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Fiber quality, yield and economic evaluation of Bt cotton hybrids under high density planting under drip irrigation

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Abstract
A field trial was conducted at Cotton Research Farm, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola during the *kharif* season of 2024-25 to evaluate the response of different Bt cotton hybrids under varying plant geometry on fiber quality, yield and economic evaluation in Bt cotton under drip irrigation. Three Bt hybrids viz. AKHH 2022-1 Bt, RCH-971 BG-2 and SWCH 4823 BG-2 tested with three plant geometry *viz*. 90 cm x 15 cm, 90 cm x 30 cm and 90 cm x 45 cm in factorial randomized block design with three replications and nine treatment combinations. The field was equipped with an inline drip irrigation system with 16 mm laterals placed at 90 cm apart and drippers spaced 40 cm apart. Results revealed significant variation among Bt hybrids and spacing levels. The hybrid AKHH 2022-1 Bt recorded the highest seed cotton yield (3134 kg ha^{-1}) and lint yield (1165 kg ha $^{-1}$), numerically higher fiber quality parameters such as UHML (29.8 mm), micronaire value (5.6 µg inch^{-1}), tenacity (29.2 g tex^{-1}), elongation (%) and uniformity index (%) and maximum economic returns. Among plant geometry, denser planting of 90 cm × 15 cm registered the highest seed cotton (3435 kg ha^{-1}) and lint yield (1260 kg ha^{-1}). The closer spacing also enhanced gross (251311 Rs ha^{-1}), net monetary returns (145573 Rs ha^{-1}) and B:C ratio (2.82) compared to wider spacing. Whereas, in interaction effect of AKHH 2022-1 Bt sown at (90 cm × 15 cm) denser spacing recorded higher profitability with 2.72 B:C ratio.

Keywords: Bt cotton, drip irrigation, economics, fiber quality, high density planting system, seed cotton yield

Introduction
Cotton (*Gossypium hirsutum* L.) is the most important crop in India and plays a significant role in agriculture and industry worldwide. As per data from the USDA, for the year 2024-25, the expected area under cotton cultivation is 31.1 million hectares and the production is 117.40 million bales, each weighing 217.72 kg. China is largely producing 28.20 lakh bales, India 25 million bales, Brazil 16.90 million bales, the United States 14.30 million bales, and Pakistan 5.50 million bales. Among the states, Maharashtra is the highest producer with 84.80 lakh bales followed by Gujarat (80.01 lakh bales), Telangana (48.95 lakh bales), Rajasthan (20.42 lakh bales) and Karnataka (18.56 lakh bales). The area under cotton for 2024-25 is 112.94 lakh hectares, which is less than the 123.70 lakh hectares covered in 2023-24. Maharashtra occupied the maximum cotton area with 40.86 lakh hectares, followed by Gujarat (23.66 lakh hectares), Telangana (17.70 lakh hectares), Karnataka (6.84 lakh hectares) and Madhya Pradesh (6.14 lakh hectares). The study aims to evaluate fiber quality, yield performance and economic returns of different Bt cotton hybrids under high density planting with drip irrigation. Recent studies on high density planting under drip systems in Maharashtra have reported significant increases in seed cotton yield and economic returns, yet comprehensive evaluation of fiber quality traits under these integrated practices remains scarce. Therefore, this study was designed to evaluate the combined effects of high density planting and drip irrigation on fiber quality, yield components, and economic viability of Bt cotton in Maharashtra's agro-ecology, filling the current research gap and providing practical recommendations for sustainable cotton production.

