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Original Research Article

Development of High Yielding and Early Maturing Cotton Variety Cyto-178 With Better Adaptation to Climatic Condition of Punjab

Farzana Ashraf[1], Khezir Hayat[1], Hafiz Muhammad Imran[1], Muhammad Akbar[1], Noor Muhammad[*1], Asifa Hameed[2], Rashida Aslam[1] Adeel Ahmad[1], Muhammad Azam Mian[1], Muhammad Adnan[1]

[1]Central Cotton Research Institute, Pakistan Central Cotton Committee, Multan, Pakistan
[2]Entomological Research Institute Faisalabad, Sub-station Multan, Pakistan
**Corresponding author`s email address:* noor.1272@yahoo.com

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Abstract: *To meet the increasing demand for cotton and improve fibre quality, the development of high-yielding, early-maturing, and disease-resistant cultivars remains essential for sustainable cotton production in Pakistan.* ***Objective:*** *This study aimed to develop and evaluate a new cotton cultivar, Bt. Cyto-178, for its agronomic performance, fibre quality, and adaptability under diverse agroecological conditions in Pakistan.* ***Methods:*** *Bt. Cyto-178 was developed at the Cytogenetic Section of the Central Cotton Research Institute (CCRI), Multan, Pakistan, from a cross between (Neelum 121 × Exotic material) × SL-365/1 (Cyto-124) during the 2003–04 cotton season. Selection was conducted from the F_2 to F_8 generations based on phenotypic traits, yield potential, and fibre quality. The cultivar was tested for 12 years in CCRI research plots, farmers' fields, and multi-location National Coordinated Varietal Trials (NCVT) across Punjab, Sindh, and other cotton-growing regions.* ***Results:*** *Bt. Cyto-178 consistently outperformed existing commercial cultivars in both preliminary and advanced yield trials. It ranked 10th in national yield performance during the 2014–15 season and demonstrated superior traits including early maturity, high yield, and resistance to major diseases. The cultivar is especially well-suited for the agroecological conditions of Punjab.* ***Conclusion:*** *Bt. Cyto-178 is a robust, early-maturing, and high-yielding cotton cultivar with enhanced fibre quality and disease resistance. Approved by the Punjab Seed Council in 2020, it is recommended for general cultivation across cotton-growing regions of Pakistan.*

Keywords: Cotton, Cultivar Development, Breeding, Seed Cotton Yield, Early Maturity, Fibre Quality

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Introduction

White gold is the most critical fibre crop worldwide and the second crucial oilseed. As an oilseed and fibre crop, it is cultivated in almost 70 countries and contributes to the worldwide economy. It is a tropical and subtropical plant, and much of the crop is grown in Asia because four Asian countries, China, India, Pakistan, and Uzbekistan, produce approximately 68% of the world's cotton. Its role in GDP is 1.6% in Pakistan. In 2008-09, the average yield was 3963, 1569, 2115 and 1959 in China, India, Uzbekistan and Pakistan, respectively (Singh, 2011). So many farmers, labourers, local textiles, etc., depend on cotton (Razzaq et al., 2021), and breeders incessantly struggle to sort out different qualitative and quantitative traits that add to enhance seed cotton yield (Sharma et al., 2021; Ballester et al., 2021; Razzaq et al., 2021).

The current cotton production is low due to various production constraints, including the lack of high-yielding cotton cultivars, which are the major ones. Similarly, drought and heat are also everyday abiotic stresses during the cotton growing season, which results in a severe adverse impact on the crop growth, yield and quality of fibre (Areej et al., 2021; Abo Sen et al., 2022). Cotton is dreadfully sensitive to heat and drought stress, which results in a severe reduction in yield due to these stresses, a complex phenomenon that influences cotton crop physiology (Areej et al., 2021). It is also susceptible to diseases, particularly cotton leaf curling disease. The flowering and boll formation stage in cotton is the most crucial, and the stresses occurring during these stages undoubtedly seriously influence cotton growth, development and final production (Yehia & Hashash, 2019; Zhong et al., 2021; Zhu et al., 2018). This heat, drought, and disease stress influences the physiological processes and alters the rate of photosynthesis, transpiration, stomatal conductance, carboxylation efficiency, and water use efficiency. Thus, even suitable cotton cultivars could be low-yielding under stress conditions (Qiu et al., 2020; Rajeev et al., 2018; Sultan et al, 2018). Mehdi et al., 2022, Montes et al., 2017, and Nidagundi et al., 2018 described that cotton cultivars developed in optimum conditions are not likely to sustain yield genotype-environment interaction, and selection is only fruitful in stress conditions.

