JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

AGRONOMIC EVALUATION OF *BT* COTTON (*GOSSYPIUM HIRSUTUM*) GENOTYPES TO DIFFERENT METHODS OF ESTABLISHMENT IN KRISHNA COMMAND AREA OF KARNATAKA

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Abstract: A field experiment was carried out to study the agronomic evaluation of *Bt* cotton (G*gossypium hirsutum*) genotypes to different methods of establishment in Krishna command area of Karnataka during the *kharif* 2018-19 and 2019-20, at Agricultural Research Station, Malnoor, University of Agricultural Sciences, Raichur, which is located in Upper Krishna Project area of Karnataka. The experiment was designed by split plot consisted of twelve treatment combinations, where *Bt* cotton genotypes *viz.*, Jaadoo BG II, ACH 199 BG II and Bindass BG II, were taken in the main plot. The sub plot treatments were four establishment methods: seedlings raised in black polythene bags, raised in pro trays and raised in biodegradable paper cups and dibbling (direct sowing). The experiment was replicated thrice. The data recorded significantly higher seed cotton yield, gross returns, net returns and benefit-cost ratio in Jaadoo BG II seedlings raised in black polythene bags (3140 kg ha^{-1}, ₹ 1,66,420 ha^{-1}, ₹ 1,22,011 ha^{-1} and 3.75, respectively) or biodegradable paper cups (3124 kg ha^{-1}, ₹ 1,65,530 ha^{-1}, ₹ 1,18,831 ha^{-1} and 3.55, respectively); this was preceded by ACH 199 BG II seedlings raised in black polythene bags (3099 kg ha^{-1}, ₹ 1,64,244 ha^{-1}, ₹ 1,19,835 ha^{-1} and 3.70, respectively) and biodegradable paper cups (3087 kg ha^{-1}, ₹ 1,63,592 ha^{-1}, ₹ 1,16,893 ha^{-1} and 3.50, respectively); the treatments were on par with each other but significantly superior to the rest of the treatments. These treatments ensure timely planting and benefit from sowing thirty days in advance of conventional dribbling techniques. Furthermore, biodegradable paper might be a sustainable replacement for polythene bags.

Keywords: *Bt* cotton, Genotypes, Establishment method, Transplanting, Dibbling

I. INTRODUCTION

Cotton (*Gossypium hirsutum* L.) is a leading fiber crop and an important agricultural commodity, providing income to millions of cotton farmers and related textile industries besides, significant export earnings in the country. It contributed two per cent to the GDP of India and employs more than 45 million people in 2017-18 and also it contributed 15 per cent to the export earnings of India in 2017-18 and this sector is the second largest provider of employment after agriculture (Anon., 2018). Among the cotton growing states, Karnataka ranks fourth in area, seventh in production and tenth in productivity. *Bt* cotton is intensively cultivated in the North Eastern Dry Zone and Northern Dry Zone of the state (Zone 2 and 3) covering partly the Tungabhadra and Upper Krishna irrigation commands on black soil. The area under this crop in these commands has been increasing distinctly over the past half decade. One of the major agronomic constraints for the low productivity in *Bt* cotton is the delayed sowing of crop as optimum time of sowing being a non-monetary input is very important for realizing better yields (Sahai, 2003). Farmers are unable to sow seeds at optimum time due to uncertainty of rainfall and delayed release of water in the canal, especially in North Eastern Dry Zone of Karnataka. In order to ensure timely sowing on account of delayed onset of monsoon and delayed release of water in the canal, transplanting of *Bt* cotton seedlings will be one of the better agronomic measures to overcome delayed sowing. This technique involves raising of seedlings in the polythene bags in the nursery for a period of one month in advance and then transplanting those seedlings in the main field, immediately after soil wetting rains or release of water in the canal. Rajakumar and Gurumurthy (2008) found that direct seeding recorded a boll setting percentage of 30.29 as against 33.43 per cent under transplanting of poly bag seedlings which resulted in higher seed cotton yield.

Cotton transplanting has numerous benefits *i.e.*, early sowing, seed saving, escape of heavy build up of pests, exclusion of thinning practice and protection from harsh environment at planting time of the crop. However, during present days the use of polythene bags are banned and discouraged due to its non-ecofriendly nature and pollution problem. Hence, bio-degradable and reusable materials need to be tested to establish cotton seedlings. Further, the performance of *Bt* cotton may vary under different methods. Hence, the popularly grown *Bt* cotton genotypes in the command area has been included to study the performance of *Bt* cotton genotypes to different methods of establishment.

