Research Article

Evaluation of Cotton Genotypes for Agro-Morphological Traits and Resistance to Insect Pests in Faisalabad, Pakistan

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Abstract | There are numerous factors that cause reduction in cotton yield and quality, insect attack is one of the major limiting factors for optimum cotton production. Among cotton pest whitefly, jassid and thrips are more important in sucking pests while pink bollworm is very destructive among bollworms. Therefore, the present study was planned to work out the behavior of different cotton cultivars i.e., MNH-1086, WEAL-AG-10, SLH-CHANDI, FH-494, MNH-1050, FH-492, WEAL-AG-9, BH-224, VH-418, SLH-Afnan-II, WEAL-AL-AG-CKC3-01, FH-142, FH-414, RH-KING 20, WEAL-AG-20 1(ii), FH-ANMOL, SLH-55, BH-225, UAM-20, FH-498, and WEAL-AG-11 for insect pest infestation and cotton yield as well as its impact on fiber quality. The cultivars differed in their susceptibility to sucking insects and pink bollworm. The lowest whitefly population was observed on genotypes FH-492 (2.48), FH-498 (2.97), and 'FH-494 (2.80) per leaf. The lowest jassid population was recorded on cultivars FH-494 (0.87), FH-498 (0.97), and FH-492 (0.68) per leaf. The lowest thrips infestation was recorded on FH-492, FH-494 and FH-498, having 1.05, 1.13, 1.20 per leaf, respectively. The cultivar FH-492 (0.20) had the lowest number of pink bollworms in left over bolls. The maximum number of bolls per plant was recorded for FH-492 (76.33) and the highest yield was observed in FH-492 (3052.95 Kg/ha). FH-492 has shown remarkable lenience of morphological and entomological features, and resistance to insect pests and CLCuD. The demands of farmers, laborers who harvest crops, and other investors including those in the cotton industry may be met by the introduction of this variety. The present study signifies for recommended as the most suitable commercial cotton cultivars for agro-climatic conditions of Faisalabad.

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Introduction

Agricultural sector is indispensable to the country's economic growth, food security, employment generation and poverty alleviation (Muzari, 2016). It contributes 19.2% to the GDP and provides employment to around 38.5% of the labour force. More than 65-70% of the population depends on agriculture for its livelihood (Samantroy, 2018). Cotton has major contribution in the agriculture. Cotton (*Gossypium hirsutum* L.), is considered as backbone of Pakistan's economy (Qaim and Zilberman, 2003). Cotton crop stands vital in agriculture as well as textile sector of the economy. It contributes and supporting the textile industry to around 0.6% of GDP and 3.1% of agricultural value-added. Cotton was grown on 2.517 million hectares in Pakistan during 2019-20, yielding 9.148 million bales (two million tonnes raw cotton) in different regions (Kalwar, 2023) Pakistan, a major producer of cotton (ranked 5th, ICAC), is facing a significant decline in major varieties of cotton crop production due to multiple challenges. However, as of right now, only about fifty species which are native to Australia, Asia, Africa, central and southern America, and South America are thought to be linked to *Gossypium* (Wendel and Grover, 2015). There are just four highly skilled and gregarious species. Two diploid species (n = 26) having a share of 1% in global cotton fabrication are *G. herbaceum* and *G. arboreum* (old-world cotton). The other two species, *G. Hirsutum* and *G. barbadense* (new world cotton), have a tetra-ploidy level (2n=52) and account for 94% of the world's total cotton production. While *G. hirsutum* yields around 90% of the total cotton foundation, *G. barbadense* adds 4.0% (Waghmare, 2022; Akhtar *et al*., 2010).

The cotton crop's acreage is decreasing since it is less profitable than sugarcane, maize, and rice. The biotic stressors of pink bollworm and white flies, as well as the abiotic challenges of climate change, heat waves, heavy rains, are additional reasons causing the decline as well as ineffective farming methods and needless pesticide application (Khan *et al*., 2021). Currently, creating cotton at excessive temperatures has become a risky endeavor. One important abiotic stressor influencing cotton performance efficiency is heat. It is usual for the global climate to warm by 0.40 to 0.80°C year. Accordingly, crops need more water due to increased evapotranspiration. One important abiotic stressor influencing cotton performance efficiency is heat (Jamshidi *et al*., 2020). Along with decreasing water availability for irrigation systems, precipitation design is also exhibiting varying areas of strength. Over the course of the century, in the unlikely event that this warming trend occurs first, cotton production will decrease and the introduction of heat-tolerant types will become mandatory (Habib *et al*., 2021).