Most cotton cultivars become susceptible to disease, heat, and drought stress. Thus, cultivating resistant and tolerant cultivars is a viable option to overcome these issues. Thus, there is always a need to develop cultivars resistant to biotic and abiotic stresses, ecologically suitable, environmentally friendly, and economically viable to sustain farmers' income and enhance their livelihood.

Bt-Cyto-178 has the edge over most cotton cultivars because of its short duration, high yield, and early maturity. This cultivar possesses enhanced genetic potency, contributed remarkably sound yield evaluation, and is thus best suitable for the existing growth conditions.

Methodology

Bt. Cyto-178 was obtained from the cross (Neelum 121 × Exotic material) × SL-365/1 (Cyto-124) during the crop season 2003-04. The F_1 were grown from single plant progeny in a pedigree method in 2004-05. During crop season 2005-06, the F2 segregation population was planted, and the selection of desired plants was made through the pedigree selection method. Cultivar was assessed in different replicated trials for 8 years consisting of micro varietal trials, standard varietal trials, and zonal varietal trials at the research area of Central Cotton Research Institute, Multan, and farmers' fields, respectively, during the year 2011-12 to

2014-15. These experiments were conducted in RCBD, having three replications except zonal trials, which were unreplicated. Bt. For comparison, CIM-598 and MNH-886 were included as local checks in all these experiments.

The line was then assessed for seed cotton yield, disease and heat tolerance, and other agronomic traits in national coordinated varietal trials (NCVT) across the country in 16 experimental locations during the 2013-14 and 2014-15 cotton crop seasons, respectively. Agronomic operations were performed according to standard recommendations for each location. After performing remarkably and achieving more seed cotton yield nationally, the Punjab Seed Council approved the line for cultivation in 2020 and named Bt. Cyto-178. The data recorded on seed cotton yield and other attributes were statistically analysed using the analysis of variance technique suggested by Steel et al., 1997 using Statistix 8.1 software program.

Results

The Punjab seed council recommended this newly developed cultivar in 2020 for general cultivation in Punjab. Important qualitative and quantitative attributes of Bt-Cyto-178 are: plants are tall and cylindrical with 0-4 monopodial branches and 8-12 sympodial branches, plant^{-1}, having perfect boll opening (Table 1). The phenology of Cyto-179 depicted that it takes 43-49 days for the first flower to have an average boll weight of 3.8 g. It possesses excellent CLCV, heat and drought tolerance with excellent fibre attributes such as GOT (40.5%), staple length (28.2 mm), strength (107.6) and fineness (4.2 ug/inch) (Table 1).

Table 1. Botanic explanation of Bt-Cyto-179.

General characteristics		**Seedling characteristics**	
Variety name	Bt-Cyto-178	Seedling length (cm)	6.8
Specie name	*Gossypium hirsutum* L.	Seedling colour	Light Green
Parentage	(Neelum 121 × Exotic material) × SL-365/1 (Cyto-124)	Foliage spot	Present
Breeding method	Hybridisation	Leaf characteristics	
Growth habit	Semi Erect	Foliage density	Intermediate
Plant height	145 cm	Leaf colour	Light Green
Plant shape	Cylindrical	Leaf length	11-13 cm
Fruit branch type	Sympodia (Short to medium)	Leaf width	14-17 cm
1st flower node	6-8	Petiole length	6-8 cm
Monopodia attitude	Semi erect	Leaf attitude	Semi erect
Monopodia plant^{-1}	0-4	Leaf type	Normal
Sympodia attitude	Semi erect	Leaf appearance	Flat
Sympodia plant^{-1}	29-32	Leaf nectaries	Present
Stigma pigmentation	Normal	Leaf hairiness	Hairy
Stem tip hair	Hairy	Boll characteristic	
Bud gossypol	Normal	Boll opening	Good
Flower characteristics		Boll weight (g)	2.8
Days to first flowering	42-47	Seed cotton yield (kg ha^{-1})	4120
Flowering duration	Long	Fibre characteristics	
Flower size	Long	Fibre colour	White
Petal spot	Absent	G.O.T.	39.4
Nectaries	Present	Staple length	28.2
Petal colour	Creamy	Micronaire value	4.5
Pollen colour	Yellow	Strength	103.6
Stamen density	Dense	Uniformity index (%)	85.2
Calyx size	Medium	Maturity ratio	1.01
Seed characteristics		Fibre length group	Medium Long
Seed size	Bold	Resistance	
Seed length/width	8.2/4.7	Lodging	Medium resistant
Seed index	7.4	Sucking	Medium resistant
Seed coat color	Brown	Boll worms	Medium resistant
Seed fuzziness	Semi fuzzy		
Fuzz Color	White		

Performance of Bt.Cyto-178 in Micro varietal trials, standard varietal trials, and zonal varietal trials

