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CYTO-124: A REMARKABLE VARIETY EVOLVED AGAINST COTTON LEAF CURL DISEASE THROUGH INTROGRESSION

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ABSTRACT

Central Cotton Research Institute (CCRI), Multan, Pakistan has evolved an upland cotton cultivar Cyto-124 through introgression for Cotton Leaf Curl Virus (Begomovirus) resistance. It was developed through crossing [{2(*Gossypium hirsutum* x *Gossypium anomalum*) X [3]*Gossypium hirsutum*} x {2(*Gossypium arborium* x *Gossypium anomalum*) x [2]*G. hirsutum*]. It was tested for seed cotton yield in varietal trials, and zonal varietal trials at Govt. and farmer fields. Cyto-124 gave 37.1, 19.9 and 22.4% higher yield as compared to three standards MNH-786, CIM-554 and CRSM-38 respectively in varietal trials while Cyto-124 had seedcotton yield of 3075 kgha^{-1} in-contrast to 2919 kg ha^{-1} of CIM-573 in zonal trials. Cyto-124 produced more seedcotton yield (SCY) than the standards for two consecutive years (2013 & 2014) in National Coordinated Varietal Trial (NCVT). In NCVT during 2013-14, this strain had a maximum yield of 2244 kg ha^{-1} compared with 1326 kg ha^{-1} of standard variety CIM-573 in Punjab. The virus data taken in NCVT indicated that minimum disease incidence (27.9%) was recorded in Cyto-124 making it the more tolerant strain against CLCuV. The approval of this CLCuV resistant cultivar will considerably contribute a lot in the revival of cotton.

***Keywords**:* Cotton, interspecific, CLCuV tolerant, Fiber quality, Pakistan.

INTRODUCTION

American cotton is considered to be the best for fiber production all over the globe. More than 50 species are found in *Gossypium* genus (Gallagher *et al.* 2017; Fryxell, 1992**)**. Out of which four are cultivated species while *G. hirsutum* contributes more than 95% production. It has been cultivated in about 80 countries and being the ultimate source of natural fiber for the textile sector (Tan *et al.* 2014). Upland cotton is the backbone for the livelihood of Pakistan as it contributes 1.8% to GDP and 8.6% to value addition in agriculture (Anjum *et al.* 2015). Upland cotton was grown on an area of 1937000 hectare with production of 8.329 million bales, which is 17.9% higher than 2020 in Pakistan (Economic Survey of Pakistan**,** 2021-22). Nonetheless, production was less than expected 10.671 million bales due to CLCuV and scarcity of water. As many biotic and abiotic factors affect the production of cotton but the main threat is CLCuV. The vector for cotton leaf curl disease is White fly (*Bemisia tabici*) (Rajagopalan *et al.* 2012; Briddon *et al.* 2014) which directly inject cotton leaf curl virus (Sattar *et al.* 2013); being a menace for cotton production for decades. Studies have reported yield losses ranging from 10% to as high as 80% due to the virus (Sattar *et al.*, 2013). CLCuV infection leads to noticeable changes in morphological traits of cotton plants. These changes include reductions in plant height, number of bolls per plant, boll weight, fiber length, fiber strength, and fiber elongation (Akhtar *et al.*, 2017; Mansoor *et al.*, 2018; Sarfraz *et al.*, 2018). CLCuV infection negatively affects the quality of cotton fiber. It results in decreased fiber length, strength, and fineness, which impacts the overall fiber quality and market value (Sattar *et al.*, 2018; Rehman *et al.*, 2017). It has been reported that CLCuV is a menace for lint production as it has reduced (80%) yield production in Pakistan and North India (Varma *et al.* 2003; Mansoor *et al.* (2003); Sattar *et al.* (2013). Morphological traits are severally effected due to

