J. Cotton Res. Dev. **36**(2), 202-207 (July, 2022) **ISSN No. 0972-8619**

Productivity, nutrient uptake and water use efficiency of irrigated *Bt* cotton based intercropping system

R. VEERAPUTHIRAN AND K. SANKARANARAYANAN

Tamil Nadu Agricultural University, Cotton Research Station, Srivilliputtur

**Email : veeraagri@yahoo.co.in*

Abstract : Field experiments were conducted at Cotton Research Station, (TNAU), Srivilliputtur, Tamil Nadu under winter irrigated season of 2020-2021 and 2021-2022 (September to February) to identify suitable inter cropping system for *Bt* cotton with higher productivity and nutrient uptake. The experiments were carried out in a randomized block design with three replications. The treatments consisted of control (T_1-Sole cotton), two rows of intercrop of small onion with cotton (T_2), two rows of cluster bean with cotton (T_3), two rows of coriander with cotton (T_4), one row onion + one row cluster bean with cotton (T_5), one row cluster bean + one row coriander with cotton (T_6), one row coriander + one row onion with cotton (T_7), one row each onion + cluster bean + coriander with cotton (T_8), normal planting of cotton + 2 rows black gram (T_9), normal planting of cotton + 2 rows green gram (T_{10}). The results revealed that the total nutrient uptake of all the intercropping systems were significantly higher than sole Bt cotton indicating complimentary effect. Among the intercropping systems, higher nutrient uptake was observed with Bt cotton intercropped with three crops (onion, cluster bean, and coriander) followed by that of two rows of cluster bean. The seed cotton equivalent yield was highest with intercropping of one row each of onion and cluster bean with cotton (3749 and 3015kg / ha) followed by two rows of cluster bean (3697 kg / ha and 2905kg / ha).The water use efficiency and labour use efficiency were also higher with one row each of onion and cluster bean intercropped with cotton followed by intercropping of two rows of cluster bean with cotton. The study inferred that intercropping of cluster bean and onion were found suitable for higher yield and nutrient uptake with efficient use of water and labour.

Key Words : Cotton, intercropping, nutrient uptake, seed cotton yield, water use efficiency

Cotton is an important fibre cum cash crop of India and Tamil Nadu as well and hence popularly known as “White Gold” and “King of Fibre Crops”. Though India has the largest area (41.3%) of cotton in the world, due to its lower productivity, the share to the total world cotton production is only 25.4 per cent. In Tamil Nadu, cotton is cultivated in an area of 1.55 lakh ha during 2020-2021 with a production of 5.0 lakh bales and productivity of 548 kg/ ha which is below the world average yield of 768 kg/ ha (Anonymous, 2021). Intercropping has been recognized as potentially beneficial and economic system of crop production. It is the only way to increase the cropping intensity and resource utilization for efficient management of inputs. Selection of suitable intercropping system is paramount importance to realize higher system productivity. Cropping system which is capable of giving maximum return per unit quantity of water on a long term sustainable basis is consider as most efficient (Jain *et al.*, 2008). In addition, availability of labour, the most important resource in agriculture should also be utilized efficiently. Keeping in view, an experiment was conducted to identify proper intercrops with higher yield and efficient use of water and labourin Bt cotton based intercropping system.

MATERIALS AND METHODS

Field experiments were conducted at Cotton Research Station, (TNAU), Srivilliputtur , Tamil Nadu under winter irrigated season of 2020-2021 and 2021-2022 (September to February) to identify suitable inter cropping

system for *Bt* cotton with higher productivity and nutrient uptake. The experiments were carried out in a randomized block design with three replications. The treatments consisted of control (T_1 - Sole cotton), two rows of intercrop of small onion with cotton (T_2), two rows of cluster bean with cotton (T_3), two rows of coriander with cotton (T_4), one row onion + one row cluster bean with cotton (T_5), one row cluster bean + one row coriander with cotton (T_6), one row coriander + one row onion with cotton (T_7), one row each onion + cluster bean + coriander with cotton (T_8), normal planting of cotton + 2 rows black gram (T_9), normal planting of cotton + 2 rows green gram (T_{10}). The paired row of planting (80-100 x60 cm) was followed for treatments T_2 to T_8. The soil of the experimental field was clay loam with a pH of 8.26 dSm/m. The available soil nutrient status was low in N (196 kg/ ha), high in P (40 kg/ ha) and also high in K (496 kg/ha). The *Bt* cotton Jaadhu was used for the study and the varieties used for the intercrops were CO 5 (small onion), CO 1 (cluster bean), CO 4 (coriander), VBN 8 (black gram) and CO 8 (green gram). Normal spacing of 120 x 60 cm followed for control (sole crop) (T_1) and intercropping of black gram (T_9) and green gram (T_{10}). Intercrops were planted between paired row by adopting 50 x 10 cm for two intercrops treatments (T_2 to T_7) and 40 x 10 cm for three intercrops treatment (T_8). A fertilizer recommendation of 120 : 60 : 60 kg NPK / ha was applied for all the treatments and no additional fertilizers or pesticides were applied to intercrops. The nutrient analysis was carried out as per standard procedure and nutrient uptake was calculated. The seed cotton yield and yield of intercrops were also recorded. The seed cotton equivalent yield was calculated by dividing unit price of intercrop by that of cotton. The water use efficiency (WUE) was worked out by dividing the seed cotton yield with total quantity of water used including effective rainfall. The water productivity was calculated by dividing the total income with unit quantity of water used. The labour use efficiency was arrived by dividing the total income with number of labour used.