The micro varietal trial produced 4087 kg ha-1 seed cotton yield compared to the local check Bt. CIM-598, which produced a seed cotton yield of 2945 kg ha^{-1}. Thus the candidate variety produced 27.94% more seed cotton yield than local check during the crop season 2013-14 (Table 2). Compared to local check Bt, the candidate line was assessed in standard varietal trials for two consecutive crop seasons, 2013-14 and 2014-15. CIM-598. It produced 4120 kg ha^{-1} and 4191 kg ha^{-1} seed cotton yield, which was 26.38% and 35.57% more compared to check during both crop seasons, respectively (Table 2). Compared to local check Bt, the candidate line was also assessed in zonal varietal trials for two

consecutive crop seasons, 2013-14 and 2014-15. CIM-598. It produced 3864.7 kg ha^{-1} and 39505 kg ha^{-1} seed cotton yield, 22.68% and 25.28% more than checked during both crop seasons, respectively (Table 2).

Table 2. Seed cotton yield (kg ha^{-1}) of Bt. Cyto-178 compared to standard checks in different yield trials from 2014-15 to 2016-17.

Trial	Year	Bt. Cyto-178	Local check	% increase
MVT	2012-13	4087	(Bt. CIM-598) 2945	27.94
VT-1	2013-14	4120	(Bt. CIM-598) 3033	26.38
VT-1	2014-15	4191	(Bt. CIM-598) 2700	35.57
ZVT	2013-14	3864.7	(Bt. CIM-598) 2987.8	22.68
ZVT	2014-15	3950.5	(Bt. CIM-598) 2951.6	25.28
NCVT	2014-15	2823	(Bt. CIM-602) 2644	6.34
NCVT	2015-16	2235	(Bt. FH-142) 2196	1.75

Performance of Bt. Cyto-178 in National Coordinated Varietal Trials (NCVT)

The NCVT data recorded during the 2014-15 and 2015-16 crop seasons revealed the incomparable performance of Bt—Cyto-178 across the country. NCVT (2014-15) ranked 10th in Pakistan by producing a seed cotton yield 2823 compared to the check, which was 2644 (Table 3). It was observed to produce 2738 and 3226 kg ha^{-1} seed cotton yield in Punjab and Sindh, respectively. Similarly, in the crop season 2015-16, it ranked 18th in NCVT and produced 2235 kg ha-1 seed cotton yield compared to local check, which produced 2098 kg ha^{-1} (Table 4). Thus, it yielded 1.75% more seed cotton yields than the check.

Table 3. Pooled seed cotton yield (kg ha^{-1}) analysis of cotton cultivars included in NCVT during crop season 2014-15.

Candidate variety	Punjab	Sindh	Pakistan
FH-Lalazar	3500	3579	3271
Baghdadi	3538	3357	3220
VH-327	3471	3347	3201
CEMB-77	3209	3347	3072
CIM-616	3238	3342	3055
FH-142 (Std-2)	3058	3441	3028
CEMB-66	3144	3133	2951
CIM-622	2989	3053	2846
BH-184	2863	3052	2825
Cyto-178	2738	3226	2823
MNH-988	2705	3137	2775
Cyto-177	2782	3081	2767
NIAB-874B	2754	3080	2755
BH-185	2615	3123	2753
SLH-8	2875	2921	2743
IUB-13	2540	3008	2653
VH-305	2684	2731	2644
CIM-602 (Std-1)	2412	3135	2644
IR-NIBGE-6	2476	2911	2587
IR-NIBGE-7	2296	3106	2572
FH-Noor	2635	2724	2563
IUB-63	2178	3057	2525
RH-647	2110	2844	2448
TH-21/09	2119	2883	2421

Table 4. Pooled seed cotton yield (kg ha^{-1}) analysis of cotton cultivars included in NCVT during crop season 2015-16.

Candidate variety	Punjab	Sindh	Pakistan
VH-327	1927	3142	2525
NIAB-878B	1934	2713	2475
GH-Baghdadi	1773	3008	2448
CIM-622	1707	3134	2438
AGC-Nazeer-1	1778	3079	2436
GH-Mubarak	1973	2598	2422
Eagle-1	2097	2500	2387
FH-326	1876	2699	2372
VH-363	1846	2521	2364
MNS-992	1831	2407	2332
BZU-75	1903	2416	2331
Saim-32	2148	2417	2322
CEMB-77	1747	2642	2279

NIAB-874B	1688	2813	2269
Sahara-120	1934	2454	2267
CIM-602 (Std-1)	1551	2894	2244
Zakriya-1	1721	2539	2243
Cyto-178	1763	2767	2235
Adan-11	1743	2631	2213
FH-142 (Std-2)	1492	2628	2196
Suncrop hybrid-2	1814	1980	2187
Cyto-179	1703	2350	2154
Sahara-150	1637	2679	2153
IR-NIBGE-7	1648	2617	2121
Crystal-1	1226	3007	2117
IUB-63	1280	2624	2078
QM-IUB-65	1407	2428	2072

Fibre quality

The mean values of the fibre quality attributes in 178 different evaluation trials showed that it possesses remarkably outstanding fibre attributes. The fibre length was more than 28 mm in micro varietal, varietal, zonal, and national varietal trails. It also depicted excellent fibre strength, micronaire value, and uniformity in all these trials, above the minimum recommended standard values (Table 5).

