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PLANT BREEDING & GENETICS

FH-444: A HIGH YIELDING AND SUPERIOR FIBER QUALITY UPLAND COTTON VARIETY SUITABLE FOR COTTON GROWING AREAS OF PUNJAB, PAKISTAN

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ABSTRACT

FH-444 is a new Bt cotton variety which was released during the year 2020-21 by Cotton Research Station, Ayub Agricultural Research Institute, for irrigated areas of Punjab, Pakistan to maintain fiber quality and production through gradually replacement of existing cotton cultivars to avoid the yield losses caused by insect, pest and unexpected disease attacks. The FH-444 possesses drought tolerance and very good combination of traits to meet the requirements of the farmers, pickers, ginners, spinners and textile industry. The evaluation of this promising line was started during 2011-12 in different yield tests viz: preliminary & advance yield trials, Provincial Coordinated Cotton Trial (PCCT), National Coordinated Varietal Trial (NCVT), Distinctness, Uniformity and Stability (DUS) Trial, Agronomic trials, 1.25 Acre trials etc. In preliminary yield trials, FH-444 showed 45.96% increase in yield (3592 kg/ha) over standard variety FH-113 (2461 kg/ha) during 2011-12 while in advanced yield trials, FH-444 exhibited 23.61% increase in yield (3408 kg/ha) over standard variety FH-113 (2757 kg/ha) during 2013-14. It was also found that the effects of Cotton Leaf Curl Disease (CLCuD) were lower (1.7 %) in FH-444 during growing season of 2014-15, while FH-142 showed increased incidence of attack (4.9%). FH-444 demonstrated significant resistance with respect to thrips, whitefly, jassid and pink bollworm infestation. In present study it was found that the variety FH-444 possesses higher yield potential and will contribute to improve cotton yield and production under different stress conditions.

KEYWORDS: *Gossypium hirsutum*; fiber; seed cotton; GOT; yield; Punjab; Pakistan

INTRODUCTION

Cotton (*Gossypium hirsutum* L.) plays a vital role in the economy of Pakistan. Cotton is the most important natural fiber producing crop in the world and represents a vital agricultural commodity in the global economy (Khan, 2003; Khattak *et al.,* 2014). Cotton and its products contribute 0.6 % of GDP and about 2.4% to value added in agriculture sector (Anonymous, 2021). It is a big source of textile fiber, oil and cotton seed meal. In severe climatic conditions of Pakistan cotton breeders not only focus on seed cotton and lint yield but also have to breed for CLCuD tolerance/ resistance, heat tolerance, along with superior fiber quality and better boll size (Saturnino *et al.,* 2002; Sheikh *et al.,* 2003). Knowledge about genetic basis of heat tolerance traits is very useful for the development of heat tolerant cotton genotypes (Azhar *et al.,* 2020). Keeping in view the demands of the farmers and industry, Cotton Research Station Faisalabad has already developed CLCuD and heat tolerant varieties like FH-142, FH-Lalazar and FH-152 which not only have the capacity to resist boll worms but also have the potential to yield better in different agro-ecological zones of Pakistan. The farmers of the country has a long standing desire for a variety possessing broad spectrum resistance / tolerance against various biotic and abiotic factors along with higher yield potential and suitable for early and normal sowing (Bronson *et al.,* 2001; Sainju *et al.,* 2005; Ahmad *et al.,* 2020). A new variety FH-444 developed at Cotton Research Station Faisalabad had all the characteristics that can fulfill the demands of farmers. The main features of this variety are higher seed cotton yield, highly heat tolerant, tolerant against drought, possesses better tolerance against sucking insect pests, medium boll size, good fiber traits and highly input responsive which are

relative to the findings of Abbas *et al.,* 2013; Azam *et al.,* 2013; Puspito *et al.,* 2015; Qamar *et al.,* 2015ab. Therefore, the adaptation of FH 444 variety by cotton growers will solve the most of their field problems.

MATERIALS AND METHODS

Place and Year of Study

FH-444 had been developed at Cotton Research Station, Faisalabad during 2020-21 through hybridization.

Parentage/Pedigree

The single cross was attempted between FH-930 (Bt) and FH-113 (Bt). After passing through continuous pedigree selection, the material was coded as FH-444.