II. MATERIALS AND METHODS

2.1 Experimental details

A field experiment was conducted in the Upper Krishna Project command area at Agricultural Research Station, Malnoor, University of Agricultural Sciences, Raichur, Karnataka, during *kharif* 2018-19 and 2019-20. The soil had a clay loam texture and was medium-deep black. Its available nitrogen and phosphorus levels were moderate (344 kg ha^{-1} and 29.21 kg ha^{-1}, respectively), while its potassium availability was high (355 kg ha^{-1}). The soil had a pH of 8.14, an average E.C. of 0.35 dS m^{-1} and a medium level of organic carbon (0.56%). Three replications of a split-plot design were used for the field experiment. There were 12 different treatment assemblages. Three *Bt* cotton genotypes, Jaadoo BG II, ACH 199 BG II and Bindass BG II, made up the main plot treatments (Table 1). Four different establishing techniques made up the subplot treatments: seedlings were grown in pro trays, black polythene bags, biodegradable paper cups and by dibbling (direct sowing).

2.2 Technique for raising seedlings in a nursery and Transplanting

Bt-cotton seedlings were raised by sowing a single seed in a mixture of Soil: FYM (3:1) in a polythene bag measuring 15 cm by 10 cm, biodegradable paper cups measuring 9 cm by 7.5 cm and pro trays measuring 52 cm by 27 cm with 98 cells, each cell measuring 3.5 cm in diameter and 3.0 cm in depth and having been moisturized to field capacity. By routinely watering as needed, soil moisture was preserved. After the canal water was discharged in August, the seedlings were transplanted to the main field at a thirty-day old. In contrast, seeds were planted on the same day that seedlings were transplanted (Fig. 1 & 2).

The soil was treated with urea, DAP and muriate of potash, according to the required amount of 180: 90: 90 N, P and K kg ha^{-1}. Fifteen days prior to treatment, transplanting or seeding, FYM at 10 t ha^{-1} was applied. Phosphorus, nitrogen and potassium were all administered to cotton as a basal application along the seed line. At 30, 60 and 90 days after transplanting by placement, the remaining 50% of the necessary doses of nitrogen and potassium were top-dressed in three separate doses. To raise the wholesome crop, a total of six irrigations were supplied at intervals of 20 days. All authorized packages of practices were also followed.

Figure 1. Black polythene bags, biodegradable paper cups and pro trays filled with a mixture of Soil and FYM (3:1)

Figure 2. Establishment of *Bt* cotton seedlings in black polythene bags, biodegradable paper cups and pro trays at 30 DAS

Table 1: Salient features of the *Bt* cotton Genotypes

Jaadoo BG-II	ACH 199 BG-II	Bindass BG-II
• Plant habit : Erect • Suitable for irrigated and rainfed cultivation. • Crop duration medium : 155-170 days • Sowing season : May-June • Specialty : Good for close spacing sowing • Boll size and shape : Medium • Boll weight : 6 - 6.5 g • Manufacturer : Kaveri Seeds Company Ltd.	• Plant height (cm) : 150-160 • Suitable for irrigated and rainfed cultivation. • Duration (days) : 145-160 • Boll weight (g) : 6.0-6.5 • Staple length (mm) : 29.5-30 • Ginning (%) : 37.5-38.0 • Tall plant type with more number of sympodia having big boll size • Good bearing and boll retention capacity. • Highly tolerant to leaf reddening, sucking pests and diseases.	• More boll bearing capacity, uniform boll size • Tolerance to sucking pests • Stay green character • Clear bursting

2.3 Growth indicating parameter

2.3.1 Leaf area (dm^2 $plant^{-1}$): The leaf area was calculated using the disc method (Johnson, 1967). Two plants were chosen at random from the second row of each plot and kept separately for observations. Plant leaves were separated, 20 leaves were chosen at random, and 20 discs were obtained. Leaf area $plant^{-1}$ was calculated using the diameter of the disc, the oven dry weight of the disc, and the oven dry weight of the leaf sample. Leaf area $plant^{-1}$ was measured in decimetre squared (dm^2) and recorded at all stages of growth.

$$\mathbf{LA} = \frac{Wa \times A}{Wd}$$

Where,

LA = Leaf area (dm^2)

Wa = Weight of all the leaves (including disc) (g)

A = Area of 20 discs (dm^2)

Wd = Weight of 20 discs only (g)