Numerous diseases and insect pests harm cotton crops, reducing both cotton output and fiber quality. Worldwide reports of insect's species on cotton have about 1326 (Nada *et al*., 2010). Cotton producers and agricultural specialists have found it difficult to control several cotton pests. In Pakistan, insect infestation is thought to be responsible for ~20–40% of the yearly production and quality losses in cotton (Shahzad *et al*., 2020). The introduction of 'Bt-cotton' in Pakistan was a major relief to farmers for lowering the damages caused by bollworms and significantly reduced the import bill of insecticides for the bollworms. The 'Bt cotton provides no control of sucking pests, the risk of bollworms damage, especially of *Heliothis armigera* is reduced, however, few years after Bt cotton introduction the problem of pink bollworm has emerged as new threat to sustainable cotton production (Naeem-Ullah *et al*., 2020). Cotton pest management in Pakistan relies on excessive use of insecticides but their non-judicious use negatively affects the sustainability of agro-ecosystems (Velmourougane *et al*., 2017).

Extreme temperature stress leads to advancements in physiological and entomological activities that affect photosynthetic activity and insect pests, respectively. The extreme temperature increases we are currently seeing, the time has come to introduce environmentally conscious type that are tolerant for these harsh conditions and will provide great returns on seed cotton. Constant use of insecticides demands the adoption of integrated pest management (IPM) approaches not only in cotton but also in other crops. Integrated pest management is a common agriculture base knowledge that the farmer has used for centuries. It uses multiple tactics in an integrated pattern to manage the pest populations below the economic injury level. It tries to manage the pest populations at an economically manageable level through the use of resistant/tolerant plant varieties, cultural control (late sowing, intercropping, crop rotation), biological control (predators, parasitoids, parasites), physical control (use of pheromones traps, hand-picking of pest) and use of less toxic pesticides. Keeping in view the present study was planned to evaluate newly developed cotton strains/lines, cultivars to work out the impact of the pest susceptibility on seed-cotton yield and fiber quality.

Materials and Methods

Experimental design and cultural practices

The current study was conducted at Cotton Research Station, Faisalabad, Pakistan during cotton growing seasons Kharif from May to October, 2023. These strains/cultivars were included in PCCT (Punjab Coordinated Cotton Trial) for screening at different localities against insect pests, viruses and yield characteristics. Twenty-one newly developed 'Bt-cotton lines of public and private sectors were collected for study (Table 1).

Physiological parameters

Plant height: Plant height was recorded with meter rod in centimeters right from the first node to apical bud of the cotton plant.

Number of nodes: Five random plants from each replication of each variety were selected to record no of nodes by visual observation starting from the node present above the cotyledonary leaves.

Monopodial: Data of indirect fruiting branches was calculated at maturity.

Sympodial: Data of direct fruiting branches was recorded at maturity

Number of bolls: Data of the mature bolls picked were recorded in each replication from all the genotypes. Average for each was calculated from each replication for data analysis.

Boll weight: Average boll weight per plant was taken by dividing plant yield to the numbers of bolls picked from the plant.

Yield (Kg/ha): The seed-cotton was manually picked at regular intervals once the bolls were open. A total 3 pickings were carried out and seed-cotton yield of all pickings was added to get total yield.

Fiber characteristics

Ginning out turn (%): The ginning out turn was calculated by following formula or Equation 1.

$$GOT\ \% = \frac{\text{Lint weight}}{\text{Seed cotton weight}} \times 100$$

Other quality parameters (Fiber length (mm), Fiber strength (g/tex), Fiber fineness (µg/g), Fiber maturity ratio) were measured using fibro graph HVI-900 from fiber technology lab at Cotton Research Station, AARI, Faisalabad, Pakistan.