RESULTS AND DISCUSSION

Nutrient uptake

The nutrient uptake of different intercropping systems is furnished in Table 1. The results revealed that though the nutrient uptake of cotton was not significant, uptake of intercrops was found to significantly different and thus total nutrient uptake as well. The total uptake of all the intercropping systems was significantly higher than sole *Bt* cotton indicating complimentary effect. Among the intercropping systems, higher nutrient uptake was observed with *Bt* cotton intercropped with three crops (onion, cluster bean, and coriander) followed by that of two rows of cluster bean during both the years of study. Higher nutrient uptake under these intercropping systems might be due to the total biomass yield of the respective cropping system. Among the intercrops, higher nutrient uptake were observed in the order of clusterbean, onion, coriander, green gram and black gram. The ability of intercropping system to make more efficient use of nutrient than sole crops and also different root growth pattern of component intercropping explores more soil mass for nutrient uptake. Similar increased nutrient uptake with cotton + vegetable intercropping system was registered by Sankaranarayanan *et al.*, (2012). Higher nutrient uptake under cotton + pulses intercropping than pure cotton crop was reported by Harisudan (2019) and Giri *et al.*, (2006)

Seed cotton yield

The influence of various intercropping system on seed cotton yield is presented in Table 2. The seed cotton yield was not significantly influenced by different treatments. However, all the inter crops studied had increased the seed cotton yield non significantly thus indicating the

Table1. Nutrient uptake (kg/ha) as influenced by inter cropping systems in cotton

Treatments	Cotton						Intercrop						Total					
	N		P		K		N		P		K		N		P		K	
	2020-21	2020-21	2020-21	2020-21	2020-21	2020-21	2020-21	2020-21	2020-21	2020-21	2020-21	2020-21	**2020-21**	**2020-21**	**2020-21**	**2020-21**	**2020-21**	**2020-21**
T1.	115.0	91.4	20.1	16.3	112.6	93.4	—	-	—	-	—	-	**115.0**	**91.4**	**20.1**	**16.3**	**112.6**	**93.4**
T2.	116.2	93.6	20.3	16.7	113.8	95.6	20.8	18.1	5.9	5.2	19.9	17.1	**137.0**	**111.7**	**26.3**	**21.9**	**133.7**	**112.7**
T3.	117.3	95.3	20.5	17.0	114.8	97.3	25.8	24.9	6.9	6.8	21.4	20.7	**143.1**	**120.2**	**27.4**	**23.8**	**136.2**	**118.0**
T4.	116.7	94.3	20.5	16.9	114.3	96.3	16.0	14.2	3.9	3.6	14.6	13.2	**132.7**	**108.5**	**24.4**	**20.5**	**128.9**	**109.5**
T5.	117.6	95.7	20.6	17.1	115.1	97.7	21.2	20.7	5.3	5.2	18.6	17.8	**138.8**	**116.3**	**25.9**	**22.3**	**133.1**	**115.5**
T6	117.3	95.8	20.5	17.1	114.8	97.8	22.8	19.9	6.7	5.8	19.3	17.3	**140.1**	**115.7**	**27.3**	**22.9**	**134.1**	**115.1**
T7	116.8	94.8	20.5	16.9	114.4	96.8	17.6	16.5	5.8	5.1	16.3	14.3	**134.4**	**111.3**	**26.3**	**22.0**	**130.9**	**111.1**
T8	118.1	96.3	20.7	17.2	115.6	98.3	30.8	28.5	8.5	8.4	25.4	23.7	**148.9**	**124.8**	**29.1**	**25.6**	**141.1**	**122.0**
T9.	115.9	93.7	20.3	16.7	113.5	95.7	12.0	11.8	3.2	3.1	11.0	10.7	**127.9**	**105.5**	**23.3**	**19.8**	**124.5**	**106.4**
T10.	116.2	94.1	20.3	16.8	113.4	96.0	12.4	12.3	3.2	3.1	11.4	10.6	**128.6**	**106.3**	**23.5**	**19.9**	**124.8**	**106.6**
SEd	4.98	4.41	1.07	0.94	4.36	4.03	1.24	1.10	0.21	0.17	1.04	0.98	**5.04**	**4.76**	**1.39**	**1.31**	**4.98**	**4.69**
CD (p = 0.05)	NS	NS	NS	NS	NS	NS	2.61	2.31	0.44	0.36	2.18	2.06	**10.58**	**0.99**	**2.91**	**2.75**	**10.46**	**9.80**