2.3.2 Leaf area index: The leaf area index was worked out by dividing the leaf area $plant^{-1}$ by the land area occupied by that plant (Sestak *et al*., 1971).

$$\mathbf{LAI} = \frac{A}{P}$$

Where,

A = Leaf area $plant^{-1}$ (dm^2)

P = Land area occupied by the plant (dm^2)

2.3.3 Leaf area duration (days)

Leaf area duration is a measure of a unit's ability to produce leaf area over the course of its life. It was calculated using the Power *et al.*, 1967 formula

$$\textbf{LAD} = \frac{LAI_1 + LAI_2}{2} \times (t_2 - t_1)$$

Where,

LAD - Leaf area duration (days)

LAI_1 and LAI_2 are the leaf area index at time t_1 and t_2, respectively.

2.4 Data Analysis

Using standardized techniques, the pertinent growth data were recorded at 30, 60, 90, 120 DAT/DAS, and at harvest. At harvest, yield characteristics and observations were made. All of the data was then statistically analysed to draw conclusions using the Analysis of Variance (ANOVA) procedure described by Gomez and Gomez (1984).

III. RESULTS AND DISCUSSION

3.1 Effect of weather on crop growth

Crop growth is primarily caused by changes in environmental elements, and weather conditions have a significant impact on a crop's ability to grow, develop, and produce. Economic yield is more important than biological output due to the inherent interconnections of numerous physiological processes. These intricate processes are determined by the growing conditions of the crop.

Weather conditions must be favourable for proper crop growth and development, as well as optimum crop yield. Weather parameters varied during the crop growth period from July to January in both the 2018-19 and 2019-20 seasons (Table 2). For the previous 26 years, the average annual rainfall was 665.8 mm. September had the highest average rainfall (168.9 mm), followed by October (123.7 mm). The total rainfall received during the first year, 2018-19, was 244.0 mm, and the total rainfall received during the second year, 2019-20, was 631.4 mm. In 2018-19, September received the most rainfall (49.0 mm), followed by August (44.6 mm), whereas in 2019-20, September received the most rainfall (167.0 mm), followed by June (105.8 mm). The maximum and minimum temperatures recorded during the crop growth period from July to January in both years (2018-19 and 2019-20) revealed that the maximum temperature was recorded in January (39.0 ^{0}C and 38.5 ^{0}C, respectively in 2018-19 and 2019-20) and the minimum temperature was recorded in July (25.5 ^{0}C and 27.5 ^{0}C, respectively in 2018-19 and 2019-20). Similarly, the maximum relative humidity in July 2018 was 75.0 percent and 92.0 percent in December 2019. Abiotic stress was experienced by the crop during its growth period in November and December. The crop was irrigated as needed because it was grown in the Upper Krishna Command area, and it did not experience stress at any stage of its growth. Transplanting is an important climate-smart technique for dealing with late planting issues. As a result, research was carried out to investigate the possibility of transplanting and its impact on cotton crop performance.

Table 2. Monthly meteorological data for the experimental year 2018-19, 2019-20 and mean of the last 26 years (1992-2017) at Agricultural Research Station, Malnoor, University of Agricultural Sciences, Raichur, Karnataka

Month	Rainfall (mm)			Temperature (°C)						Relative humidity (%)		
				Mean maximum			Mean minimum					
	Average 1992-2017	2018-19	2019-20	Average 1992-2017	2018-19	2019-20	Average 1992-2017	2018-19	2019-20	Average 1992-2017	2018-19	2019-20
April	20.4	43.0	48.0	27.0	39.0	38.4	13.5	34.0	33.7	32.1	47.0	46.0
May	51.9	35.4	24.4	26.7	31.5	31.2	15.9	31.2	30.1	34.9	55.0	56.8
June	67.9	40.6	105.8	21.9	31.6	32.7	15.0	26.5	28.9	41.7	61.5	63.5
July	71.7	16.6	92.2	23.3	30.1	31.2	14.2	25.5	27.5	48.5	75.0	76.1
August	111.2	44.6	80.6	25.0	31.0	30.3	15.0	27.2	28.3	49.1	64.1	65.0
September	168.9	49.0	167.0	20.4	31.0	31.2	13.8	28.9	29.1	49.9	67.5	68.2
October	123.7	14.8	96.8	22.7	32.1	31.3	13.2	29.0	28.7	44.7	68.0	66.6
November	22.5	0.0	16.6	21.9	33.0	32.1	12.3	29.7	29.4	52.8	72.0	71.8
December	7.4	0.0	0.0	22.4	37.2	38.0	11.7	29.9	31.0	45.2	69.9	92.0
January	5.4	0.0	0.0	23.1	39.0	38.5	11.1	31.6	32.5	47.0	72.5	73.0
February	2.0	0.0	0.0	23.3	41.5	40.0	12.5	33.5	33.0	41.7	74.2	74.5
March	12.8	0.0	0.0	26.6	42.5	42.0	14.9	34.0	34.5	43.7	74.9	75.0
Total	**665.8**	**244.0**	**631.4**									