Field Evaluation

The local field evaluation of FH-444 at station yield trials was started in 2012-13 which continued upto 2016-17 in preliminary and advanced yield trials. After that, this strain was tested in provincial and national trials from 2017 to 2019. After passing all trials, this strain was recommended by Expert Sub Committee for approval during 2019-20 and was finally approved by Punjab seed council during 2020-21.

Chronological development:

The chronological development of FH-444 is given in **Table 1.**

RESULTS AND DISCUSSIONS

Preliminary yield trial

The new strain FH-444 was tested in Preliminary Yield Trial at Cotton Research Station, Faisalabad during 2011-12 & 2012-13. FH-444 showed 45.96% increase in yield over standard variety FH-113 during 2011-12 and 20.91% during 2012-13. Performance of FH-444 in preliminary yield trial significantly evidenced that FH-444 is more stable in yield showed in **Table 2**.

Advanced yield trial

The new strain FH-444 was tested in advanced Yield Trial at Cotton Research Station, Faisalabad during 2013-14 & 2014-15. This line produced 23.61% higher seed cotton yield than the check variety FH-142 during 2013-14 and 17.31% during 2014-15.

National yield trials

The data from **Table 3** indicated that the average seed cotton yield of FH-444 at NCVT and PCCT trials showed higher yield 2888kg/ha and 2416kg/ha respectively as

Table 1. The Chronological Development of FH-444

2006-2007	Cross was made between FH-930 x FH-113(Bt.) in field
2007-2008	F_1 was grown in field and bulked
2008-2009	A large number of F_2 plants were grown in the field and single plants were selected
2009-2010	F_3 progenies were grown in field and superior progenies and single plants within progenies were selected
2010-2011	F_4 progenies were grown in field and superior progenies and single plants within progenies were selected
2011-2012	F_5 progenies were grown in field and superior progenies and single plants within progenies were selected
2012-2013	F_6 progenies were grown in field and superior lines were selected and bulked for preliminary yield trials
2013-2014	Preliminary Yield Trial (1st year)
2014-2015	Preliminary Yield Trial (2nd year)
2015-2016	Advanced Yield Trial (1st year)
2016-2017	Advanced Yield Trial (2nd year)
2017-2018	PCCT, NCVT, DUS, Biosafety Trial, Agronomy Trial (1st year)
2018-2019	PCCT, NCVT, DUS, Biosafety Trial, Agronomy Trial (2nd year)
2019-2020	Recommended by Expert Sub Committee for Approval
2020-2021	Approved by Punjab Seed Council

NCVT: National Coordinated Varietal Trial, PCCT: Provincial Coordinated Cotton Trial, DUS: Distinctness, Uniformity and Stability Trial

Table 2. Yield performance of FH-444 in preliminary yield trials

Year	Trial	No. of entries tested	Variety	Seed cotton yield (kg/ha)	(%) increase over Check
2011-12	PYT	14	FH-444	3592	45.96
			FH-113	2461	
2012-13	PYT	10	FH-444	3499	20.91
			FH-113	2894	
Yield performance of FH-444 in advanced yield trials					
2013-14	AYT	10	FH-444	3408	23.61
			FH-142	2757	
2014-15	AYT	10	FH-444	3049	17.31
			FH-142	2599	

Table 3. Yield performance of FH-444 in NCVT, PCCT and 1.25 acre trials

Trial	Year	No. of locations	Variety/standard	Av. seed cotton yield (Kg/ha)	% Increase over standard		Rank
					I	II	
NCVT	2017-18	06	FH-444	2888	6.2	10.0	3rd /24
			CIM-602 (Check-I)	2719			
			FH-142 (Check-II)	2626			
	2018-19	06	FH-444	2416	-0.05	2.5	21st/27
			CIM-602 (Check-I)	2540			
			IUB-13 (Check-II)	2356			
PCCT	2017-18	16	FH-444	2748	11.5		9th/40
			FH-142 (Check)	2465			
	2018-19	13	FH-444	2151	1.3		20th/34
			FH-142(Check)	2123			
1.25 Acre Trial	2018-19	PSC, Khanewal	FH-444	17.46 *	-	-	38th/44

NCVT: National Coordinated Varietal Trial, PCCT: Provincial Coordinated Cotton Trial, 1.25 acre trials: Yield trials at Punjab Seed Corporation (PSC), Khanewal

Table 4. Fiber quality traits of FH-444 (Bt.) Spot Examination (22.10.2018)

