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FH-326: A HIGH YIELDING, DROUGHT TOLERANT, TRANSGENIC BT. AND GOOD FIBER QUALITY TRAIT COTTON VARIETY FOR WATER SHORTAGE AREAS OF PUNJAB, PAKISTAN

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ABSTRACT

'FH-326' cotton (*Gossypium hirsutum* L.) was developed by the Cotton Research Station (CRS), Faisalabad, Pakistan, and approved by Punjab Seed Council in 48th meeting on 06-03-2017. This variety developed as a part of investigations oriented towards evolving high-yielding cotton cultivars that can tolerate drought stress.FH-326 was developed through making the cross between FH-942 (Non-Bt.) and FH-114 (Bt.). FH-326 was tested in multiple trials conducted by various public agencies. In Provincial Coordinated Cotton Trial (PCCT) FH-326 out yielded (more than 35%) significantly to both standards FH-142 and MNH-886. In the National Coordinated Varietal Trial (NCVT), FH-326 produced more Seed Cotton Yield than the standards for two consecutive years (2016 and 2017). FH-326 is highly drought tolerant variety (Required 4 irrigation instead of 8 after germination) and also possesses high fiber quality (staple length 29.2 mm and fiber fineness 4.2µg/inch). The commercial cultivation of this variety will contribute sustainability of cotton production in Pakistan and can also be used as valuable genetic resource in future cotton breeding programs.

KEYWORDS: Cotton, Drought, Morphological, Physiological, Yield, Fiber Traits.

INTRODUCTION

Cotton (*Gossypium* spp.) is the leading natural fiber crop worldwide. Cotton is a pivotal ingredient of the economic growth of Pakistan with share of 1.0 percent in GDP and contributes 5.1 percent in agriculture value addition (Anonymous, 2015-16). Breeding efforts for improving *G. hirsutum* L. were initiated since its introduction in this region. Many high yielding and good quality varieties developed and successfully cultivated in this region. But cotton production in Pakistan faces the threats of both biotic and abiotic stresses (Saeed et al. 2015). So, with the passage of time the need of new varieties with tolerance against various factors/stresses is always there.

Drought is one of the most important abiotic stress factors that limit plant growth and production around the World (Deeba et al. 2012) particularly when the stress occurs during reproductive growth, affecting production whether it is for subsistence or economic gain (Selote and Khana-Chopra, 2004). Drought-induced loss in crop yield probably exceeds losses from all other causes, since both the severity and duration of the stress are critical (Farooq et al. 2009). Approximately one-third of the world's arable land suffers from chronically inadequate supplies of water for agriculture (Massacci et al. 2008).

It is estimated that the percentage of drought terrestrial areas will be double by the end of 21st century (Deeba et al. 2012). Particularly, in Central Asia, located mostly in desert zones, the first limiting factor of crop yield is water deficit and agriculture can be practiced only with additional irrigation (Massacci *et al*., 2008). During drought, plants are affected by two different physical factors i.e., water deficiency and high temperature (overheating) (Kuznetsov et al. 1999). However, the irrational use of water resources for cotton production has lead to an increased soil salinization and, moreover, to the exhaustion of

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the Aral Sea. Therefore, increasing the adaptation potential of this major crop and creating drought-tolerant genotypes is one of the biggest scientific and economic issues for this region. This would allow not only to obtain higher cotton yield and quality in conditions of limited water resources, but also to improve local environment by stopping desertification of the region (Massacci et al. 2008).

In Pakistan, there is a focus on improving cotton germplasm and cultivars that can combat drought stress (Rahman et al. 2008; Ullah et al. 2008), exhibit resistance to the CLCuD (Rahman et al. 2002), and possess higher yield potential with improved fiber traits (Khan et al. 1989; Afzal et al. 2001; Hanif et al. 2001; Arshad et al. 2003). FH-326 is a newly developed cotton variety which has been reported to be highly drought tolerant with good quality and good yield under adverse conditions (water deficient). It also shows tolerance against CLCuV. It has deeper root system which is useful for obtaining water from deep layer of soil. The present study is aimed at examining the qualities of FH-326 in comparison with the other strains of cotton. This will help authenticate the claims on the desirable qualities of the new strain FH-326.