CLCuV as on mean basis plant height (40.6%), number of bolls per plant (72.5%), boll weight (33.8%), upper half-mean length (3.44%), strength (10%) and about 10% to fiber elongation (Ahmad *et al.* 2002). Moreover, Ashraf *et al.* (2013); Hasan *et al.* (2016) reported that 30% cotton yield is reduced due to CLCuV in Pakistan. Cotton is a crop of prime value for Pakistan's economics and foreign reserves. Nonetheless, Pakistan produces less quantity of seed cotton as compared to other high yielding nations of the world (Sattar *et al.* 2013). It is a matter of great concern in the scientific community to overcome this disease. CLCuV resistant variety development is need of the day to protect cotton crop from the loss of this devastating disease likewise virus was controlled earlier in Sudan and Egypt (Hussain *et al.* 1975). The transference of disease resistance from interspecific crosses is the base to tackle this alarming situation. CIM-443, CIM-446 and CIM-448 approved for CLCuV tolerance at Central Cotton Research Institute, Multan (Shah *et al.* 2006). These variety found to be resistant when but with the occurrence of different variant for of this disease; these genotypes were declared susceptible. The ultimate strategy of this work was to transfer CLCuV resistance to *Gossypium hirsutum*. Despite having resistance for CLCuV to all available approved cultivars; new cultivar Cyto-124 has good yield potential and good fiber traits. Fabric of high quality could be develop using this cultivar. It is thought that registration of this cultivar will substantially contribute to cotton production. Sahar *et al.* 2021 found statistically significant differences for yield and yield components among the genotypes developed in *G. hirsutum*. Likewise, significant variation was observed for seedcotton yield among genotypes Ahmad *et al.* (1982). Moreover, statically significant variation was observed among varieties for seedcotton yield, lint percentage and fiber length (Soomro *et al.* 1986). Wider variation was observed for bolls per plant, boll weight, seedcotton and ginning outturn among the genotypes (Khan *et al.* 1989). Afzal *et al.* (2001) revealed that genotypes and their interaction (year x genotypes) were found highly significant for bolls per plant, boll weight and seedcotton yield also interaction year x genotypes. Afzal *et al.* (2002) observed statistical significance for plant height, bolls per plant, boll weight and seedcotton yield in the genotypes. Hanif *et al.* (2001) also observed that genotypes played significant part in seedcotton yield. Khan *et al.* (2002) observed that varietal differences matter a lot for plant development. Significant differences for different yield-related traits like bolls per plant, boll weight and seed cotton yield (Arshad *et al.* 2003a, 2003b) revealed that varieties significantly affect the yield of plant and observed significant difference in cotton crop due to sowing of different varieties. The loss in cotton production has been minimized by evolution of CLCuV tolerance/ resistant varieties i.e., CIM-1100, CIM-448, CIM-443, CIM-446, CIM-482, CIM-473, CIM-499, CIM-496, CIM-707 and CIM-506 for the first time in the history of Pakistan by the breeders of Central Cotton Research Institute Multan. Later on, Cotton Research Institutes/Stations of Punjab and Federal Government respectively, developed CLCuV tolerance/ resistant varieties i.e., FH-634, FVH-53, FH-900, FH-901 FH-1000, and NIAB-999 up to 2005. With the introduction of this new CLCuV tolerant, early maturing strain Cyto-124 above mentioned problems can be solved (Arshad 2003c, 2003d). Several studies have been conducted for developing CLCuV tolerant varieties but no durable resistance has been observed yet. So, it is need of the day to transfer resistance from wild germplasm sources to upland cotton Baig and Khan (2013). Anjum *et al.* (2014) found that CIM-608 developed from introgression 2(*G. hirsutum* × *G. anomalum*) × ^{3}*G. hirsutum* showed highest CLCuV tolerance. They also observed that CIM-608 produced highest seedcotton yield as compared to standards MNH-786. With the evolution of this elite CLCuV tolerant, early maturing Cyto-124 aforementioned problems would be solved and consequently yield will be increased.

MATERIAL AND METHODS

Parentage/Pedigree: The new cotton cultivar Cyto-124 was evolved through introgression [{2(*G. hir.* x *G. ano.*) x ^{3}*G. hir.*} x {2(*G. arb.* x *G. ano.*) x ^{2}*G. hir.*}] x ^{2}*G. hir.* [{2(*G. hirs.* x *G. anom.*) x ^{3}G. *hirs.*}x {2 (*G. arbo.* X *G. anom.*) x ^{2}G.*hirs.*}] x^{2}*G. hirs* in 2004-05 at CCRI Multan. The elite strain was bulked in 2009-10 in F_6 and then tested in yield comparison and adaptability trials.

Breeding History: These interspecific hybrids evolved at CCRI, had indeterminate growth habit, better yield and economical fiber traits according to the demands of textile sector. These interspecific hybrids were extremely resistant to the CLCuV, showed earliness and high tolerance to heat (Gill and Bajaj, 1987). Approximately 80 F_1 individuals were sown in highly infested field at CCRI, Multan and were selfed to get next generation seed from each individual. CIM-573 was used as a spreader for CLCuV disease in each 3rd row as grown for raising F_2 generation at CCRI Multan on 15th June Further, whitefly was not controlled by pesticides till 90 days for the management of whitefly vector. T-shape grafting procedure like petiole grafting was used in F_2 plants and following generations for high CLCuV incidence Grafting was done at evening and evaporation from grafted buds was reduced by using polythene strips. CLCuV resistant plants were used for advancement of generations on daily basis Virus susceptible buds in F_3 generation were used for ensuring maximum disease inoculum and white fly population. F_4 individuals were developed from F_3 plants having good