Fiber traits	CRI, MUL	CCRI, MUL	NIBGE, FSD	APTMA	Average
GOT (%)					43.0
Staple Length (mm)	28.7	29.2	29.03	27.43	28.59
Fineness (µg/inch)	4.1	4.5	4.81	4.6	4.50
Fiber Strength (g/tex)	42.0	28.3	34.2	25.6	32.53
Fiber Uniformity (%)	83.5	85.3	85.0	80.7	83.63

Source: Director Agronomy, AARI Faisalabad

compared check varieties. The higher seed cotton yield under different traits indicated that the variety FH-444 might be used to increase cotton yield and fiber quality under different climatic conditions as also reported by Abbas et al., 2013 and Rizwan et al., 2015.

Fiber characteristics

The data indicates that the average GOT% was reported as 43% for all of the locations in **Table 4**. The higher staple length was reported at CCRI, Multan and NIBGE, FSD growing locations as compared with other locations. The higher fiber fineness was reported for locations NIBGE, FSD and APTMA. The highest fiber strength was recorded for location CRI, Multan while higher fiber uniformity was reported for location CCRI, Multan. Good fiber strength and fineness revealed that FH-444 may be used to enhance fiber quality of cotton as reported in previous studies by (Meena *et al.,* 2007; Rizwan *et al.,* 2015).

Bt identification

The presence of Bt. gene was found positive for all of the locations with 100% trait purity. The higher amount of protein was found for location NIBGE in **Table 5.**

Morphological & cotton leaf curl disease (CLCuD) data

The data from **Table 6** showed that the effects of CLCuD were lower for FH-444 as compared with other varieties grown as checks and for comparison. It is also clear form table that the effects of CLCuD were found similar in FH-444 during growing seasons of 2013-14 and 2014-15 while FH-142 showed increased incidence of attack. The better performance indicated that the variety FH-444 may be used as CLCuD tolerant variety as compared with other grown varieties.

Varietal response study against prevailing climate change

Five advance cultivars viz: FH-326, FH-490, FH-444, FH-N00R and MNH-992 were studied to check response for daily flowers and boll opening with respect to changing climate. FH-NOOR and MNH-992 produced more flowers in the month of July (39.32) and (36.6) respectively in **Table 7**. The month of August remained maximum blossom month for FH-490 and FH-444 in which these produced (35.75) and (38.1) flowers/plant respectively. While FH-326 produced more no. of flowers (56.5) in the month of September. Firstly, FH-NOOR opened more no. of bolls/plant (23.5) in the month of August. Secondly, FH-490, FH-444 and MNH-992 opened more no. of bolls/plant in the month of September viz., 18.4, 17.1 and 21.9 respectively. In addition FH-326 opened more no. of bolls/plant (21.4) in the month of October. Therefore it was concluded that FH-444 produced maximum flowers in the month

Table 5. Bt. Gene Identification in leaf (80 days after sowing µg/gram of fresh leaf) of FH-444 through Bt strip testing and quantitative elisa at 3 designated labs

Traits	NIGAB	ABRI	NIBGE	Avg.
Gene/Event	Cry1Ac/Mon531	Cry1Ac/Mon531	Cry1Ac/Mon531	-
Trait confirmation (+/-) PCR	+ve	+ve	+ve	+ve
Trait purity (%)	100	100	100	100
Bt. Protein (µg/gm)	0.97	0.98	1.28	1.08

Source: Director Research PCCC Multan

Table 6. Morphological & CLCuV incidence in advance yield trials (2013-14 & 2014-15)

Advance yield trials (2013-14)								
Genotypes	No. of nodes	No. of monopodi	No. of symp.	No. of bolls	Plant height (cm)	Days to 1st bud	Days to 1st flower	CLCuD %
FH-118	4	2	33	27	144	34	51	7.30
FH-301	8	3	32	22	138	32	53	6.21
FH-155	6	3	20	19	113	35	52	4.5
FH-173	8	2	33	25	138	33	52	9.24
FH-182	7	1	28	21	118	35	54	8.45
FH-314	9	3	33	28	163	31	53	1.7
FH-142	8	2	23	18	132	34	52	1.25
FH-308	8	2	36	27	142	33	51	4.9
FH-330	8	2	30	19	143	37	55	3.5
FH-444	9	2	37	29	138	32	51	1.7
Advance yield trials (2014-15)								
FH-168	5	2	33	27	147	33	52	6.80
FH-187	7	3	32	22	139	33	52	8.12
FH-413	5	3	20	19	112	36	53	4.5
FH-416	7	2	33	25	137	34	52	8.24
FH-424	8	1	28	21	119	34	52	9.45
FH-444	9	3	40	29	161	33	53	1.7
FH-490	8	2	33	20	134	33	52	1.25
FH-142	8	2	36	27	141	33	51	4.9
FH-167	7	2	30	19	142	37	54	3.5
FH-329	9	2	23	18	130	36	54	4.7