MATERIAL AND METHODS

The new cotton variety FH-326 was developed through making the cross between FH-942 (Non-Bt.) and FH-114 (Bt.). The genotype FH-942, developed at CRI, is drought tolerant parent, semi determinant growth habit, and desirable fiber characteristics; however it is susceptible to the virus disease. The male parent FH-114 (Bt.) is highly tolerant to the CLCuV, has exhibited high heat tolerance, compact and is also early maturing. F_1 was grown in greenhouse under the drought conditions (minimum water) at the CRI, FSD. F_1 seed obtained was pooled to get maximum F_2 plants. The F_2 plants were raised in the field during 1st week of May at the breeding area of CRI, Faisalabad under the water stress (only 3 irrigations after germination instead of 10 normal).

The F_3 plant progenies of drought tolerant F_2 plants were grown under water stress (minimum water) in greenhouse during 2010-11. The F_3 progenies that showed drought tolerance and exhibited acceptable yield potential with superior fiber traits were advanced to the F_4 generation in the field during 2011-12. The F_5 generation was grown under drought conditions (minimum water) in greenhouse during 2011-12. In 2012-13 one of the F_6 progeny that was highly drought tolerant and showed high yield potential and good fiber traits was selected and designated as FH-326. The physiological and biochemical parameter of this line was measured and compared with two commercial checks FH-942 and FH-142.

During 2013-14 and 2014-15 yield potential and other morphological traits of FH-326 were evaluated in Preliminary yield trial (PYT) and advancedyield trial (AYT). During 2014-15 and 2015-16 FH-326 was evaluated in Zonal Trials at 6 locations of Punjab (Faisalabad, Multan, Sahiwal, Vehari, Bahawalpur and Khanewal). Data of various morphological traits such as number of monopodial and sympodial branches per plant, plant height (cm), boll weight (g), and boll number were recorded at maturity. Average number of monopodial and sympodial branches per plant was calculated by counting them from 10 consecutive plants from each plot. Similarly, plant height was recorded in centimeters from the first cotyledonary node to the apical bud. Bolls from 10 consecutive plants were counted and average number of bolls per plant was calculated and seed cotton yield was recorded from 2 central rows. Seed cotton was handpicked twice (50% and 100% boll opening) and was sundried after removing the trash before weighing the seed cotton was ginned out with a small laboratory scale roller ginning machine for determining the lint percentage and fiber quality traits. Lint percentage was calculated by dividing the lint sample with total weight of sample and multiplying by 100. A lint sample size of 50 g was taken to measure the fiber length, fiber strength, uniformity index, and micronaire value using a high volume instrument (HVI-1000).

Physiological traits measured during 2013-14 and 2014-15 at 6 locations of Punjab were canopy temperature, water potential, osmatic potential and stomatal conductance under both normal and water stress conditions. Root shoot parameters were also recorded during 2013-14 under both normal and water

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stress conditions. Root shoot length, root shoot fresh weight and dry weights were measured at 60 Days after sowing (DAS) and compared with checks.

FH-326 was tested at 16 and 17 locations of Punjab in the Provincial Coordinated Cotton Trials (PCCT) in 2015 and 2016, respectively. FH-326 was also tested at 12 and 13 locations of Pakistan in the National Coordinated Varietal Trial (NCVT) in 2016 and 2017, respectively, conducted by the Pakistan Central Cotton Committee, Karachi, Pakistan (a semiautonomous organization). Each of the field trials was arranged in an RCBD with three replications. Standard agronomic practices were followed.

Analysis of variance was performed on each measured trait using appropriate procedures of the MSTAT-C computer software package. Statistical significance was reported at a 5% level of probability. Differences among means were tested by the least significant difference test at the 5% probability level.