yield and no differences for CLCuV infestation. The same methodology was used till F_5. During 2012-13, individuals found to be resistant for CLCuV and good yield were designated as Cyto-124. During 2012-2014, Cyto-124 was screened with standards (CIM-554, CRSM-38 and MNH-786) for yield potential and phenological characters at PSC, Khanewal and CCRI, Multan. RCBD (Randomized complete Block Design) with 4 replications was used at both locations with plot size of $56m^2$. Standard agronomic practices were followed while pest control measures were done according to insects. Manual picking was done from two mid rows at maturity for assessing the yield potential of the elite strain. Moreover, during 2012-13 & 2013-14, adaptability trials were conducted at 20 different locations and at progressive farmer fields in Punjab following RCBD with 4 replicates using CIM-573 as a check. Recommended agronomic and pest control measures were taken at all locations. Roller gin was done for the determination of lint percentage and fiber traits. Ginning outturn was determined. While about 50g sample was used for fiber quality using HVI like span length, uniformity index, fiber fineness and fiber strength.

RESULTS

Varietal Trials: Cyto-124 was screened for yield potential with commercial varieties MNH-786, CIM-554 and CRSM-38 at Central Cotton Research Institute, Multan in varietal trials. Cyto-124 produced significantly higher yield 37.1, 19.9 and 22.4% respectively than all standards (Table 2).

Zonal Varietal Trials were conducted at the progressive growers in different districts of Punjab during 2012-13 and 2013-14 for yield. Table 3 showed that average of 19 locations was 2879 kg ha^{-1} compared with 2735 kg ha^{-1} of CIM-573 during 2012-13. During 2013-14; Cyto-124 was further tested in zonal varietal trials at 20 different ecological zones. Cyto-124 gave the highest yield of seed cotton 3075 kg ha^{-1} compared with 2919 kg ha^{-1} of CIM-573 as a mean of all locations (Table-3).

Regional Adaptability Trials:

National Coordinated Varietal trials: Yield potential of Cyto-124 was assessed at different locations in National Coordinated Varietal Trials were conducted for two years i.e., 2012-13 and 2013-14. Table 5 showed that Cyto-124 had higher yield (1828 kg ha^{-1}) compared to check CIM-573 with 1790 kg ha^{-1}. Cyto-124 was also included in NCVT during 2013-14. Upon mean basis of all locations in Punjab, Cyto-124 gave higher yield 2244 kg ha^{-1} in-contrast to control CIM-573 with 1326 kg ha^{-1} (Table 6).

Insect-pest Host Resistance: Cyto-124 was evaluated for tolerance against sucking pests (Jassid, White fly, Thrips) and bollworms in "Host-plant resistance trial" with standard CIM-573 (Table 7). Cyto-124 had highest tolerance for sucking insects while found about similar to other strains for bollworm damage (Table 8).

Pathological Screening of Cyto-124: NCVT consisting of 15 elite strains conducted at CCRI, Multan for the determination of Cyto-124 response in field conditions for CLCuV resistance, tolerance, stunting and boll rot during 2012-2013. It was observed from CLCuD severity that all the strains found to be highly susceptible but Cyto-124 had least severity (2.98%) (Table 9). While maximum infestation (100%) was found in about all elite strains like (NIA-80, VH300, NIAB-112, CIM-573 and PB-38) compared to Cyto-124 with minimum (27.4%). During 2013-14, almost same pattern was observed in NCVT as Cyto-124 had least (9.2%) CLCuD compared to standard CIM-573 with 76.0%. Moreover, it was also shown from (Table 10) that TH-112/05 had maximum stunting (2.5%) in-contrast to Cyto-124 (0.5%). It has been reported in the past that disease tolerance/resistance should be included in the screening of genotypes to get outcome from management practices (Weiss, 2000). Anjum *et al.* (2014) found that elite strain i.e CIM-608 found to highly tolerant to CLCuD and our findings are in accordance to this screening.

Ginning outturn (GOT %) and fiber traits: Cyto-124 has GOT % of 42.0% while other fiber quality traits like fiber length, micronaire and strength were 28.7mm, 4.5 (µg $inch^{-1}$) and 99.6 thousand pounds per square inch (tppsi) respectively as compared to standards MNH-786 with 39.9%, 26.1, 5.2 and 101.2 alternatively (Table 11). Counts lea strength product (CLSP) at 50 counts was 2208 in CIM-496 which is included in A-grade. It has been observed that Cyto-124 had very good fiber traits than standards.

Morphological characters: Cyto-124 was screened for two years in NCVT and morphological traits were observed which include plant height (124cm), monopodial branches per plant (1.1), sympodia branches per plant (29.0), bolls per plant (29.5) and boll weight (2.8g) as compared to standard with 153.0cm, 1.15, 24, 18.5 and 2.35g per plant alternatively (Table 12).