Table 1: *Details of different cotton strains/cultivars.*

Strains/Cultivars	Institute/Developer	City	Institute type
MNH-1086	Cotton Research Institute, Multan	Multan	Government
WEAL-AG-10	Allah Din group of Companies	Multan	Private
SLH-CHANDI	Cotton Research Institute, Sahiwal	Sahiwal	Government
FH-494	Cotton Research Station, Faisalabad	Faisalabad	Government
MNH-1050	Cotton Research Institute, Multan	Multan	Government
FH-492	Cotton Research Station, Faisalabad	Faisalabad	Government
WEAL-AG-9	Allah Din group of Companies	Multan	Private
BH-224	Cotton Research Institute, Bahawalpur	Bahawalpur	Government
VH-418	Cotton Research Station, Vehari	Vehari	Government
SLH-Afnan-II	Cotton Research Institute, Sahiwal	Sahiwal	Government
WEAL-AL-AG-CKC3-01	Allah Din group of Companies	Multan	Private
FH-142	Cotton Research Station, Faisalabad	Faisalabad	Government
FH-414	Cotton Research Station, Faisalabad	Faisalabad	Government
RH-KING 20	Cotton Research Institute, Khanpur	Khanpur	Government
WEAL-AG-201(ii)	Allah Din group of Companies	Multan	Private
FH-ANMOL	Cotton Research Station, Faisalabad	Faisalabad	Government
SLH-55	Cotton Research Institute, Sahiwal	Sahiwal	Government
BH-225	Cotton Research Institute, Bahawalpur	Bahawalpur	Government
UAM-20	MANSUA, Multan	Multan	Government
FH-498	Cotton Research Station, Faisalabad	Faisalabad	Government
WEAL-AG-11	Allah Din group of Companies	Multan	Private

Insect data

Population monitoring of sucking insects Population of sucking insects such as jassid (either adults or nymphs), whitefly (adults) and thrips (either adult and nymphs) per leaf was monitored at weekly intervals. The presence of adults or nymphs was monitored early in the morning. Fifteen randomly leaves were selected randomly in each treatment. The number of insects were recorded from upper, middle and lower leaf of alternate plants. In pink bollworm observations, destructive sampling was used to record observations during seasons. In order to determine the prevalence of bollworms in completely opened bolls during harvest, 100 randomly selected opened bolls per plot were gathered in polyethylene bags and the amount of locule damage was calculated.

Statistical analysis

Data analysis was performed by analysis of variance and means were separated using HSD test at 5% level of significance, by using Statistix 8.1.

Results and Discussion

Cotton leaf curl virus (CLCuD) incidence

No CLCuD infestation was recorded at 30 days after sowing (DAS) during the year of study. However, CLCuD incidence accelerated with the passage of time. The tested cultivars significantly differed in their susceptibility to CLCuD. The highest CLCuD infestation for cultivar strains was observed in 'SLH-chandi (8.44±0.48%), whereas the lowest infestation was recorded for 'VH-418' (1.11±0.29), followed by SLH-55, UAM-20, and Wheel-AG-11 (1.89±0.29) (Table 2).

Agronomic characters

Significant differences were observed for plant height, boll weight, sympodial branches, number of bolls, GOT% (Table 3), and yield (Table 2), whereas non-significant differences were observed for the number of monopodial branches and internodal distance. The highest value recorded in the case of plant

Table 2: *Details of different agronomic characters of different cotton strains/cultivars.*