complimentary effect offered by intercrops without competition to base crop cotton during the growth and development. Among them, intercropping of onion, cluster bean, coriander at one row each with *Bt* cotton recorded the highest seed cotton yield (2460 and 2048 kg/ha) followed by that of one row each of onion and cluster bean (2449 kg/ ha) and intercropping of two rows of cluster bean (2443 and 2035 kg/ha).Similar result of non significant response between pure cropping and intercropping of cotton was reported by Sankaranarayanan *et al.*, (2012) and Maitra *et al.*, (2001). The enhanced seed cotton yield by intercropping articulate that intercropped legume(cluster bean, green gram, blackgram) improved the soil health and soil fertility as evident from higher uptake of N, P and K nutrient as reported by Sankaranarayanan *et al.*, (2010) and Rao *et al.*, (2009). The results of cluster bean (1:1) intercropping system recorded higher seed cotton yield than cotton + black gram (1:1) and cotton + green gram (1:1) intercropping system as reported by Ravindra Kumar *et al.*, (2017) was also in line with the present investigation.

Seed cotton equivalent yield (SCEY)

The total productivity in terms of seed cotton equivalent yield (SCEY) was increased by all intercropping system attempted in the experiment (Table 2). Among them, the total SCEY was the highest with intercropping of onion and cluster bean each one row with cotton (3749 and 3015 kg/ha) followed by two rows of cluster bean (3697 and 2905 kg/ha) and two rows of onion (3689 and 2813 kg/ha). The next higher total SCEY was observed with intercropping of three crops (onion, cluster bean and coriander) as one row each with *Bt* cotton (3598 and 2783kg/ha). The higher SCEY estimated under these intercropping system than sole cotton was due to additional yield harvested by intercrops and prevailing remunerative market price for produce of intercrops. The lesser total SCEY under pulses intercropping was a result of lower

Table 2. Seed cotton yield and seed cotton equivalent yield as influenced by inter cropping system in cotton

Treatments	Seed cotton yield (kg/ha)		Intercrop yield (kg/ha)		Seed cotton equivalent yield* (kg/ha)	
	2020-2021	2021-2022	2020-2021	2021-2022	2020-2021	2021-2022
T1. Sole Bt cotton	2395	1945	-	-	2395	1945
T2. Paired row planting of *Bt* cotton with two rows onion	2422	1991	Onion 1810	Onion 1684	3689	2813
T3. Paired row planting of *Bt* cotton with two rows cluster bean	2443	2028	Cluster bean 3136	Cluster bean 3590	3697	2905
T4. Paired row planting of *Bt* cotton with two rows coriander	2431	2007	Coriander 1130	Coriander 982	2838	2366
T5. Paired row planting of *Bt* cotton with one row onion+ one row cluster bean	2449	2035	Onion 1008 Cluster bean 1487	Onion 909 Cluster bean 1925	3749	3015
T6. Paired row planting of *Bt* cotton with one row cluster bean+ one row coriander	2443	2028	Cluster bean 1379 Coriander 611	Cluster bean 1846 Coriander 503	3215	2672
T7. Paired row planting of *Bt* cotton with one row coriander+ one row onion	2434	2016	Onion 853 Coriander 558	Onion 802 Coriander 534	3232	2602
T8. Paired row planting of *Bt* cotton with one row row onion+one row cluster bean+one row coriander	2460	2048	Onion 737 Cluster bean 1145 Coriander 456	Onion 585 Cluster bean 1397 Coriander 298	3598	2783
T9. Normal spacing of *Bt* cotton with 2 rows black gram	2415	1993	Black Gram 126	Black Gram 149	2554	2102
T10. Normal spacing of *Bt* cotton with 2 rows green gram	2420	2001	Green Gram 131	Green Gram 155	2564	2114
SEd	89.5	71.6	-	-	-	-
CD (p = 0.05)	NS	NS	-	-	-	-

Price of produces 2020-2021(Rs/ kg): cotton = 51, onion=35, cluster bean=20, vegetable coriander= 18, green gram, black gram= 55
Price of produces 2021-2022(Rs/ kg): cotton = 82, onion=40, cluster bean=20, vegetable coriander= 30, green gram, black gram= 60

grain yield of pulses than vegetables. The findings of higher SCEY reported under cotton intercropped with cluster bean (Ravindra Kumar *et al.*, (2017) and Sankaranarayanan *et al.,* (2012)), onion (Maitra *et al.,* 2001), coriander (Sankaranarayanan *et al.*, 2012) than sole cotton were in agreement with the present study. Similar results of yield advantage of cotton + pulse inter cropping as reported by Pandagale *et al.,* (2019) and Khagkharate *et al.*, (2014) was also in conformity with the findings of present investigation.