Table 1. Different stages of hybridization and selection

Year	Generation/Trial	A c t i v i t i e s
2004 -05	F_1	2(*G. hirs. X G. anom.*) x ^{3}G. *hirs.* was crossed with 2 (*G. arbo.* X *G. anom.*) X ^{2}G. *hirs.*} in green house when these crosses were at tetraploid level. Petiole grafting was carried out to screen and selection CLCuV disease free plants and back crossing method was applied to integrate economic & fibre traits *in G. hirsutum*.

2004-2005	BC_1	Selected CLCuV resistant plant were back crossed with *G. hirsutum* to increase the frequency of genes which are responsible for economic & fibre traits *in G. hirsutum*.
2005-06	F_1 BC_2	Screened plant from F_1 of BC_1 through petiole grafting, CLCuV resistant plant were back crossed with *G. hirsutum* to increase the frequency of genes which are responsible for economic & fibre traits *in G. hirsutum*.
2006-2009	F_2-F_5	Finally Bulked in F_5 after continuous screening and selection in different segregating (F_2-F_5)generations
2010-2013	Micro Varietal Trial, Varietal Trial, Zonal Varietal Trial, NCVT, DUS TRIAL and BIGGER BLOCKS	Different yield, DUS and National Trials were done to test the performance of variety. DUS trial was conducted by National Seed Certification and Registration Department and bigger blocks at Punjab Seed Corporation Farms, Khanewal. Spot examination by the Expert Sub-Committee of Punjab Seed Council.
2014-15	Proposal Submission	Proposal was submitted to Expert Sub-Committee for forwarding to the Punjab Seed Council for approval & finally approved for general cultivation.

Table2. Seedcotton Yield of Cyto-124 in Varietal trials at Central Cotton Research Institute, Multan during 2010-11 to 2013-14

Year	Trial	Location	Varieties / seed cotton (kg ha^{-1})				CD (5%)
			Cyto-124	MNH-786	CIM-554	CRSM-38	
2010-11	MVT-2	Multan	4022	3381	-	-	625.26
2011-12	VT-1	Multan	3030	-	2621	2498	50.6
2012-13	VT-1	Multan	2847	1947	2481	-	174.17
2013-14	VT-3	Multan	2331	1363	-	-	218.2
Average			3058	2230	2551	2498	
Percent increase over				37.1	19.9	22.4	

Table3. Seedcotton Yield of Cyto-124 at various locations during 2012-13

Sr. No.	**Location**	Seedcotton (kg ha^{-1})	
		Cyto-124	CIM-573
1	Shujabad, Multan	3150	2950
2	Duniyapur Lodhran	3060	2861
3	Alipur, Mazafar Ghar,	3092	2924
4	Kabirwal, Khanewal	2793	2687
5	Jahanianm, Khanewal	2831	2587
6	Kot. Addu, Mazafarghar	2744	2459
7	Fazalpur, District Rajanpur	2711	2564
8	18 Kasi, Multan	2692	2647
9	Choti Zaari, D G Khan	2799	2945
10	Kot Sultan Layyah	2792	2764
11	Chiatian, Bahawalnagar	2844	2758
12	Hasalpur, Bahawalnagar	2906	2675
13	Khan Bela Rahim Yar Khan	2792	2576
14	Liaqatpur, Rahim Yar Khan	2844	2864
15	Bahawalpur	3033	2951
16	Lodon Vehari	2916	2574
17	Kot. Chutta,D G Khan	2863	2681
18	Uch Sharif, Bahawalpur	3111	2875
19	Sadiqabad, R Y Khan	2735	2654
Mean		**2879**	**2735**

Table 4. Yield performance of Cyto-124 at farmers' fields during 2013-14

Sr.No.	**Location**	**Seedcotton Yield (kg ha^{-1})**	
		Cyto-124	**CIM-573**
1	Shujabad, Multan	3099	2790
2	Duniyapur Lodhran	2932	2800
3	Alipur, Mazafar Ghar,	2709	2730

4	Kabirwal, Khanewal	3222	3040
5	Jahanianm, Khanewal	2741	2700
6	Kot. Addu, Mazafarghar	3052	2900
7	Fazalpur, District Rajanpur	2701	2550
8	18 Kasi, Multan	2990	2810
9	Choti Zaari, D G Khan	3333	3100
10	Kot Sultan Layyah	3226	3000
11	Chiatian, Bahawalnagar	3301	3270
12	Hasalpur, Bahawalnagar	2943	2830
13	Khan Bela Rahim Yar Khan	2866	2600
14	Liaqatpur, Rahim Yar Khan	3121	2920
15	Bahawalpur	3377	3220
16	Lodon Vehari	3549	3430
17	Kot. Chutta,D G Khan	3267	3220
18	Uch Sharif, Bahawalpur	2990	3100
19	Sadiqabad, R Y Khan	2963	2580
20	Mian Channu Khanewal	3120	2780
	Mean	**3075**	**2919**