3.2 Performance of *Bt* cotton genotypes

The results showed that the *Bt* cotton genotype Jaadoo BG II had a significantly higher number of sympodial branches plant^{-1} (28.07) and total dry matter production (576.13 g plant^{-1}) than ACH 199 BG II (26.22 and 564.67 g plant^{-1}) and that both treatments were comparable. Bindass BG II produced significantly less sympodial branches plant^{-1} and total dry matter production (25.01 and 498.87 g plant^{-1}, respectively) (Table 3 & 4). Cotton is an indeterminate species, so cultivation practices can have a big impact on the dry matter accumulation in the vegetative and reproductive parts. Since cotton is an indeterminate species, cultivation methods may greatly affect the dry matter buildup of the vegetative and reproductive portions. Better seedling quality, increased leaf area, ideal leaf area index, dry leaf weight, dry stem weight, and dry weight of the reproductive organs may all contribute to the higher dry matter accumulation in transplanted *Bt* cotton genotypes.

The *Bt* cotton genotypes Jaadoo BG II (2188 kg ha^{-1}) and ACH 199 BG II (2145 kg ha^{-1}) recorded significantly higher seed cotton yield hectare^{-1} than Bindass BG II (1738 kg ha^{-1}) in Krishna command area, indicating the genotypes' adoptability and superiority (Table 3 & 4). The overall increase in seed cotton yield was a function of all growth and yield characteristics. Giri *et al.* discovered similar results (2008). The increase in seed cotton yield was attributed to seed cotton yield plant^{-1}, which is directly related to boll weight plant^{-1} and the number of bolls plant^{-1}, where Jaadoo BG II and ACH 199 BG II outperformed Bindass II. Increased plant height allowed for additional monopodial and sympodial branches to develop, which in turn enabled the plant generate more leaves to fix more photosynthates, boosting the yield of seed cotton.

The economic analysis clearly showed that the gross returns, net returns, and B:C in Jaadoo BG II were significantly higher (₹ 115928, ₹ 74,851 ha^{-1} and 2.72, respectively). ACH 199 BG II (₹113677, ₹ 72,600 ha^{-1} and 2.67, respectively) were comparable. Significantly higher than Bindass BG II (₹ 92010, ₹ 50,934 ha^{-1} and 2.18, respectively) (Table 5); this may be attributed to higher seed cotton yields recorded in Jaadoo BG II and ACH 199 BG II Bt cotton genotypes than Bindass BG II genotypes.

3.3 Effect of methods of establishment

In pooled data, seedlings raised in black polythene bags (29.17 and 616.01 g plant^{-1}, respectively) and biodegradable paper cups (28.66 and 604.53 g plant^{-1}, respectively) had a significantly higher number of sympodial branches plant^{-1} and total dry matter production at harvest than pro trays and dibbling method. The early establishment of the crop in polythene bags and biodegradable paper cups 30 days earlier, which encouraged early vigour and robust growth for better efficient use of natural resources, may be the cause of the increased sympodial branches plant^{-1} in transplanted cotton. The findings support those of studies by Pyati *et al.* (2017), Honnali *et al.* (2013) and Sahai (2003) noted that transplanted plants raised in plastic bags displayed greater height, earlier maturity, more branches, and larger bolls than plants grown from seed that was sown directly into the field.