Variety	CLCuD %	Boll weight	Plant height	Number of nodes	Monopodial	Sympodial	Number of bolls	Yield (Kg/ha)
MNH-1086	6.44±0.48 b	4.18±0.09 a	199.33±2.96 a	7.00±0.00^{ns}	1.67±0.33^{ns}	17.00±1.00 g	46.33±0.88 g	2725.69±15.32 abc
WEAL-AG-10	2.77±0.48 f	4.03±0.09 ab	193.33±4.41 ab	7.00±0.00^{ns}	1.67±0.33^{ns}	29.33±0.67 abc	47.33±1.20 g	2313.25±31.06 a-d
SLH-CHANDI	8.44±0.48 a	3.58±0.09 e-h	183.33±4.41 a-d	7.00±0.58^{ns}	2.00±0.58^{ns}	22.33±0.88 d-g	52.67±2.85 efg	2572.19±174.22a-d
FH-494	6.61±0.48 b	3.65±0.06 d-g	185.00±5.00 a-d	7.67±0.33^{ns}	2.00±0.58^{ns}	23.33±0.88 c-f	65.00±2.08 a-d	2964.55±82.06 ab
MNH-1050	6.61±0.48 b	4.10±0.06 ab	183.33±3.33 a-d	7.67±0.33^{ns}	2.67±0.67^{ns}	31.33±0.67 a	57.33±1.45 c-g	2426.58±31.37 a-d
FH-492	0.33±0.19 i	3.57±0.09 e-i	170.00±2.89 de	8.33±0.33^{ns}	2.33±0.33^{ns}	20.00±1.15 fg	76.33±2.03 a	3052.95±560.52 a
WEAL-AG-9	2.50±0.38 fg	3.32±0.09 ij	175.00±2.89 b-e	8.33±0.67^{ns}	3.00±0.58^{ns}	17.00±1.00 g	54.00±3.21 d-g	1443.54±287.33 e
BH-224	5.50±0.38 cde	3.42±0.09 g-j	174.67±3.18 b-e	6.33±0.67^{ns}	1.67±0.33^{ns}	22.00±1.15 d-g	64.33±2.91 b-e	1463.44±14.86 e
VH-418	1.11±0.29 hi	3.47±0.09 f-j	172.67±3.71 cde	7.00±1.15^{ns}	2.00±0.00^{ns}	22.00±1.15 d-g	71.33±1.20 ab	2386.77±33.46 a-d
FH-Afnan-II	6.11±0.29 bc	3.62±0.09 efg	178.33±3.33 bcd	6.67±0.88^{ns}	1.67±0.33^{ns}	22.00±1.15 d-g	65.33±1.20 a-d	2300.70±14.09 a-d
WEAL-AL-AG-CKC3-01	6.11±0.29 bc	3.93±0.15 abc	190.00±1.15 abc	8.00±0.58^{ns}	2.33±0.33^{ns}	28.00±1.15 a-d	67.00±2.89 abc	1923.76±16.82 de
FH-142	5.11±0.29 de	3.90±0.17 bcd	173.67±4.10 b-e	7.00±0.00^{ns}	1.33±0.33^{ns}	21.67±1.20 efg	57.33±1.45 c-g	2321.32±61.04 a-d
FH-414	5.00±0.19 e	3.75±0.17 cde	157.67±1.45 ef	7.67±0.33^{ns}	1.33±0.33^{ns}	23.33±0.67 c-f	61.67±1.76 b-f	2182.70±42.90 b-e
RH-KING 20	3.00±0.19 f	3.60±0.17 e-h	181.33±4.10 a-d	7.33±0.33^{ns}	1.33±0.33^{ns}	30.33±2.03 ab	52.67±4.10 efg	2179.06±20.03 b-e
WEAL-AG-20 1 (ii)	5.89±0.29 bcd	3.35±0.17 hij	140.00±2.89 f	8.00±0.58^{ns}	2.33±0.33^{ns}	28.67±1.76 abc	49.00±2.65 g	2150.96±7.35 cde
FH-ANMOL	4.89±0.29 e	3.55±0.17 e-i	175.00±2.89 b-e	7.67±0.67^{ns}	2.33±0.33^{ns}	22.33±0.88 d-g	51.67±2.33 fg	2211.75±29.09 b-e
SLH-55	1.89±0.29 gh	3.90±0.17 bcd	168.33±2.03 de	8.67±0.33^{ns}	1.67±0.33^{ns}	25.00±0.58 b-f	55.00±1.53 d-g	2546.37±38.77 a-d
BH-225	5.89±0.29 bcd	3.65±0.17 d-g	182.33±6.23 a-d	6.33±0.33^{ns}	1.67±0.33^{ns}	25.00±0.58 b-f	55.67±1.45 c-g	2328.85±4.30 a-d
UAM-20	1.89±0.29 gh	3.25±0.17 j	185.33±3.71 a-d	6.67±1.45^{ns}	1.00±0.00^{ns}	30.00±1.15 ab	65.67±2.33 a-d	2559.46±41.15 a-d
FH-498	2.89±0.29 f	3.70±0.17 c-f	185.00±2.89 a-d	7.00±0.58^{ns}	2.00±0.58^{ns}	27.67±0.88 a-e	65.67±3.28 a-d	2776.98±53.48 abc
WEAL-AG-11	1.89±0.29 gh	3.35±0.17 hij	183.67±4.48 a-d	8.00±0.00^{ns}	2.00±0.58^{ns}	26.67±1.76 a-e	57.67±2.03 c-g	2912.18±62.12 abc
HSD	0.7812	0.2609	19.806	3.3075	2.1918	6.0465	11.792	801.05