Table5. National Coordinated Varietal Trial for Adaptability Testing in Punjab zone during 2012-13

Varieties	Punjab					Average
	NIBGE FSD	CCRI Multan	CRS Multan	PSC Khanewal	CRS R Y Khan	
GS-444	1812	1099	1418	3265	2624	2044
PB38	1616	1349	1336	3193	2237	1946
BH-176	1835	1175	1239	2987	2357	1918
CRIS-510	2069	1193	1206	3032	2022	1904
Cyo-124	**1359**	**1507**	**1581**	**2673**	**2021**	**1828**
CIM-573	1888	1310	1483	2189	2081	1790
DNH-105	1706	1418	1190	2260	2283	1771
NIAB-112	1193	1103	1500	2781	2152	1746
VH-300	1284	843	1467	2314	2771	1736
NIA-80	1767	1516	1500	1955	1811	1710
JS-212	1540	992	1060	1812	2134	1508
IUB-11	1268	1106	1108	1668	1766	1383
CIM-612	1133	1213	1108	1740	1563	1351
CIM-591	680	1214	1239	1758	1535	1285
MPS-II	1012	1051	929	1830	1533	1271

Table 6. National Coordinated Varietal Trial for Adaptability Testing in Punjab zone during 2013-14

Varieties	Punjab							
	Fsd	FSD	Multan Zone				Multan	Punjab
	NIBGE FSD	Zone Avg	CCRI Multan	CRS Multan	PSC Khanewal	CRSR Y Khan	zone Avg	Avg
CIM-612	708	708	1712	1437	1506	2484	1785	1569
Cyto-124	**1252**	**1252**	**2016**	**2227**	**3363**	**2362**	**2492**	**2244**
DNH-105	842	842	1674	1902	3591	2850	2504	2172
CRIS-533	696	696	1527	1408	3403	2730	2267	1953
MPS-27	682	682	1481	1704	3107	2359	2163	1867
BH-177	1239	1239	1416	1903	4304	2276	2475	2228
TH-112/05	365	365	973	529	1762	2041	1326	1134
PB-896	1005	1005	1644	2054	3699	2410	2451	2162
Sun-2	818	818	1185	1408	3376	2718	2172	1901

CIM-573	812	812	828	781	2098	2113	1455	1326

Table7. Response of Cyto-124 against sucking pests

Genotypes	**Sucking pest per leaf**								
	Jassid			**Whitefly**			**Thrips**		
	June 2013	**July2013**	**Av.**	**June 2013**	**July2013**	**Av.**	**June 2013**	**July2013**	**Av.**
Sun-2	3.79	0.40	2.10	3.57	1.96	2.77	0.44	2.09	1.27
BH-177	5.28	0.33	2.81	1.61	1.70	1.66	0.22	5.49	2.86
CIM-612	4.53	0.06	2.30	1.61	0.96	1.29	0.06	11.04	5.55
CRIS-533	5.10	0.25	2.68	1.33	0.93	1.13	0.23	2.40	1.32
TH-112/05	4.28	0.24	2.26	2.07	1.14	1.61	0.17	3.49	1.83
MPS-27	5.40	0.36	2.88	1.38	1.96	1.67	0.06	5.9	2.98
DNH-105	4.00	0.20	2.10	1.96	1.33	1.65	0.11	5.08	2.60
Cyto-124	**5.36**	**0.50**	**2.93**	**1.60**	**0.80**	**1.20**	**0.06**	**9.55**	**4.81**
PB-896	3.34	0.46	1.90	2.03	1.19	1.61	0.10	2.55	1.33
CIM-573 (Std)	4.04	0.04	2.04	3.45	2.06	2.76	1.16	2.44	1.80

Table 8. Bollworm damage (%age) of Non-Bt strains at different stages

Strains	Bollworm damage				Spotted Boll Worm larvae/25 plants		Pink Boll Worm larvae/100 bolls
	September 2013		October 2013				
	Immature	Mature	Immature	Mature	Sep 2013	Oct2013	
MPS-27	3.5	0.1	6.00	0.29	2.0	3.0	4.17
DNH-105	0.0	0.0	1.82	0.94	0.0	1.0	4.86
Cyto-124	1.0	0.4	2.3	0.73	0.85	1.3	15.28
CRIS-533	2.0	0.5	5.48	1.75	1.0	5.0	6.94
Sun-2	8.0	2.0	14.29	0.78	4.0	3.0	5.56
CIM-612	1.0	0.2	2.52	0.00	1.0	1.0	8.33
TH-112/05	0.0	0.0	1.28	1.90	0.0	1.0	0.00
PB-896	0.0	0.0	1.56	0.98	0.0	1.0	2.08
BH-177	3.2	0.2	5.51	0.61	2.0	2.0	6.25
CIM-573 (Std)	1.0	0.0	6.67	0.45	1.0	1.0	4.17