RESULT AND DISCUSSION

Characteristics

FH-326 was tested in Preliminary Yield Trial at Cotton Research Institute, Faisalabad under minimum irrigation conditions (3) during 2013-14. FH-326 showed 54% and 23% increase in yield over standard varieties FH-942 and MNH-886 respectively. The new strain FH-326 was tested in advanced yield trial under water stress conditions at Cotton Research Institute, Faisalabad during 2014-15. This line produced 29% and 30% higher seed cotton yield than the check varieties FH-942 and FH-142

Table-1: Yield performance of FH-326 in PYT and AYT

Year	Trial	No. of entries tested	Variety	Seed Cotton Yield (kg/ha)	(%) increase over Check
2013-14	PYT (DN)	14	FH-326 (6020/13)	2792	
			FH-942	1275	54
			MNH-886	2151	23
2014-15	AYT	12	FH 326	3838	
			FH-942	2681	29
			FH-142	2691	30

FH-326 was tested in Provincial Coordinated Cotton Trials (PCCT) during 2014-15 and 2015-16 at 16 and 17 different ecological zones of Punjab respectively to study its adaptability. FH-326 showed 35% and 16% increase over better yielding check during 2014-15 and 2015-16 respectively and it ranked at 1st position both year by producing 3431 kg/ha and 1688 kg/ha seed cotton yield during 2014-15 and 2015-16 respectively. The performance of FH-326 in PCCT is given as Table-2.

Table-2. Yield performance of cotton cultivars in Provincial Coordinated Cotton Trial (PCCT) in Pakistan from 2014-2016.

Year	Trial name	Locations	Yield of seed Cotton (kg ha^{-1})		
			FH-326	FH-142	MNH-886
2014–2015	PCCT-I	16	3431	2957	2712
	(%) increase over Check		-	16	27
2015–2016	PCCT-I	17	1688	1246	1253
	(%) increase over Check		-	35	35

FH-326 was tested in National Coordinated Varietal Trials (NCVT) during 2015-16 and 2016-17 at 12 and 13 different climatic zones of Pakistan respectively. FH-326 showed 9% and 28% increase over check during 2015-16 and 2016-17 respectively at Punjab level. The performance of FH-326 in NCVT is given as Table-3.

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Table-3. Seed cotton yield of 'FH-326' cotton variety and standards CIM-602 and FH-142 in National Coordinated Varietal Trials (NCVT) in Pakistan.

Year	Region	No. of Locations	Seed cotton yield (kg ha^{-1})		
			FH-326	CIM-602	FH-142
2016	Punjab Average	6	1876	1464	1613
	% increase over		-	28	16
2017	Punjab Average	6	2488	2291	-
	% increase over		-	9	-

Entomological Studies

The FH-326 gave better results related to sucking insect pests and bollworms compared to check (FH-142) in Biosafety trials conducted at Breeding area of Cotton Research Institute, Faisalabad during 2013-14 and 2014-15. There were significant differences in the number of thrips, white fly and jassid per leaf in both years. American and spotted boll worm attack was not observed in both years. However, army bollworm attack was reported in patches which have to be sprayed with pesticide to control the army bollworm. No pink bollworm attack was reported during both years at FH-326. The screening of FH-326 along with the standards continued for two consecutive normal cotton growing seasons (2014-15 & 2015-16). FH-326 exhibited tolerance to Cotton Leaf Curl Virus (Table-4).

Table-4. Response of cotton cultivars to insect pests and cotton leaf curl virus disease (CLCuD) for 2013-14 and 2014-1

Cultivar	Jassid	Insects leaf^{-1} Whitefly	Thrips	% of CLCuD infected plants
		2013-14		
FH-326	1.2	3.1	6.1	5.6
FH 142	1.4	4.6	7.0	1.9
FH-942 (Non-Bt)	1.8	13.2	7.5	13
		2014 15		
FH-326	1.2	5.7	4.7	3.7
FH 142	1.7	5.7	6.5	1.6
FH-942 (Non-Bt)	4.6	5.5	6.6	7.5

Evaluation For Morphological and Fiber Traits

FH-326 (156.00 cm) was taller than FH-942 (135.00 cm) and FH-142 (108.00 cm). The number of monopodial branches of FH-326 was more than that of FH-942 and FH-142. The number of sympodial branches per plant of FH-326 was more than either of the checks (Table-5). Average boll weight of FH-326 was 4.0 g, compared with 3.8 g for FH-942 and 4.2 g for FH-142. The number of bolls per plant was 65 for FH-326, 45 for FH-942, and 55 for FH-142 (Table-5).