Water use efficiency and water productivity

Water use efficiency (WUE) denotes the quantity of total seed cotton equivalent yield produced per unit quantity of water whereas water productivity indicates the total income obtained from unit quantity of water. In the present study, WUE and water productivity were drastically improved by all the intercropping systems than sole cotton (Table 2). Among the intercropping systems, the most efficient one was one row each of onion and cluster bean intercropped with cotton which recorded highest WUE of 5.73 and 3.63 kg / ha / mm and water productivity of 29.04 and 29.09 Rs / m^3. The next efficient intercropping systems in terms of better WUE and water productivity were two rows of cluster bean inter cropped with cotton. The improvement in both WUE and water productivity under the above intercropping systems were due to higher intercrop yield as compared to other intercropping system. Similar higher WUE and water productivity under cotton + vegetable

intercropping was observed by Sankaranarayanan *et al.,* (2012) and Khalifa *et al.,* (2018) was in accordance with the results of present study.

Labour utilized and labour use efficiency (LUE)

The total labour requirement and LUE interms of gross return per number of labour used in different intercropping systems are presented in Table3. The total labour requirement of all the intercropping systems was higher than sole cropping indicating more employment opportunity. More over, the labours were also effectively utilized by all the intercropping systems as evident from higher LUE in all the intercropping systems than pure cropping. Among the intercropping systems, higher numbers of labourers (351) were utilized for intercropping of three crops (onion, cluster bean and coriander) followed by intercropping of two rows of cluster bean (347 and 332) and one row each of onion and cluster bean (325 and 310). However higher LUE was associated with intercropping of two rows of onion with cotton (593 and 769 Rs/ labour) followed by intercropping of one row each of onion and clusterbean (577 and 770 Rs/ labour) and two rows of cluster bean intercropped with cotton (540 and 717 Rs/ labour). Higher LUE under cotton + onion intercropping was due to single harvest of onion than more number of harvest of cluster bean. Similar higher labour required and LUE under cotton + cluster bean intercropping system was realized by Sankaranarayanan *et al.,* (2012).

The study inferred that cluster bean and onion were found suitable inter crops for higher yield and nutrient uptake with efficient use of water and labour in cotton.

Acknowledgement

The authors greatly acknowledge the ICAR – All India Co- Ordinate Research Project on Cotton for funding this study.

Table 3. Water use efficiency and Labour use efficiency as influenced by inter cropping system in cotton

Treatments	Water use efficiency (kg/ha/mm)		Water productivity (Rs/m^3)		Labour utilized (No/ha)		Labour use efficiency (Rs/labour)	
	2020-2021	2021-2022	2020-2021	2021-2022	2020-2021	2021-2022	2020-2021	2021-2022
T1. Sole *Bt* cotton	3.66	2.34	18.68	19.19	295	280	414	570
T2. Paired row planting of *Bt* cotton with two rows onion	5.64	3.39	28.57	27.75	315	300	593	769
T3. Paired row planting of *Bt* cotton with two rows cluster bean	5.65	3.50	28.64	28.66	347	332	540	717
T4. Paired row planting of *Bt* cotton with two rows coriander	4.34	2.85	22.07	23.35	307	295	470	658
T5. Paired row planting of *Bt* cotton with one row onion + one row cluster bean	5.73	3.63	29.04	29.09	329	314	577	770
T6. Paired row planting of *Bt* cotton with one row cluster bean +one row coriander	4.92	3.22	24.94	26.37	325	310	502	707
T7. Paired row planting of *Bt* cotton with one row coriander + one row onion	4.94	3.13	25.08	25.68	312	297	526	719
T8. Paired row planting of *Bt* cotton with one row row onion + one row cluster bean + one row coriander	5.50	3.35	27.99	27.46	351	325	522	702
T9. Normal spacing of *Bt* cotton with 2 rows black gram	3.90	2.53	19.89	20.74	308	293	422	588
T10. Normal spacing of Bt cotton with 2 rows green gram	3.92	2.54	19.97	20.86	308	293	424	592

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Received for publication : January 18, 2022
Accepted for publication : May 19, 2022