Table 5. Fibre quality attributes of Bt. Cyto-178 compared to standard checks in different yield trails from 2013-13 to 2014-15.

Trial	Year	Bt. Cyto-178			
		Fibre length (mm)	Fibre strength	MIC	Uniformity
MVT	2012-13	27.3	104.6	4.7	48.6
VT-1	2013-14	28.7	105.2	4.8	48.7
VT-1	2014-15	28.2	98.7	4.6	49.1
ZVT	2013-14	28.2	101.3	4.7	48.1
ZVT	2014-15	28.3	103.2	4.6	48.8
NCVT	2014-15	27.5	100.7	4.7	49.3
NCVT	2015-16	27.2	107.0	4.7	49.0

Production technology

In order to attain the maximum production, the following production technology for Bt-Cyto-178 is recommended (Table 6): 2-3 deep ploughs followed by a cultivator and then a rotavator to pulverise and prepare good root zone and soil conservation. Evil sowing is recommended to attain maximum seed cotton yield because it facilitates the maintenance of plant population, weed eradication, and efficient use of fertiliser and conserves irrigation water. The Fertiliser application consists of 1-1.5 bags DAP and 2-3 bags urea, and it must be applied before the end of August. First, irrigation must be done after sowing, followed by frequent irrigation on the fourth or fifth day. Then, three more irrigations with 15-day intervals are required, while further irrigations depend on weather conditions and soil structure.

Table 6. Recommended production technology for cultivation of Bt-Cyto-178.

Sowing time	March 15 to June 15
Seed rate	
Drill sowing	8-10 kg acre^{-1}
Ridge sowing	06-08 g acre^{-1}
Plant spacing	9-12” 1ft
Bad spacing	2.5 ft
Irrigations	6-7
1st irrigation	35-40 days after sowing
Subsequent irrigations	15 days interval
Last irrigation	1st week of October
Fertiliser	DAP 1-1.5 bags at sowing and 2-3 bags urea with split irrigations, and the last split dose of urea must be applied from 15 to 25th August.
Plant protection	As per insect pest infestation

Discussion

Cultivar development with maximum yield potential and improved adaptability is needed because less seed availability is accredited to the non-availability of pure seeds of better-quality cultivars (Areej et al., 2021). The evolution of high-yielding genotypes can significantly enhance cotton production (Arshad et al., 2020). Approximately 25-40% improvement in yield can be achieved by breeding new high-yielding resistant cultivars (Arshad et al., 2020). In Pakistan, a handful of short-duration and tolerant cultivars were developed, but this was in the past, and from the last decade, the short-duration potential has not been utilised and heat-resistant cultivars for the development of the community. In such circumstances, Bt-Cyto-178 is a blessing because it is a short-duration, high-yielding, heat and drought-resistant cultivar. Bt-Cyto-178 has many outstanding attributes which distinguish it from the existing approved cultivars.

Based on the consolidated results of nationally coordinated varietal trials and technology tests from highly alleged bio-labs, Cyto-178 was confirmed as a competitive and favourable Bt cultivar of maximum yield potential and sturdy adaptability to heat and drought conditions. This

cultivar can resolve all-out challenges in the area of good crop production. The introduction of Bt-Cyto-178 is the source of maintenance and enrichment of germplasm for which a filial population study was carried out.

Conclusion

The development of Bt-Cyto-178 is the pinnacle of achievement in cultivar development. Nothing can be compared with this cultivar's short duration, high yielding, and heat resistance under the agro-ecological conditions of Punjab, particularly across the country. Furthermore, its resistance to cotton leaf curling disease makes it highly suitable for growing throughout the country. This will not only diversify the genetic base of the area regarding cotton cultivars but also enhance the livelihood status of the farming community by having short duration, high yielding, and being best tolerant to high temperatures and under drought conditions.

Declarations

Data Availability statement
All data generated or analysed during the study are included in the manuscript.
Ethics approval and consent to participate
Approved by the department concerned.
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Conflict of interest

The authors declared the absence of a conflict of interest.

Author Contribution

All authors contributed equally

All authors reviewed the results and approved the final version of the manuscript. They are also accountable for the integrity of the study.

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