Materials and Methods

The field experiment was conducted at the Cotton Research Farm, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola during the kharif season of 2024-25, to standardize the most suitable plant geometry suitable for different Bt cotton hybrids under high density planting (HDP) with drip irrigation, in order to maximize growth, yield and economic returns. Three Bt hybrids viz. AKHH 2022-1 Bt (V1), RCH-971 BG-2 (V2) and SWCH 4823 BG-2 (V3) were tested at 90 cm x 15 cm (S1), 90 cm x 30 cm (S2) and 90 cm x 45 cm (S3) plant geometry. Experiment was laid out in factorial randomized block design with three replications and nine treatment combinations. The field had a fairly flat and uniform topography. The farm equipped with inline drip irrigation system with 16 mm lateral lines placed at 90 cm intervals and 40 cm dripper spacing. Cotton planting was done on 7th July 2024. The recommended dose of fertilizer (RDF) (120:60:60 N:P_2O_5:K_2O kg ha^{-1}) was applied through drip fertigation as per the schedule. Phosphorus was applied as basal, while nitrogen and potassium were supplied in five splits (10% at sowing, 20% at 20 DAS, 25% each at 40 and 60 DAS, and 20% at 80 DAS). The drip system supplied 2.2-4.5 Ltr $plant^{-1}$ day^{-1} depending on crop stage, crop production increases by 15-30 % and the efficiency of nitrogen, phosphorus and potassium obtained up to 95%, 45% and 80%. The growth and quality attributing parameters were recorded at appropriate time. The fiber quality parameters viz. Upper Half Mean Length (UHML), micronaire, tenacity, elongation and uniformity index were tested at CIROT, Nagpur laboratory and accordingly observations were noted.

Results and Discussion

Effect on fiber quality parameters

The numerically higher UHML was observed in AKHH 2022-1 Bt (29.8 mm) followed by RCH-971 BG-2 (29.6 mm), whereas SWCH-4823 BG-2 recorded comparatively lower UHML (29.3 mm). Micronaire ranged from 5.0-5.6 µg $inch^{-1}$, falling within the acceptable range for spinning and indicative of a medium-to-coarse fiber category (Bradow and Davidonis, 2000) [2]. Tenacity values varied from 28.4 to 29.2 g tex^{-1}, with AKHH 2022-1 Bt registering the highest fiber strength. Elongation percentage did not show a marked variation (5.6-5.7%), indicating consistency of fiber maturity among cultivars. Uniformity index ranged from 84.5-84.8%, suggesting well-balanced fiber length distribution, which is desirable for rotor and ring spinning operations (Basal and Tiftik, 2007) [1]. The fiber quality is genetic character and there were major difference in fiber quality of cotton due to different Bt hybrids under various planting geometry. The tested Bt cotton hybrids did not differ significantly with respect to Upper Half Mean Length (UHML), micronaire, tenacity, elongation and uniformity index. Similarly plant spacings did not exert a significant influence on quality parameters UHML remained statistically similar (29.5-29.7 mm), while micronaire ranged between 5.2-5.5 µg $inch^{-1}$ across all spacing treatments. The 90 cm × 45 cm spacing recorded numerically higher UHML (29.7 mm), whereas 90 cm × 15 cm recorded slightly higher tenacity (29.1 g tex^{-1}) and elongation (5.7%). Uniformity index values remained within a narrow range (84.5-84.8%). Similar results were reported by Reddy and Kumar (2010) [8]. The interaction effect of hybrid and spacing was non-significant for all fiber quality parameters (Table 1). The interaction effect among Bt cotton hybrids and different plant geometry were found to be non-significant.

Table 1: Fiber quality parameters [UHLM, Micronaire value, Tenacity, Elongation (%), Uniformity index (%)] as influenced by different Bt hybrids and plant geometry under drip irrigation