Means sharing similar letters are not significantly different by Tukey's Test at P = 0.05; HSD= Highly Significant Difference Value: Significant at P ≤ 0.05. (±) = the sign commonly indicates the confidence interval or uncertainty.

Table 3: *Details of different fiber parameters of different cotton strains/cultivars.*

Variety	GOT %	Staple-length	Staple fineness	Fiber-strength
MNH-1086	40.00±0.26 g	5.42±0.05 b	27.62±0.12 defg	23.40±0.61 l
WEAL-AG-10	40.94±0.26 f	4.99±0.05 ef	30.31±0.11 a	32.00±0.61 c
SLH-CHANDI	34.44±0.26 k	4.85±0.05 g	26.68±0.28 fgh	25.90±0.61 j
FH-494	40.87±0.26 f	5.01±0.05 ef	28.09±0.05 de	31.80±0.61 c
MNH-1050	42.22±0.26 d	4.24±0.04 l	30.18±0.12 a	31.30±0.61 d
FH-492	40.05±0.17 g	5.15±0.04 d	28.36±0.12 cde	28.50±0.61 h
WEAL-AG-9	38.40±0.17 h	5.21±0.03 c	25.43±0.21 h	30.30±0.61 f
BH-224	44.09±0.17 b	5.02±0.03 e	26.09±0.17 h	30.10±0.61 f
VH-418	41.56±0.17 e	4.62±0.03 ij	27.81±0.19 def	32.83±0.66 a
FH-Afnan-II	44.32±0.17 b	4.64±0.03 i	28.22±0.16 cde	27.50±0.64 i
WEAL-AL-AG-CKC3-01	43.12±0.17 c	4.47±0.03 k	27.48±0.26 efg	28.30±0.64 h
FH-142	36.98±0.17 j	4.57±0.03 j	26.51±0.30 gh	30.70±0.64 e
FH-414	42.32±0.17 d	4.65±0.03 i	28.29±0.14 cde	29.70±0.64 g
RH-KING 20	44.76±0.17 a	4.96±0.03 f	28.86±0.43 bcd	25.97±0.66 j
WEAL-AG-20 1(ii)	42.32±0.17 d	5.68±0.02 a	29.83±0.15 ab	24.80±0.61 k
FH-ANMOL	37.81±0.15 i	4.76±0.02 h	25.84±0.59 h	31.10±0.61 d
SLH-55	40.18±0.15 g	4.74±0.02 h	26.53±0.23 gh	29.70±0.61 g
BH-225	38.01±0.15 i	4.73±0.02 h	27.36±0.27 efg	28.30±0.61 h
UAM-20	40.05±0.15 g	4.77±0.02 h	27.80±0.18 def	32.50±0.61 b
FH-498	44.11±0.15 b	5.22±0.02 c	29.42±0.24 abc	29.80±0.61 g
WEAL-AG-11	40.12±0.15 g	5.42±0.02 b	27.68±0.28 defg	29.70±0.61 g
HSD	0.2761	0.0595	1.2480	0.2570

Means sharing similar letters are not significantly different by Tukey's Test at P = 0.05. HSD = Highly significant difference value: Significant at P ≤ 0.05. (±) =the sign commonly indicates the confidence interval or uncertainty.