Table9. CLCuV Disease Infestation on NCVT 2012-13

Strain	**Disease% age**	**Disease Severity**	**Disease Index**
Cyto-124	27.49	2.98	20.38
CIM-573	99.68	3.01	75.08
NIAB-112	100.00	3.32	83.08
MPS-II	99.66	3.28	81.60
IUB-11	94.71	3.38	80.43
PB-38	100.00	3.08	77.05
CIM-612	48.26	2.87	34.17
DNH-105	100.00	3.46	86.41
GS-444	100.00	3.60	90.11
BH-176	99.56	3.32	82.58
CIM-591	100.00	3.30	82.62
NIA-80	100.00	3.12	77.88
CRIS-510	100.00	3.45	86.25
VH-300	100.00	3.36	83.95
JS-212	98.00	3.70	90.77
Disease Severity		2 = Greater parts of veins involved	
*0 =No symptoms		3 =Whole veins involved	
1 =Vein thickening and minute scattered		4 =Veins involved completely and severe curling	

Table10. CLCuV Disease Infestation on NCVT during 2013-14

NCVT	**Cotton Leaf Curl Virus Disease**		
Strain	**Incidence**	**Severity**	**Disease Index**
CRIS-533	100.00	3.17	79.18

MPS-27	100.00	3.12	77.98
BH-177	100.00	3.07	76.64
TH-112/05	100.00	3.33	83.36
PB-896	100.00	3.04	75.88
Sun-2	100.00	2.99	74.86
CIM-612	64.26	2.67	43.94
Cyto-124	14.95	2.47	9.21
DNH-105	100.00	2.96	73.91
CIM-573	100.00	3.04	76.06

Disease Index= Disease percentage x Disease severity/maximum severity value (4)

Table 11. Comparison of fiber quality traits of Cyto-124 cotton with the standards, MNH-786, CIM-554 and CRSM-38, recorded from 2013 to 2014.

Traits	Cyto-124	MNH-786	CIM-554	CRSM-38
Ginning out turn (%)	42.0	39.9	42.4	41.9
Staple length (mm)	28.7	26.1	27.1	28.5
Fibre Fineness	4.5	5.2	4.1	4.4
Fiber strength (tppsi)	99.6	101.2	99.1	96.1

Table 12. Comparison of morphological traits of 'Cyto-124' cotton with the standards, 'CIM-554' recorded from 2013 to 2014.

Traits	Cyto-124	CIM-554
Plant height (cm)	124	153.0
Monopodial branches plant–1	1.1	1.15
Sympodial branches plant–1	29	24
Avg. boll weight (g)	2.8	2.35
Bolls plant–1	29.5	18.5

Agronomic studies:

Effect of time of sowing on productivity of advanced genotypes: Cyto-124 and CIM-620 were screened in five different sowing dates from 15th April to 15th June with CIM-608 as check on 15 days' interval following split plot design with four replications. Main plots had sowing date and genotypes were assigned to sub-plots. Fertilizer was applied in three doses @150kg ha^{-1}. CIM-608 had highest seedcotton yield in contrast to Cyto-124 and CIM-620 upon mean of all sowing dates (Figure 1). Seedcotton yield was diminished as sowing delayed among genotypes. CIM-608 had 4.5% and 5% alternately as compared to standard Cyto-124 & CIM-620.

During 2014-15; Cyto-122, Cyto-124 and FH-942 screened at different sowing dates with 15 days' interval from 15th April to 15th June. Fertilizer was applied @150kg ha^{-1} in three times. Cyto-124 had the highest seedcotton yield as overall mean basis of sowing dates in contrast to Cyto-122 and FH-942. Cyto-124 had 0.86 and 5.51% more yield in-contrast to Cyto-122 and FH-942 (Figure 2). Cyto-124 had the highest (3032kg ha^{-1}) which was sown on 15th April.

Significant addition in seedcotton yield was observed with the use of 150 kg hai^{-1}. While non-significant differences were observed for seedcotton yield between 150 and 200 kg hai^{-1}. Significant addition found among genotypes on 150 and 200 kg N ha-1 than 0, 50 and 100 kg N ha^{-1}. CIM-573 had more seedcotton yield on means over the nitrogen application (Figure 3).