Table 7. Varietal response study against prevailing climate change

No. of flowers/plant/month as affected by various genotypes					
Variety	June	July	August	September	October
FH-490	3	33.92	35.754	24.8	2.9
FH-NOOR	5.896	39.324	28.175	27.3	3.6
FH-326	2.1	12	16.9	56.5	6.1
FH-444	6	29.5	38.1	18.6	3.6
MNH-992	4	36.6	30	25.1	5

No. of open bolls/plant/month as responded by different genotypes						
Variety	June	July	August	September	October	November
FH-490	0	1.6	13.7	18.4	11.8	1.1
FH-NOOR	0	3.6	23.5	18	10	0.6
FH-326	0	1.1	5.7	14	21.4	2
FH-444	0	1.6	8.3	17.1	7.9	0.8
MNH-992	0	1.3	18.6	21.9	11.5	1.3

of August while maximum open bolls were present in September. Similar response of cotton was also observed by (Robertson *et al.,* 2007) while studying cotton physiology.

Sowing date study

The yield data recorded was analyzed by using software statistix 8.1. The data presented in **Table 8** disclosed that sowing dates, varieties and their interaction significantly affected the seed cotton yield. Irrespective of sowing dates, FH-490 by yielding 2929 kg/ha seed cotton yield, surpassed other varieties namely FH-152 and FH-444 which gave 2269 and 2785 kg/ha seed cotton yield respectively. Irrespective of varieties, seed cotton yield was linearly decreased with any delay in sowing from 15th April sowing date. While 16th June by

yielding 1116 kg/ha seed cotton yield was significantly lower than all early sowing dates. Whereas, in case of interaction, 1st May sowing date proved best sowing time for FH-444 by giving 3756 kg/ha seed cotton yield. Huang, (2016) also reported the effect of different sowing dates on seed cotton yield.

Table 8. Seed cotton yield (kg/ha) of FH-444 in sowing dates

Dates	FH-152	FH-490	FH-444	Date Average
16-04-2017	3611	4075	3756	3814
1-05-2017	3136	4182	3611	3643
16-05-2017	2686	3383	3484	3184
1-06-2017	1041	1858	1594	1497
16-06-2017	871	1147	1481	1166
Variety. Average	2269	2929	2785	

LSD:0.05: Var: 343.24, Date: 482.40, Variety × Date: 767.52

ENTOMOLOGICAL PHASE

Relative resistance test against pink boll bollworm &sucking pests attack

Sucking insect pest population and pink bollworm infestation were recorded among different cultivars of cotton. All the genotypes demonstrated significant variation with respect to thrips, whitefly, jassid and pink bollworm infestation. The studied genotypes established population of thrips ranging from 6.2 to 9.0/ White fly 1.5 to 7.2/leaf and jassid 0.5 to 1.8/leaf respectively. FH-242 showed more infestation of pink boll worm larvae 0.6/5 plants followed by FH-326 and FH-313 (0.4 pink boll worm/5plants). Considerable damage have been caused by Bt-resistant pink bollworm larvae which led to panic in the cotton sectors of India and Pakistan (Rao *et al*. 2021). The Strain FH-444 gave best results related to sucking insect

Table 9. Relative resistance test against pink boll bollworm &sucking pests attack

Response of Some Advanced Cultivars of Cotton to Sucking and Pink Bollworm Incidence					
Sr. No.	Varieties/genotypes	Sucking Insects population/leaf			Helicoverpa larvae/5 plants
		Thrips	Whitefly	Jassid	
1	MNH-992	6.7	8.4	0.8	0.0
2	VH-363	7.8	3.6	1.6	0.0
3	FH-444	8.2	1.5	0.5	0.0
4	FH-LALAZAR	9.0	4.1	0.6	0.0
5	FH-242	8.1	5.3	1.7	0.6
6	FH-342	7.5	6.9	1.2	0.0
7	FH-312	8.2	7.2	1.8	0.0
8	FH-326	6.7	4.7	0.5	0.4
9	FH-313	8.1	3.2	1.6	0.4
10	FH-142	6.3	2.6	0.8	0.0
LSD (0.05)		2.6	3.8	0.4	NS