Table 3. Growth attributes of *Bt* cotton genotypes as influenced by different methods of the establishment at harvest

Treatments	Plant height (cm)			Number of monopodial branches plant^{-1}			Number of sympodial branches plant^{-1}			Leaf area plant^{-1} (dm^2 plant^{-1})			Leaf Area Index			Total dry matter production (g plant^{-1})		
	2018	2019	Pooled	2018	2019	Pooled	2018	2019	Pooled	2018	2019	Pooled	2018	2019	Pooled	2018	2019	Pooled
Main plot																		
G_1	129.50	126.69	117.30	2.25	2.23	2.24	28.37	27.77	28.07	86.57	79.32	82.95	1.60	1.47	1.54	604.50	547.76	576.13
G_2	120.51	121.13	110.73	2.18	2.18	2.18	26.82	25.62	26.22	84.35	76.92	80.63	1.56	1.42	1.49	589.54	539.80	564.67
G_3	113.47	116.37	105.22	2.15	2.17	2.16	25.79	24.24	25.01	76.06	73.93	74.99	1.41	1.37	1.39	526.15	471.60	498.87
S. Em±	**1.66**	**1.22**	**1.24**	**0.05**	**0.05**	**0.03**	**0.12**	**0.26**	**0.17**	**0.79**	**0.67**	**0.82**	**0.01**	**0.01**	**0.02**	**10.11**	**8.65**	**6.00**
C.D. at 5%	**6.51**	**4.78**	**3.91**	**NS**	**NS**	**NS**	**0.48**	**1.02**	**0.53**	**3.09**	**2.61**	**2.57**	**0.06**	**0.05**	**0.05**	**39.68**	**33.96**	**18.91**
Subplot																		
E_1	135.03	128.58	120.96	2.40	2.36	2.38	29.64	28.71	29.17	89.05	87.73	88.39	1.65	1.62	1.64	649.32	582.69	616.01
E_2	111.23	113.60	102.80	2.02	2.04	2.03	24.67	23.38	24.03	78.12	67.03	72.57	1.45	1.24	1.34	510.05	457.75	483.90
E_3	131.41	130.82	120.17	2.31	2.33	2.32	29.25	28.08	28.66	85.42	85.95	85.69	1.58	1.59	1.59	634.49	574.57	604.53
E_4	106.97	112.60	100.40	2.04	2.04	2.04	24.41	23.33	23.87	76.71	66.19	71.45	1.42	1.23	1.32	499.72	463.88	481.80
S. Em±	**1.63**	**1.68**	**1.40**	**0.03**	**0.03**	**0.02**	**0.15**	**0.46**	**0.24**	**1.77**	**2.07**	**1.45**	**0.03**	**0.04**	**0.03**	**7.23**	**7.47**	**5.40**
C.D. at 5%	**4.85**	**4.99**	**3.99**	**0.09**	**0.10**	**0.06**	**0.44**	**1.37**	**0.68**	**5.27**	**6.14**	**4.13**	**0.10**	**0.11**	**0.08**	**21.48**	**22.19**	**15.37**
Interaction																		
S. Em±	**2.96**	**2.80**	**3.45**	**0.07**	**0.07**	**0.06**	**0.25**	**0.74**	**0.56**	**2.77**	**3.17**	**3.29**	**0.05**	**0.06**	**0.06**	**14.82**	**14.15**	**14.25**
C.D. at 5%	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

Main plot: *Bt* Cotton Genotypes (G)

G_1- Jaadoo BG II

G_2- ACH 199 BG II

G_3- Bindass BG II

Subplot: Methods of Establishment (E)

E_1- Seedlings raised in Black Polythene bags

E_2- Seedlings raised in Pro trays

E_3- Seedlings raised in Biodegradable Paper cup

E_4- Dibbling (Direct Sowing)

The transplanted seedlings raised in black polythene bags had a significantly higher seed yield per hectare than other establishment methods (2864 kg ha^{-1}), which were followed by seedlings raised in biodegradable paper cups (2853 kg ha^{-1}), which were comparable to one another but significantly better than seedlings raised in pro trays (1243 kg ha^{-1}) and the dibbling method (1134 kg ha^{-1}). Early sowing (*i.e.,* growing in black polythene bags or biodegradable paper cups) may have increased the growth characteristics (plant height, number of monopodial branches, number of sympodial branches, leaf area, leaf area index, and dry matter production per plant), which in turn increased the yield characteristics (number of bolls $plant^{-1}$, boll weight and seed cotton yield $plant^{-1}$). Yet, growing seeds in professional trays also aided in sowing early. The seedlings' growth was hampered, and they were unable to compete with the other two transplanting techniques because they lacked sufficient seedling supportive medium. Hence, the direct dibbling method of establishment was not in any way preferable to raising seedlings in professional trays. These outcomes were consistent with those reported by Buttar *et al.* (2011) and Sahai (2003), who described how cotton seedlings were raised at the ideal time of sowing in environmentally friendly bags like Donas (made of tree leaves) for 15 days, and then seedlings were transplanted in the main field with the onset of monsoon after the soil profile was uniformly wet. This was a typical low-cost and environmentally friendly technique that gives higher yields with minimal resources.