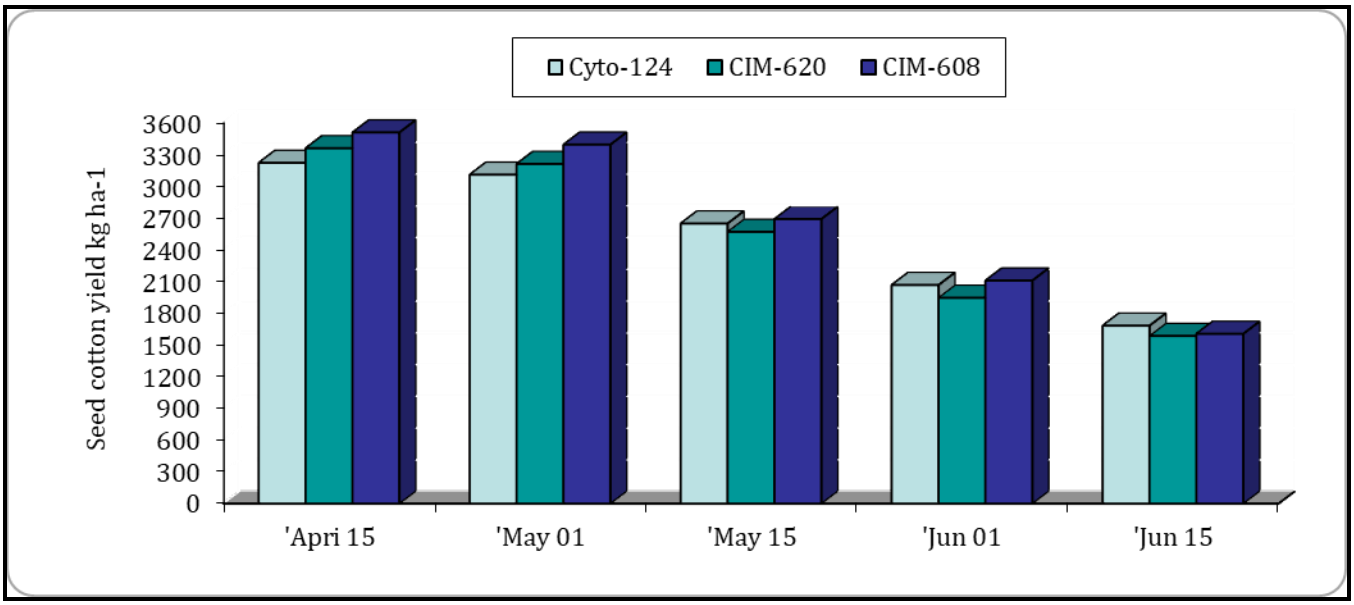

Figure 1. Effect of Sowing dates x Genotypes interaction on seed cotton yield

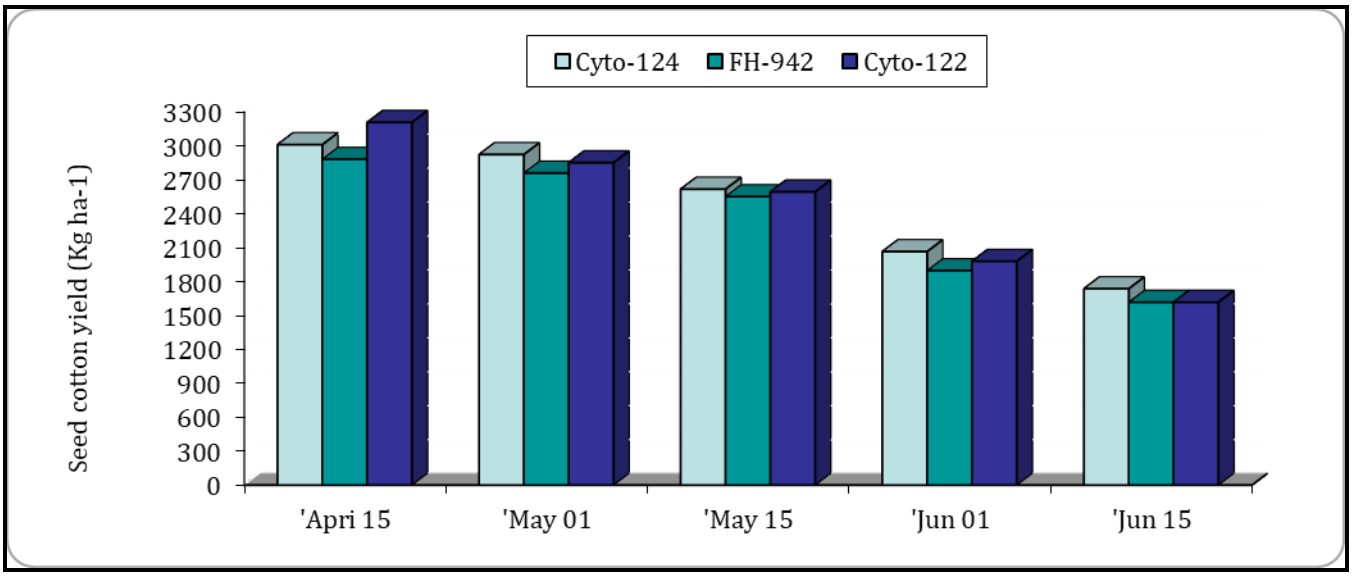

Figure 2. Seedcotton yield in different sowing dates

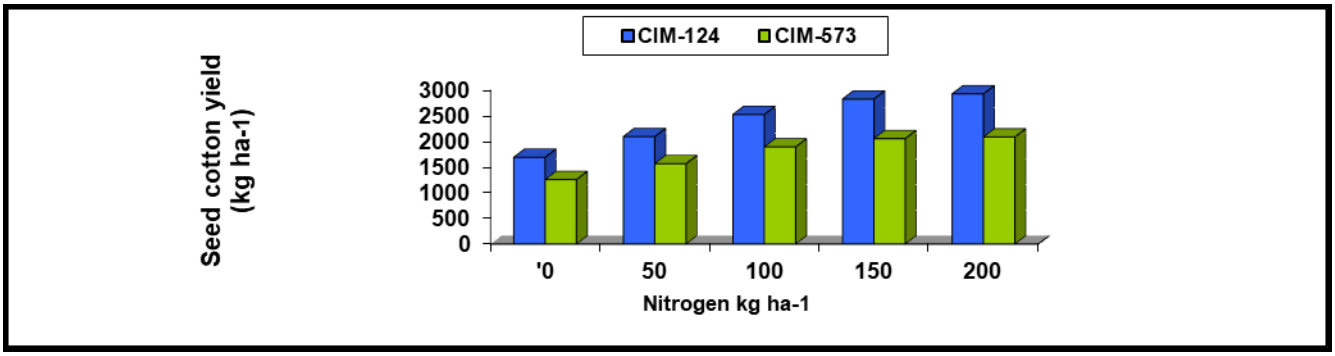

Figure 3. Effect of Nitrogen levels X genotypes interaction on seed cotton yield

DISCUSSION

In varietal trials, Cyto-124 exhibited significantly higher yields compared to standard varieties MNH-786, CIM-554, and CRSM-38. It also demonstrated higher yields in zonal trials conducted in different districts of Punjab and national coordinated trials across multiple locations. Cyto-124 showed tolerance against sucking pests and had favorable fiber traits, including good ginning outturn percentage and fiber quality. Additionally, it exhibited resistance to Cotton Leaf Curl Virus (CLCuV) with lower severity compared to other strains. Resistance against biotic e.g. CLCuV and abiotic stresses as well as refinement of fiber quality is at slow speed due to confined genetic variability in American cotton. Transference of desirable traits e.g. disease and insect resistance from wild species to upland cotton has a considerable potential to overcome such bottlenecks as has been done in the past. Hence, it is highly useful to use such germplasm for the release of cultivars with introgression from wild species.