Response of Bt Cotton Advance Lines to Sucking Insect Pests and Helicoverpa Incidence at CRS, Faisalabad (2017-18)											
Sr. No.	Variety	Yield (kg/ ha)	Plant height (cm)	CLCuV (%)	White Fly	Jassid	Thrips	Army Bollworm	Spotted Bollworm	American Bollworm	Pink Bollworm infestation % age
1	FH-142	2724	121	1.9	3.6	1.3	5.0	0	0	0	2.5
2	FH-490	3235	99	1.3	2.1	1.0	3.4	0	0	0	1.6
3	FH-152	3145	119	1.2	2.9	1.6	4.2	0	0	0	0
4	FH-444	3995	124	4.4	3.8	1.2	3.3	0	0	0	2.1
5	FH-342	3240	132	2.3	4.2	1.7	6.5	2.9	0.5	0.9	1.9

Screening of promising lines against sucking pests and pink bollworm under field conditions (2018-19)					
Sr. No.	Entry	Sucking Insects population/leaf			Pink bollworm %age infestation
		Thrips	Whitefly	Jassid	
1	FH-490	4.46 e	3.72 d	1.20 d	6.89 g
2	FH-342	8.11 bc	4.67 c	2.76 c	9.33 f
3	FH-444	8.67 bc	3.11 d	0.91 d	13.11 b
4	FH-458	9.02 b	4.74 c	0.95 d	11.77 c
5	FH-466	10.38 a	6.83 b	3.26 ab	14.89 a
6	FH-326	8.63 bc	8.23 a	2.91 bc	10.89 cde
7	FH-Lalazar	6.76 cd	8.61 a	3.47 a	15.77 a
8	FH-315	6.21 d	4.94 c	0.98 d	10.00 ef
9	FH-498	6.65 cd	4.99 c	1.19 d	10.67 de
10	FH-Anmol	7.15 c	5.54 c	1.30 d	11.33 cd
	LSD (0.05)	0.7787	1.1771	0.4207	0.9900

pests and bollworms compared to check FH-142 in Biosafety trials. The results from **Table 9** indicated that the strain FH-444 showed better performance against insect pest attacks; therefore, it was screened out as tolerant variety against CLCuD, white fly, thrips, army worm, spotted bollworm, American bollworm and pink bollworm.

CONCLUSION

Although, cotton breeders has released a large number of cotton varieties for general cultivation to the farmers in the province Punjab, but some of them, considered long-lasting varieties by the farmers due to their long-stay in the field along with their high yielding worth. Cotton varieties like CIM-602, FH-142, CIM-602, IUB-13, MNH-886 and MNH-992 would remember as some of the important varieties in this regard. Moreover, with the passage of time the potential and genetic sole of these varieties, under the scenario of global warming were deteriorated. On the façade of CLCuD, the canvass of diseases infestation was multiplying in wider range on existing susceptible cotton varieties. There was need to develop such cotton varieties which showed resistance against varying environmental conditions, disease and insect pest attack, while showed higher cotton seed as well as fiber yield with good and improved quality. The reporting variety FH-444 may be a higher potential genotype to improve cotton yield and production under different stress conditions.

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CONTRIBUTION OF AUTHORS

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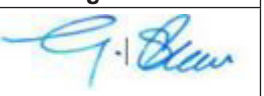
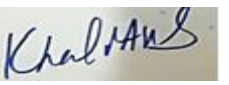
1.	Ghulam Sarwar	Supervised the research work	
2.	Hafiz Ghazanfar Abbas	Collected agronomic data of variety and helped in write up	
3.	Muhammad Rizwan	Wrote results and discussion of manuscript	
4.	Furrkh Ilahi	Wrote introduction of manuscript	
5.	Amjad Farooq	Collected yield and fiber quality data of variety	
6.	Jehanzeb Farooq	Managed the experiment	
7.	Abia Younas	Helped in review of literature	
8.	Muhammad Kashif Shahzad Sarwar	Helpd in statistical analysis and manuscript write-up	
9.	Khalil Ahmad	Performed statistical analysis	
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