Seedlings raised in black polythene bags had significantly greater gross returns, net returns, and B:C ratios (₹ 1,51,734 ha^{-1}, ₹ 1,07,326 ha^{-1} and 3.42, respectively), while seedlings raised in biodegradable paper cups had comparable results (₹ 1,51,131 ha^{-1}, ₹ 1,04,433 ha^{-1} and 3.24, respectively). In seedlings cultivated in pro trays (₹ 65,864 ha^{-1}, ₹ 27,103 ha^{-1} and 1.70, respectively) and the dibbling method (₹ 60,090 ha^{-1}, ₹25,652 ha^{-1} and 1.74, respectively), which were comparable to each other and lower gross returns, net returns, and B:C were reported (Table 4 and Fig. 1). Due to the high seed cotton yield, the cost of cultivation, gross returns, net returns, and B:C were higher when the Bt cotton was grown in black polythene bags or biodegradable paper. Due to the high seed cotton yield, the cost of cultivation, gross returns, net returns, and B:C were higher when the Bt cotton was grown in black polythene bags or biodegradable paper. According to Honnali and Chittapur (2012), compared to farmers' traditional technique of dibbling, the yield increased by 32%. Compared to dibbling, the cost of transplanting was higher (₹ 5,854 ha^{-1}); nevertheless, the net yields (₹ 13,813 ha^{-1}) increased by 39%. In the UKP region, where the release of water is always late in the season and results in low output, transplanting is more favourable as it guarantees optimal use of resources, notably water and the growing season. Transplanting ensures timely planting and benefits from 25 days early sowing over dibbling.

However, despite being high yielders, Bt cotton genotypes Jaadoo BG II and ACH 199 BG II did not prove their ability to produce higher yields because the media in pro trays was insufficient to support earlier growth, which in turn did not cope with the transplanting shock. As a result, the genotypes' efficiency was not evidenced. While the reduced yield and gross returns in the dibbling method were primarily due to late sowing with seedlings 30 days advanced, the transplanting method demonstrated the beneficial effect of advanced sowing.

Table 4. Yield attributes and seed cotton yield of *Bt* cotton genotypes as influenced by different methods of establishment

Treatments	Number of bolls plant^{-1}			Boll weight (g boll^{-1})			Seed cotton yield (g plant^{-1})			Seed cotton yield (kg ha^{-1})		
	2018	2019	Pooled	2018	2019	Pooled	2018	2019	Pooled	2018	2019	Pooled
Main plot												
G_1- Jaadoo BG II	42.70	42.26	42.48	5.42	5.31	5.37	120.39	117.72	119.05	2215	2161	2188
G_2- ACH 199 BG II	42.05	40.89	41.47	5.30	5.24	5.27	117.85	115.88	116.86	2164	2127	2145
G_3- Bindass BG II	36.26	35.27	35.76	4.41	4.49	4.45	102.82	91.14	96.98	1851	1626	1738
S. Em±	**0.38**	**0.67**	**0.35**	**0.05**	**0.02**	**0.03**	**1.84**	**2.46**	**1.83**	**35**	**66**	**41**
C.D. at 5%	**1.48**	**2.62**	**1.11**	**0.21**	**0.08**	**0.11**	**7.23**	**9.65**	**5.77**	**137**	**260**	**129**
Subplot												
E_1- Seedlings raised in Black Polythene bags	46.53	44.22	45.38	5.43	5.42	5.43	159.17	153.35	156.26	2942	2787	2864
E_2- Seedlings raised in Pro trays	35.49	35.50	35.50	4.72	4.65	4.68	69.42	66.06	67.74	1265	1221	1243
E_3- Seedlings raised in Biodegradable Paper cup	45.41	43.17	44.29	5.33	5.36	5.34	158.76	150.02	154.39	2934	2772	2853
E_4- Dibbling (Direct Sowing)	33.92	35.00	34.46	4.70	4.63	4.66	67.39	63.56	65.47	1164	1104	1134
S. Em±	**0.75**	**0.59**	**0.52**	**0.05**	**0.03**	**0.03**	**2.06**	**3.41**	**1.86**	**50**	**65**	**39**
C.D. at 5%	**2.23**	**1.74**	**1.49**	**0.16**	**0.10**	**0.08**	**6.12**	**10.12**	**5.30**	**148**	**192**	**111**
Interaction												
G_1E_1	49.54	47.50	48.52	5.81	5.72	5.77	171.19	168.68	169.94	3164	3117	3140
G_1E_2	36.71	37.03	36.87	5.09	4.96	5.03	71.68	70.29	70.98	1325	1299	1312
G_1E_3	49.90	45.90	47.90	5.68	5.60	5.64	170.49	167.57	169.03	3151	3097	3124
G_1E_4	34.66	38.60	36.63	5.11	4.95	5.03	68.20	64.34	66.27	1219	1132	1175
G_2E_1	49.46	46.27	47.86	5.56	5.62	5.59	168.68	166.74	167.71	3117	3081	3099
G_2 E_2	36.51	37.57	37.04	5.07	4.90	4.99	68.61	68.48	68.55	1268	1265	1267
G_2 E_3	47.33	46.43	46.88	5.55	5.56	5.56	168.27	165.83	167.05	3110	3065	3087
G_2 E_4	34.91	33.30	34.10	5.01	4.89	4.95	65.83	62.48	64.15	1159	1096	1128
G_3 E_1	40.59	38.90	39.75	4.91	4.93	4.92	137.65	124.63	131.14	2544	2163	2353
G_3 E_2	33.25	31.90	32.58	4.00	4.07	4.03	67.98	59.43	63.71	1204	1098	1151
G_3 E_3	38.99	37.17	38.08	4.75	4.91	4.83	137.51	116.65	127.08	2541	2156	2348
G_3 E_4	32.20	33.10	32.65	3.98	4.04	4.01	68.13	63.87	66.00	1114	1085	1100
S. Em±	**1.19**	**1.10**	**1.21**	**0.09**	**0.05**	**0.08**	**3.60**	**5.67**	**4.72**	**83**	**117**	**101**
C. D. at 5%	**3.53**	**3.28**	**3.46**	**NS**	**NS**	**NS**	**10.68**	**16.85**	**13.45**	**245**	**332**	**288**