The ultimate factor for the development of fertile hybrids is the setting of bolls without required traits after hybridization. The researchers have been involved in developing new combinations by using different ploidy level like diploid and tetraploid species (Dhamayanthi *et al.*, 2010). They revealed that it needs tremendous effort to derive such hybrids as it involves hybrid inviability, hybrid breakdown and self-incompatibility barriers. Nardeli (2018) observed indirect effect of embryo on endosperm in upland cotton accessions in-contrast to desi cotton (*G. arboreum*). An enormous number of introgressed hybrids were developed via ovule and embryo culture in *Gossypium* (Louant, 1971) yet traditional breeding approaches was found to be better for such introgressed material. Gibberellic acid was utilized for overcoming hybrid development problems like hybrid breakdown, hybrid in viability (Liang and Sun, 1982). The introgressed developed hybrid from *G. anomalum* and American cotton had exhibited resistance to CLCuV, which revealed that biotic stress like disease can be introgressed in upland cotton from *G. anomalum* using backcrossing and using gibberellic acid and naphthalene acetic acid. Hence, it is revealed that auto-tetraploids can be used for the transference of required characters in American cotton from non-cultivated species of genus via classical breeding especially disease resistance as the developed cultivar Cyto-124 has a tremendous potential to overcome the CLCuV disease. It is also speculated that auto tetraploids can be used to transfer required characters in American cotton from *G. arboreum* while more durable resistance can be produced in the available cotton germplasm for CLCuV via conventional breeding.

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