Treatments	UHML (mm)	Micronaire value (µg $inch^{-1}$)	Tenacity (g tex^{-1})	Elongation (%)	Uniformity Index (%)
A) Bt hybrids					
V_1-AKHH 2022-1 Bt	29.8	5.6	29.2	5.6	84.8
V_2-RCH-971 BG-2	29.6	5.6	28.4	5.7	84.5
V_3-SWCH 4823 BG-2	29.3	5.0	28.6	5.6	84.6
SE (m) ±	0.1	0.2	0.1	0.04	0.1
CD at 5%	NS	NS	NS	NS	NS
B) Plant geometry					
S_1-90 cm x 15 cm	29.5	5.5	29.1	5.7	84.8
S_2-90 cm x 30 cm	29.5	5.4	28.4	5.6	84.5
S_3-90 cm x 45 cm	29.7	5.2	28.7	5.7	84.6
SE (m) ±	0.1	0.2	0.1	0.04	0.1
CD at 5%	NS	NS	NS	NS	NS
Interaction (V × S)					
SE (m) ±	0.2	0.3	0.2	0.08	0.2
CD at 5%	NS	NS	NS	NS	NS

Table 2: Seed cotton yield (kg ha^{-1}), lint yield (kg ha^{-1}) and economics of Bt cotton as influenced by different Bt hybrids and plant geometry under drip irrigation

Treatments	Seed cotton yield (kg ha^{-1})	Lint yield (kg ha^{-1})	Cost of cultivation (Rs. ha^{-1})	Gross monetary returns (Rs. ha^{-1})	Net monetary returns (Rs. ha^{-1})	B:C ratio
A) Bt hybrids						
V_1-AKHH 2022-1 Bt	3134	1165	83838	229411	145573	2.72
V_2-RCH-971 BG-2	2928	1088	82400	214669	132269	2.59
V_3-SWCH 4823 BG-2	2787	1024	81409	204371	122962	2.50
SE (m) ±	50	19	-	1956	1763	-
CD at 5%	150	58	-	5864	5286	-

B) Plant geometry						
S_1-90 cm x 15 cm	3435	1260	89106	251311	162205	2.82
S_2-90 cm x 30 cm	2899	1076	81800	212564	130764	2.60
S_3-90 cm x 45 cm	2514	941	76741	184576	107835	2.40
SE (m) ±	50	19	-	1956	1763	-
CD at 5%	150	58	-	5864	5286	-
Interaction (V × S)						
SE (m) ±	86	33	-	3388	3054	-
CD at 5%	259	100	-	10157	9155	-

Table 3: Seed cotton yield (kg ha^{-1}) as influenced by interaction between Bt hybrids and plant geometry in cotton

Seed cotton Yield (kg ha^{-1})				
Treatments	**S_1 90 cm x 15 cm**	**S_2 90 cm x 30 cm**	**S_3 90 cm x 45 cm**	**Mean**
V_1-AKHH 2022-1 Bt	3744	3030	2626	**3134**
V_2-RCH-971 BG-2	3429	2908	2447	**2928**
V_3-SWCH 4823 BG-2	3132	2758	2470	2787
Mean	3435	2899	2514	
SE (m) ±	86			
CD at 5%	259			

Table 4: Lint yield (kg ha^{-1}) as influenced by interaction between Bt hybrids and plant geometry in cotton

Lint yield (kg ha^{-1})				
Treatments	**S_1 90 cm x 15 cm**	**S_2 90 cm x 30 cm**	**S_3 90 cm x 45 cm**	**Mean**
V_1-AKHH 2022-1 Bt	1392	1121	981	**1165**
V_2-RCH-971 BG-2	1270	1083	912	**1088**
V_3-SWCH 4823 BG-2	1117	1024	931	1024
Mean	1260	1076	941	
SE (m) ±	33			
CD at 5%	100			

Table 5: Net monetary returns as influenced by interaction between Bt hybrids and plant geometry in cotton

Net monetary returns (Rs. ha^{-1})				
Treatments	**S_1 90 cm x 15 cm**	**S_2 90 cm x 30 cm**	**S_3 90 cm x 45 cm**	**Mean**
V_1-AKHH 2022-1 Bt	182106	139421	115193	145573
V_2-RCH-971 BG-2	161663	131636	103508	132269
V_3-SWCH 4823 BG-2	142847	121236	104803	122962
Mean	162205	130764	107835	
SE (m) ±	3054			
CD at 5%	9155			