Table 5. Economics of *Bt* cotton genotypes as influenced by different methods of establishment

Treatments	Cost of cultivation (₹ ha^{-1})			Gross returns (₹ ha^{-1})			Net returns (₹ ha^{-1})			B: C		
	2018	2019	Pooled	2018	2019	Pooled	2018	2019	Pooled	2018	2019	Pooled
Main plot												
G_1 – Jaadoo BG II	41377	40777	41077	115154	116701	115928	73778	75925	74851	2.69	2.76	2.72
G_2 – ACH199 BG II	41377	40777	41077	112503	114851	113677	71126	74074	72600	2.62	2.71	2.67
G_3 – Bindass BG II	41377	40777	41077	96239	87781	92010	54863	47005	50934	2.26	2.10	2.18
S. Em±	-	-	-	**1818**	**3581**	**2244**	**1818**	**3581**	**2244**	**0.04**	**0.10**	**0.06**
C.D. at 5%	-	-	-	**7136**	**14059**	**7072**	**7136**	**14059**	**7072**	**0.18**	**0.38**	**0.23**
Subplot												
E_1 - Seedlings raised in Black Polythene bags	44708	44108	44408	152960	150509	151734	108251	106401	107326	3.42	3.41	3.42
E_2 - Seedlings raised in Pro trays	39061	38461	38761	65802	65926	65864	26741	27465	27103	1.68	1.71	1.70
E_3 - Seedlings raised in Biodegradable Paper cup	46998	46398	46698	152558	149704	151131	105560	103305	104433	3.25	3.23	3.24
E_4 - Dibbling (Direct Sowing)	34738	34138	34438	60542	59639	60090	25803	25501	25652	1.74	1.75	1.74
S. Em±	-	-	-	**2592**	**3483**	**2059**	**2592**	**3483**	**2059**	**0.07**	**0.09**	**0.07**
C.D. at 5%	-	-	-	**7701**	**10350**	**5864**	**7701**	**10350**	**5864**	**0.19**	**0.27**	**0.20**
Interaction												
G_1E_1	44708	44108	44408	164506	168333	166420	119798	124225	122011	3.68	3.82	3.75
G_1E_2	39061	38461	38761	68879	70139	69509	29817	31678	30747	1.76	1.82	1.79
G_1E_3	46998	46398	46698	163837	167222	165530	116839	120824	118831	3.49	3.60	3.55
G_1E_4	34738	34138	34438	63395	61111	62253	28657	26973	27815	1.82	1.79	1.81
G_2E_1	44708	44108	44408	162099	166389	164244	117390	122281	119835	3.63	3.77	3.70
G_2 E_2	39061	38461	38761	65936	68333	67135	26875	29872	28373	1.69	1.78	1.73
G_2 E_3	46998	46398	46698	161698	165486	163592	114699	119088	116893	3.44	3.57	3.50
G_2 E_4	34738	34138	34438	60279	59194	59737	25540	25056	25298	1.74	1.73	1.73
G_3 E_1	44708	44108	44408	132274	116806	124540	87565	72697	80131	2.96	2.65	2.80
G_3 E_2	39061	38461	38761	62593	59306	60949	23531	20844	22188	1.60	1.54	1.57
G_3 E_3	46998	46398	46698	132140	116403	124271	85142	70004	77573	2.81	2.51	2.66
G_3 E_4	34738	34138	34438	57952	58611	58281	23213	24473	23843	1.67	1.72	1.69
S. Em±	-	-	-	**4292**	**6334**	**5399**	**4292**	**6334**	**5399**	**0.11**	**0.17**	**0.12**
C. D. at 5%	-	-	-	**12751**	**18820**	**15378**	**12751**	**18820**	**15378**	**0.32**	**0.49**	**0.35**