The lint percentage of FH-326 was 38.8%, staple length (29.25mm), micronaire (4.28µg/inch) and fiber strength (30.30 g/tex) accomplishing the values of the standards (Table-5).

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Table-5. Comparison of morphological and fiber quality traits of FH-326 cotton variety with the standards, FH-942 and FH-142, recorded during 2014-15.

Trait	FH-326	FH-942	FH-142
Plant height (cm)	175	155	116
Monopodial branches plant^{-1}	2-6	1-4	1-3
Sympodial branches plant^{-1}	42	39	35
Avg. boll weight (g)	4.0	3.7	4.2
Bolls plant^{-1}	75	60	65
Ginning out turn (%)	38.8	38.0	41.4
Staple length (mm)	29.2	28.0	28.2
Micronaire value ([µg mm^{-1} [µg inch^{-1}])	4.2	4.4	4.6
Fiber strength (g tex^{-1})	30.3	28.5	29.0
Uniformity index (%)	82.3	83.0	84.0

FH-326 is of the spreading type with green foliage. The leaves are of normal shape and medium size with nectaries. FH-326 is glanded and has a pubescent stem and leaves. The pollen color is creamy, and the boll shape is oval. FH-326 has wider adaptability to many types of environments. It has outstanding yield. This cultivar would be an excellent candidate for doing value addition work through nonconventional means. This variety has Cry1 Ac gene conferring resistance to chewing insect pests especially American and Spotted bollworms. By cultivation of this variety by cotton growers of water shortage areas will earn more profit by reducing their cost of production.

Physiological Parameters

FH-326 has lower canopy temperature, high leaf water potential, high osmatic potential and low stomatal conductance under water stress conditions as compared to checks (Table-6).

Table-6. Comparison of physiological traits of FH-326 cotton variety with the standards, recorded from 2013-2015

Year	Cultivar	Physiological Parameters							
		Canopy Temperature		Water Potential		Osmatic Potential		Stomatal Conductance	
		N	D	N	D	N	D	N	D
2013 14	**FH 326**	27.92	26.84	1.74	1.63	0.12	0.07	64.33	58.54
	FH 142	28.02	27.20	1.80	1.83	0.11	0.07	68.33	60.91
	MNH 886	27.96	27.48	1.53	1.57	0.08	0.08	51.33	43.37
2014-15	**FH 326**	26.05	25.77	2.27	2.10	0.38	0.61	149.87	140.8
	FH-142	26.08	25.98	2.43	2.28	0.62	0.64	152.74	145.3
	FH-942	25.78	26.73	2.23	2.33	0.48	0.74	149.33	143.3

Root Shoot Study

During 2013-14 some root shoot parameters of FH-326 were studied under drought and normal conditions. The root shoot parameters were recorded at 60 DAS (Table-7).

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Table-7. Comparison of Root Shoot Parameters of FH-326 cotton variety with the standards, recorded from 2013-2014

Cultivar	Root Shoot Parameters (60 DAS)											
	Root length (cm)		Shoot length (cm)		Fresh root weight (g)		Fresh shoot weight (g)		Root dry weight (g)		Shoot dry weight (g)	
	N	D	N	D	N	D	N	D	N	D	N	D
FH-326	127.6	128.8	17.6	20.0	3.6	4.0	2.4	2.4	0.42	0.68	0.96	0.43
FH-142	122.4	122.6	19.8	18.0	3.4	3.2	2.5	2.4	0.47	0.94	0.58	0.84
FH-942	124.5	125.2	17.0	13.0	4.8	2.8	3.4	2.3	0.64	0.41	1.24	0.22

Availability

The pre basic seed of FH-326 will be available after getting commercialization certificate from National Biosafety committee and approval from Punjab Seed Council.

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