Effect on yield

Bt cotton hybrid AKHH 2022-1 recorded significantly higher seed cotton yield (3134 kg ha^{-1}), which was significantly superior to the other two hybrids. This was followed by RCH-971 BG-2 (2928 kg ha^{-1}), while the lowest seed cotton yield was noted with SWCH 4823 BG-2 (2787 kg ha^{-1}). The higher productivity of AKHH 2022-1 Bt could be attributed to its greater plant vigour, higher yield attributes and higher dry matter partitioning towards economic yield. Similar results were reported by Singh *et al.* (2010), Parlawar *et al.* (2017) and Parihar *et al.* (2018) [7, 9, 6]. Plant geometry significantly influenced seed cotton yield. Closer plant spacing of 90 cm x 15 cm (3435 kg ha^{-1}) topped in rank compared to wider spacing of 90 cm x 30 cm (2899 kg ha^{-1}) and 90 cm x 45 cm (2514 kg ha^{-1}), indicating better utilization of space and higher plant population under high-density planting. Similar results were found by Solanki *et al.* (2020) and Gouthami *et al.* (2023) [10, 3] (Table 2). Bt hybrid AKHH 2022-1 sown at denser plant spacing of 90 cm x 15 cm noted significantly higher seed cotton yield (3744 kg ha^{-1}) and lint yield (1392 kg ha^{-1}) over rest of treatment combinations (Table 3 and 4).

Effect on Economics

Among the treatments, AKHH 2022-1 Bt recorded the highest gross monetary returns (Rs. 229411 ha^{-1}), net monetary returns (Rs. 145573 ha^{-1}) and benefit-cost ratio of (2.72). In contrast, the Bt hybrid SWCH 4823 BG-2 registered the lowest gross monetary returns (Rs. 204371 ha^{-1}), net monetary returns (Rs. 122962 ha^{-1}) and benefit: cost ratio (2.50). In respect to plant geometry, closer spacing of 90 cm × 15 cm proved most remunerative by realizing maximum gross monetary returns (Rs. 251311 ha^{-1}), net monetary returns (Rs. 162205 ha^{-1}) and benefit: cost (2.82). While, the wider spacing of 90 cm x 45 cm resulted in the lowest economic returns with gross monetary returns (Rs. 184576 ha^{-1}), net monetary returns (Rs. 107835 ha^{-1}) with benefit-cost ratio (2.40) and lower seed cotton yield per ha. Similar results were reported by Kakade *et al.* (2023) and Latkar *et al.* (2024) [4, 5]. The interaction was found to be significant only for net monetary returns. The treatment combination AKHH 2022-1 Bt sown at denser planting of 90 cm x 15 cm registered higher NMR of Rs.1,82,106 ha^{-1} over rest of treatment combination (Table 5).

Conclusion

The study found that fiber quality (UHML, micronair value, tenacity, elongation% and uniformity index%) were numerically higher with Bt hybrid AKHH 2022-1 Bt and denser spacing of 90 cm x 15 cm. Bt cotton hybrids and plant geometry significantly influenced yield and economics of Bt cotton under high density planting system (HDPS) with drip irrigation.

Among the hybrids, AKHH 2022-1 Bt exhibited superior performance in terms of seed cotton yield and lint yield, which resulted in higher GMR, NMR and B:C ratio compared to the other hybrids. Similar kind of results observed in closer spacing of 90 cm × 15 cm enhanced seed cotton yield on a per hectare basis due to higher plant population, thereby achieving the highest GMR and NMR. Among interactions AKHH 2022-1 Bt with 90 cm x 15 cm spacing recorded the maximum productivity and profitability, proving its suitability for high density planting systems.

Thus, adoption of AKHH 2022-1 Bt at a spacing of 90 cm x 15 cm under drip irrigation is the most effective strategy to maximize yield and economic returns of Bt cotton hybrids.

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