Transplanted seedlings raised in black polythene bags

Transplanted seedlings raised in biodegradable paper cups

Transplanted seedlings raised in pro trays

Dibbling method

Figure 3. View of Jaadoo BG II seedlings established in different methods of an establishment at 60 DAT/DAS

3.4 Interaction effect between *Bt* cotton genotypes and methods of establishment

Significant interaction between *Bt* cotton genotypes and establishment techniques was observed. The research showed that growing Jaadoo BG II seedlings in black polythene bags or biodegradable paper cups greatly increased the number of bolls plant^{-1}, boll weight, and seed cotton yield plant^{-1}. Yet, when same genotypes were raised in pro trays or dibbled, the performance was subpar.

Seed cotton yield, gross returns, net returns, and benefit-cost ratio were significantly higher in Jaadoo BG II seedlings raised in black polythene bags (3140 kg ha^{-1}, ₹ 1,66,420 ha^{-1}, ₹ 1,22,011 ha^{-1} and 3.75, respectively), followed by ACH 199 BG II seedlings raised in black polythene bags (3099 kg ha^{-1}, ₹ 1,64,244 ha^{-1}, ₹ 1,19,835 ha^{-1} and 3.70, respectively), Jaadoo BG II seedlings raised in biodegradable paper cups (3124 kg ha^{-1}, ₹ 1,65,530 ha^{-1}, ₹ 1,18,831 ha^{-1} and 3.55, respectively) were found to be comparable to ACH 199 BG II seedlings raised in biodegradable paper cups (3087 kg ha^{-1}, ₹ 1,63,592 ha^{-1},₹ 1,16,893 ha^{-1} and 3.50, respectively). Better seedling growth may be the cause of higher seed cotton output in biodegradable paper cups and black polythene bags. It helps plants get over transplant shock, which improved growth characteristics that improved photosynthetic absorption and translocation to different regions of the plant. These elements boosted yield characteristics such bolls plant^{-1} and boll weight, improving the yield of seed cotton. According to Salakinkop *et al.* (2010), transplanted cotton had higher gross returns while having a higher cultivation cost. The financial advantage was 12.5 to 32 percent greater in transplanted cotton than in dibbling due to increased yield and gross returns.

Transplanted *Bt* cotton seedlings raised in biodegradable paper cups or black polythene bags incurred higher cultivation costs. Besides that, the increased seed cotton yield attained in these treatments as a result of *Bt* cotton's superior growth and yield qualities led to higher gross returns, net returns and B:C.

IV. CONCLUSION

The results of the current study indicate that raising the *Bt* cotton genotypes ACH 199 BG II and Jaadoo BG II in biodegradable paper cups is the most effective way to solve the issue of late sowing in Krishna command areas of Karnataka. Utilizing biodegradable paper cups is another environmentally responsible way to avoid the dangers of raising seedlings in black polythene bags. Hence, transplanting is a crucial climate-smart approach that aids in overcoming the issues associated with *Bt* cotton's delayed sowing while increasing output and productivity.

V. ACKNOWLEDGEMENT

The personnel of the Agricultural Research Station and College of Agriculture, Raichur, are gratefully recognized for the assistance provided over the course of this study.

CONFLICT OF INTEREST

The author(s) declares no conflict of interest.

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