2005;92(10-12):646-652.

36. Vaghasia PM, Dobariya KL. Nutrient management in groundnut (*Arachis Hypogaea* L.) - Bt cotton (*Gossypium hirsutum* L.) intercropping system. Legume Research. 2021;44(3):334-338.
37. Vekariya PD, Khokhani MG, Gajera MS, Akbari KN. Productivity and economics of cotton (*Gossypium hirsutum* L.) based intercropping system under rainfed conditions of north Saurashtra agro climatic zone of Gujarat. Journal of Cotton Research and Development. 2015;29(2):264-267.
38. Wang GS, Asiimwe RK, Andrade P. Growth and yield response to plant population of two cotton varieties with different growth habits. Arizona Cotton Report (P-161); c2011 Aug. p. 6-11.
39. Wankhade ST, Turkhede AB, Solanke VM, Malvi SD, Katkar RN. Effect of intercropping on yield of cotton. Crop Research. 2000;19(3):409-413.