height was for MNH-1086 (199.33±2.96), whereas the lowest was for Wheel-AG-201(140.00±2.89). The highest value of boll weight was recorded in MNH-1086 (4.18), whereas the lowest was recorded in UAM-20 (3.25). Similarly, for the number of sympodial branches, the highest value was recorded for MNH-1050 (31.33) and the lowest for MNH-1086 (17.00); in the case of the number of bolls per plant, the highest number was recorded for FH-492 (76.33) and the lowest for MNH-1086, WEAL-AG-10 (46.33), and 47.33, respectively. Significant differences were observed for yield (Kg/ha); the highest yield was observed for FH-492 (3052.95±56.52) and the lowest for BH-224 and Wheel-AG-9, i.e., 1463.44±14.86 and 1443.54±28.33, respectively (Table 2).

Fiber traits

Significant differences were observed for all the fiber quality parameters (GOT, staple length, fiber fineness, and fiber strength). The lowest GOT% was observed for SLH-Chandi (34.44±0.26) and the highest for RH-King-20 (44.76±0.17) (Table 3). The highest value of staple length was recorded for wheal-AG-20 (5.68±0.02), whereas the lowest was recorded for MNH-1050 (4.24±0.04). The highest value recorded in the case of fiber fineness was for Wheel-AG-201 (30.31±0.11) and MNH-1050 (30.18±0.12), whereas the lowest was for Wheel-AG-09 (25.43±0.21). The highest value for fiber strength was recorded for VH-418, i.e., 32.83±0.66, and the lowest observed for MNH-1050, i.e., 4.24±0.04 (Table 3).

Population of sucking insects and pink bollworm

Different cotton cultivars significantly differed for their susceptibility to whitefly. The highest whitefly population was recorded on BH-224 (11.38±0.54)' followed by FH-414 and Wheel-AG-20 i.e., 6.88±0.35 and 6.77±0.20, respectively. The lowest whitefly population was observed on cultivars 'FH-492 (2.48±0.27), FH-498 (2.97±0.38), and 'FH-494 (2.80±0.33). The lines/strains studies significantly differed for their susceptibility to jassid population. The highest jassid population was recorded for 'BH-224 (2.25±0.17). The lowest jassid population was recorded on cultivars FH-494 (0.87±0.12), FH-498 (0.97±0.02), and FH-492 (0.68±0.06) (Table 4).

Table 4: *Details of different insect pest population of different cotton strains/cultivars.*

Variety	Whitefly	Jassid	Pink-Bollworms	Thrips
MNH-1086	3.43±0.16 f-j	1.08±0.07 d-g	0.58±0.12 d-g	1.23±0.09 cde
WEAL-AG-10	4.90±0.48 d-g	1.32±0.09 c-g	0.63±0.07 c-f	1.47±0.12 a-e
SLH-CHANDI	3.67±0.42 f-j	1.10±0.17 d-g	0.58±0.03 d-g	1.28±0.02 b-e
FH-494	2.80±0.33 ij	0.87±0.12 fg	0.30±0.05 gh	1.13±0.09 de
MNH-1050	4.71±0.39 d-h	1.27±0.15 c-g	0.72±0.06 b-e	1.50±0.05 a-e
FH-492	2.48±0.27 j	0.68±0.06 g	0.20±0.05 h	1.05±0.12 e
WEAL-AG-9	3.23±0.43 g-j	1.02±0.04 d-g	1.02±0.11 ab	1.57±0.13 a-d
BH-224	11.38±0.54 a	2.25±0.17 a	1.13±0.06 a	1.87±0.06 a
VH-418	4.92±0.41 d-g	1.38±0.15 c-f	0.67±0.02 cde	1.57±0.06 a-d
FH-Afnan-II	5.22±0.24 c-f	1.50±0.17 b-f	0.73±0.09 b-e	1.62±0.12 a-d
WEAL-AL-AG-CKC3-01	7.67±0.28 b	2.12±0.15 ab	1.00±0.05 ab	1.68±0.16 abc
FH-142	4.75±0.21 d-h	1.28±0.04 c-g	0.65±0.06 cde	1.45±0.12 a-e
FH-414	6.88±0.35 bc	1.78±0.25 abc	0.92±0.06 abc	1.82±0.13 a
RH-KING 20	6.37±0.39 bcd	1.62±0.10 a-e	0.85±0.03 a-d	1.77±0.02 ab
WEAL-AG-20 1(ii)	6.77±0.20 bc	1.67±0.19 a-d	0.83±0.04 a-d	1.78±0.12 ab
FH-ANMOL	5.90±0.24 b-e	1.43±0.15 c-f	0.77±0.09 b-e	1.67±0.11 abc
SLH-55	4.35±0.44 e-i	1.17±0.04 c-g	0.60±0.03 d-g	1.50±0.06 a-e
BH-225	4.92±0.41 d-g	1.28±0.06 c-g	0.72±0.03 b-e	1.37±0.10 a-e
UAM-20	4.22±0.30 e-j	1.12±0.10 d-g	0.67±0.04 cde	1.45±0.06 a-e
FH-498	2.97±0.38 hij	0.97±0.02 efg	0.33±0.04 fgh	1.20±0.03 cde
WEAL-AG-11	3.30±0.21 g-j	1.07±0.07 d-g	0.50±0.05 e-h	1.38±0.10 a-e
HSD	1.8016	0.6601	0.3146	0.5088

Means sharing similar letters are not significantly different by Tukey's Test at P = 0.05. HSD = Highly Significant Difference Value: Significant at P ≤ 0.05. (±) =the sign commonly indicates the confidence interval or uncertainty.

Significant differences were found among tested cultivars for thrips population during each study year (Table 4). The highest thrips population was recorded for BH-224 (1.87±0.06) and FH-414 (1.82±0.13), respectively. The lowest thrips infestation was recorded for 'FH-492, 'FH-494 and FH-498, having 1.05±0.12, 1.13±0.09, 1.20±0.03, respectively. The population of pink bollworm for tested strains significantly differed for population index. Similarly, no rosette flower was observed on any of the tested cultivars. The highest pink bollworms were recorded for BH-224 (1.13±0.06) by 'Wheel-AG-9' (1.02±0.11) and 'Wheel-AL-AG-CKC3-01(1.00±0.05) (Table 4). The cultivar FH-492(0.20±0.05)' had the lowest number of pink bollworms in left over bolls during both years of study (Table 4).

Twenty-one newly developed 'Bt-cotton' strains and cultivars evolved by the public and private sectors of Punjab, Pakistan, were assessed for their susceptibility to sucking insects and bollworms, CLCuD attack, seed-cotton yield, and fiber quality traits under field conditions. The yields of FH-492, FH-494, and WEAL-AG-11 were 3053, 2964, and 2912 kg/ha, respectively (Table 2). According to the results, it was proven that the new variety or cultivar, RH-492, stood first for yield performance in provincially coordinated cotton trials (Noor-ul-Islam *et al*., 2006; Haidar and Aslam, 2016). Jamil *et al*. (2022) and Khakwani *et al*. (2022) conveyed similar results for newly developed varieties FH-492 with elite performance in cotton research station, Ayub Agricultural Institute, Faisalabad.

Fiber quality traits

The fiber quality tested by Central Cotton Research, Institute, Multan (CCRI), National Institute for Biotechnology and Genetic Engineering (NIBGE), Faisalabad, Cotton Research Station (CRS), Faisalabad and All Pakistan Textile Mills Association (APTMA), Lahore during SPOT examination presented impressive figures for GOT (40.05 %), staple length (5.15 mm), Fiber-strength 28.50 (g/tex.), and Fineness (28.36%) (Table 3).

Morphological studies

The parental line FH-492 was discovered to be an excellent combiner for Boll Weight, plant height, internodal distance, monopodial branches, sympodial branched, number of bolls, and yield. These results indicated that these five lines, FH-494, WEAL-AG-11, and FH-498, have desired traits for a breeder to exploit variability in the traits that are investigated here. All other yield associated traits studied; boll weight, plant height, nodes/plant, fruiting node and inter-nodal distance produced better results under water induced stress in FH-492 depicting that it can survive better in areas with lesser water and higher temperature. For Plant Height FH-492 was good generally among the others cultivars so is supposed to be used in future breeding programs. Both type of factors i.e. additive and non-additive found to be important for plant height (Meyer-Grünefeldt *et al*., 2015; Barton and Shiels, 2020). These findings were reported by (Ladd and Facelli, 2008). The plants seem bushy due to their branches, which causes the creation of bolls to occur slowly. On-additive gene action is more significant than additive gene action for sympodial branches. According to Chaudhry and Guitchounts (2003) sympodial branches are more dependent on the gene activity of non-additive types. Because plants reach the fruiting stage sooner, higher fruiting results from bigger sympodial branches.

The choice of parents plays a crucial role in the success of the breeding programme (Pandey *et al*., 2016). After a breeding programme is successful due to the selection of capable parents, attention must be paid to many characteristics such as staple length, fineness, homogeneity, and maturity in order to increase the quality of the fiber (Salentijn *et al*., 2015). Less genetic variety is the cause of the decline in production and other indices including fiber quality (Ali *et al*., 2023). In plant breeding, the introduction of new cultivars with altered genetic bases is a crucial step. Researchers encounter difficulties because of the smaller genetic basis. As a result, understanding the variances and inheritance of certain features is crucial for breeders.

Population of sucking insects and pink bollworm

During the seedling, vegetative, flowering, and fruiting phases of cotton growth, sucking insects pose a significant threat (Amin *et al*., 2016). The study revealed significant whitefly, jassid, thrips, and pink-bollworm infestations in cotton leaves and bolls, indicating varied responses and susceptibility among different cultivars. Significant differences in infestation levels of leaves and bolls among cultivars indicated that their responses and resistance to or susceptibility to these pests varied. We observed different levels of infestation among 21 cotton varieties and reported that three varieties (Fh-492, Fh-494, and WEAL-AG-11) were resistant, whereas two (WEAL-AG-9 and BH-224) were susceptible. The present study showed that FH-492 and FH-494 sustained lower infestation levels in comparison to the other cultivars, whereas BH-224 was subjected to the highest level of infestation. We observed the abundance of Whitefly, thrips and jassid from the vegetative stage to harvest. Infested leaves and bolls turned pale and rusty red, turned downwards, dried up, and fell to the ground. Infested bolls scarred and became rusty brown (Amin *et al*., 2016). Our cotton cultivars differed in the number of morphological characteristics, and entomological parameters, which might have affected the feeding, oviposition, and population buildup of the pests (Rajendran *et al*., 2018).

Conclusions and Recommendations

In the cotton producing regions of Pakistan, numerous events of temperatures greater than 40°C come about between mid of June to mid of Aug. According to reports, the ideal temperature range for cotton crops throughout the stages of squaring and boll growth is between 27 and 35°C. Cotton seed production will be limited in the near future and cotton output in semi-arid zones will be higher if the impacts of global warming play out as predicted. The genotypes of FH-492 showed the lowest number of whiteflies, jassid and thrips infestations. When it came to leftover bolls, the cultivar FH-492 also had the lowest pink bollworms. Out of all the cultivars, FH-492 produced the biggest number of bolls and the highest yield. Additionally, the breeding program's selection of new cultivars has aided in raising cotton output. Parents with strong overall trait-combining capacity are used in crosses to produce improved genotypes. It was intended to be used in upcoming breeding initiatives to enhance these characteristics in cotton. It has a broad adaptability in all of Punjab's cotton-growing regions. With a medium blooming length, it works well even in situations of stress and poor fertility. Tolerant cultivars are a novel high producing Bt as a result. Variety with positive attributes is strongly recommended across Punjab.

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Novelty Statement

To important source to be utilized in future Cotton breeding programs for the improvement of yield and quality traits in cotton.

Author's Contribution

Muhmmad Asif and Farrukh Ilahi: Performed the experiment and collected data.
Khunsa Khakwani and Muhammad Hasnain: Write first manuscript and Managed overall crop.
Muhammad Hussnain Babar and Shahid Munir Chuhan: Helped in paper write up.
Jehanzeb Farooq, Hammad Hussnain and Hafiz Ghazanfar Abbas: Performed the statistical analysis.
Iqra Parveen, Saeed Ahmad and Ghulam Sarwar: Collected the literature and supervised the study.

Conflict of interest
The authors have declared no conflict of interest.

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